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USAL-SoNA1: Technical Review of Phase 1 of the Survey of Noise Attitudes (SoNA) studies.

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Executive Summary

Scope

- This report includes the technical review of the analysis carried out by the Civil Aviation Authority (CAA) for the Survey of Noise Attitudes (SoNA) studies.
- The CAA Environmental Research and Consultancy Department (ERCD) has analysed social survey data in conjunction with noise modelling to draw conclusions on attitudes to aircraft noise
- The Department for Transport (DfT), the client, intend to use these conclusions to help their management of noise at the designated airports, and for developing policies relating to aircraft noise.
- This technical review covers the **Phase 1: SoNA1 Annoyance 2nd Edition and Sleep studies**.
- This report presents the findings of the technical peer review of the calculations which underpin the analysis presented in SoNA1 Annoyance 2nd Edition and Sleep studies.

Objectives

- Assure DfT, the client, that the analysis has been undertaken accurately and meet relevant standards.
- Assure the studies' audience, which comprises academics, community, industry and other government stakeholders, that the conclusions drawn are reliable and based on robust analysis.

Conclusions

- These reviewers have reviewed the noise dose analysis and the master dataset (including both social survey output data and noise modelling results).
- These reviewers have gone through all the calculations and datasets used in the Phase 1: SoNA1 Annoyance 2nd Edition and Sleep studies.
- **These reviewers are confident that the analyses undertaken are accurate, reliable and robust**, and meet standard practice in the field.
- Some recommendations are included to improve the noise validation of prediction model (ANCON) for new aircraft entering into service, and to quantify the uncertainty of noise dose calculations based on logarithmically averaged noise metrics.

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1. Review of noise dose analysis

1.1 Underlying noise validation process

Appendix A in the SoNA Peer Review scope document (attached) details the methodology for noise validation.

- Extraction of radar data and noise events: Radar data and noise events are extracted from the Airport Noise and Flight Track Monitoring System (ANOMS). Noise events are extracted for the summer period (16 June to 15 September inclusive) and processed separately for Arrival and Departure operations. The data in each noise event dataset include operation number (opnum), monitor ID, arrival/destination airport, noise levels (in terms of SEL(A) and L_{Amax} metrics) and runway. Full process covered in detail in peer review meetings with CAA.

- Generation of aircraft vertical profiles:

  (1) The closest point between the aircraft and noise monitor (noise receptor) is calculated for each radar track and for each noise monitor. This calculation is made using CAA's proprietary software.

  (2) The noise events extracted and the geometry between the aircraft and noise monitor are linked by the unique operation number and noise monitor ID.

  (3) Noise events that do not meet the acceptance criteria (see attached SoNA Peer Review scope document for full details) are discarded. For instance, noise events are discarded if the angle formed between receptor on the ground and aircraft source (elevation angle) is less than 60 degrees. This is done to avoid noise events with small elevation angles, and therefore, highly affected by the effects of the ground in the sound propagation.

  (4) SEL(A) and L_{Amax} levels of each event are corrected to an "under the flight path" position using standard lateral attenuation rules (if the noise monitor is not beneath the flight path).

  (5) Using the dataset containing all noise events extracted, a logarithmically averaged SEL(A) and L_{Amax} is calculated for each aircraft model type, monitor and runway combination.

  (6) The logarithmically averaged SEL(A) and L_{Amax} are corrected to account for the height of the monitor (measurements are assumed to take place in a flat surface, as ANCON accounts for terrain in noise contour calculations). After this correction, the logarithmically averaged SEL(A) and L_{Amax} are linked to the appropriate distance from SOR (start of roll, for departure operations) or distance to Threshold (for arrival operations).

(7) Noise calculations with the ANCON model are performed using mean height, speed and thrust data calculated from the extracted radar data. SEL(A) and L_{Amax} are calculated at distances from SOR or threshold for departures and arrivals respectively, and compared with the logarithmically averaged SEL(A) and L_{Amax} recorded in the noise monitor. An iteration process is carried out to adjust the mean profiles so that the model calculates average noise levels which reflect the average noise measurements. This is done separately for each aircraft type, for arrivals and departures separately, and for SEL(A) and L_{Amax}. Note that these changes in the mean profiles are based on expertise on how these aircraft operate in different airports.

The full process described above was covered in detail in peer review meetings with CAA.

1.1.1 Sources of uncertainty

- "Under the flight path" correction. The correction applied to SEL(A) and L_{Amax} measured at lateral distances from the flight path, to modified them to a "under the flight path" position might lead to some degree of uncertainly due to lateral directivity of (engine) installation effects. Looking at Figure 4-4 of ECAC.CEAC Doc 29 4th Edition Volume 2[1], the error associated with this correction for noise events with elevation angles > 60 degrees can be assumed negligible. The effect of atmospheric attenuation could be considered of similar magnitude for both noise events at lateral positions with elevation angles > 60 degrees and noise events under the flight path.

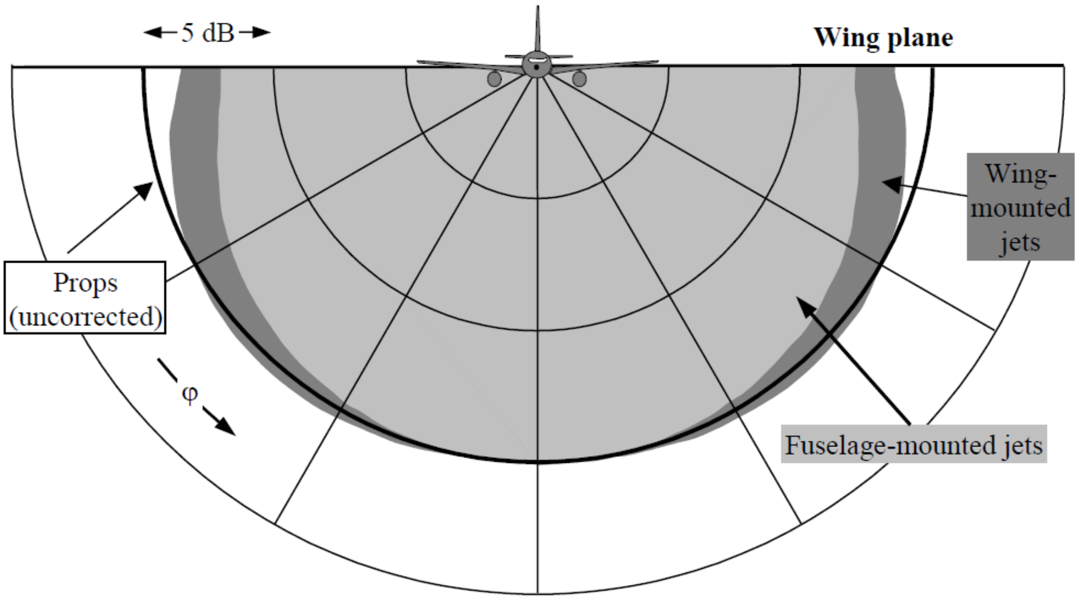

Figure 1: Lateral directivity of installation effects[1].

[1]https://www.ecac-ceac.org/documents/10189/51566/02.+Doc29+4th+Edition+Volume+2.pdf/4a63f339-11e1-4604-afaf-f1e34030d9e9

- Calculation of logarithmically averaged SEL(A) and L_{Amax} for each aircraft model type, monitor and runway combination. The calculation of logarithmically averaged SEL(A) and L_{Amax} for each aircraft model type using mean profiles may lead to a certain degree of uncertainty, compared to, for instance, a stratification of aircraft movements with different Maximum Take-Off Weight (MTOW). However, these logarithmically averaged SEL(A) and L_{Amax} are calculated with a significant amount of aircraft movements, and the standard deviation is very reduced. Furthermore, these logarithmically averaged SEL(A) and L_{Amax} are calculated accounting for the characteristics of each aircraft type in each airport of reference, and for each runway combination. Therefore, a small uncertainty might be assumed for the calculation of the noise dose based on logarithmically averaged SEL(A) and L_{Amax} for each aircraft model type, monitor and runway combination. However, further work is recommended to quantify the uncertainty.

- Validation of noise calculations for each aircraft model type. The noise calculations performed with ANCON are validated with measurements carried out by noise monitors. This way, the vertical profiles used in ANCON to calculate noise contours are optimised for each aircraft model type, runway combination and airport. These reviewers believe that this approach is highly preferable than other approaches such as the use of standard vertical profiles for aircraft (based on MTOW). The noise calculations are validated with an extensive number of measurements at different distances from SOR (departures), or to Threshold (arrivals) for the aircraft fleet with the vast majority of movements in the reference London airports[2] (see Fig. 3). Other aircraft (with a very reduced number of movements) are only validated with a few measurements due to the lack of data (see Fig. 2). As the majority of aircraft movements, in reference London airports, are extensively validated, a small uncertainty might be assumed. However, further work is recommended to validate this assumption and quantify the uncertainty.

[2] See tables displaying movements by ANCON aircraft type in Noise Exposure Contours reports for Heathrow, Gatwick and Stansted airports.

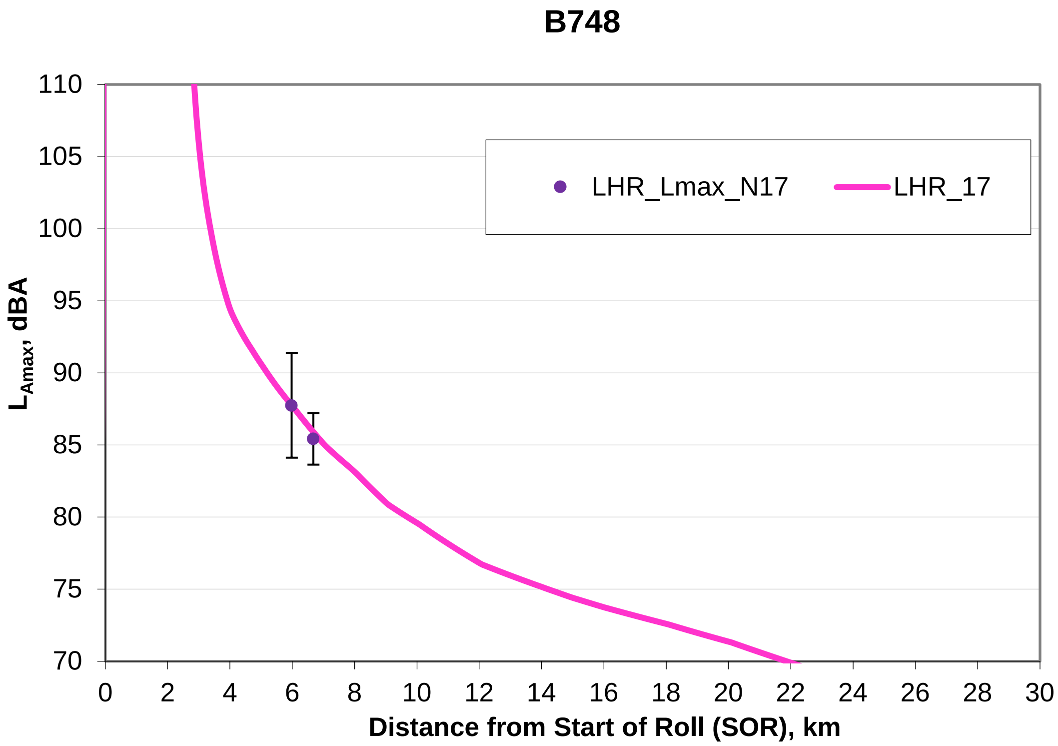

Figure 2: Noise calculations (L_{Amax}) with ANCON model along the extended runway centreline for year 2017 (magenta line) vs. noise monitor measurements (L_{Amax}) in year 2017 (purple dots) for the Boeing 747-8 in Heathrow airport. Note that 'N' is short for NMT (Noise Monitoring Terminal).

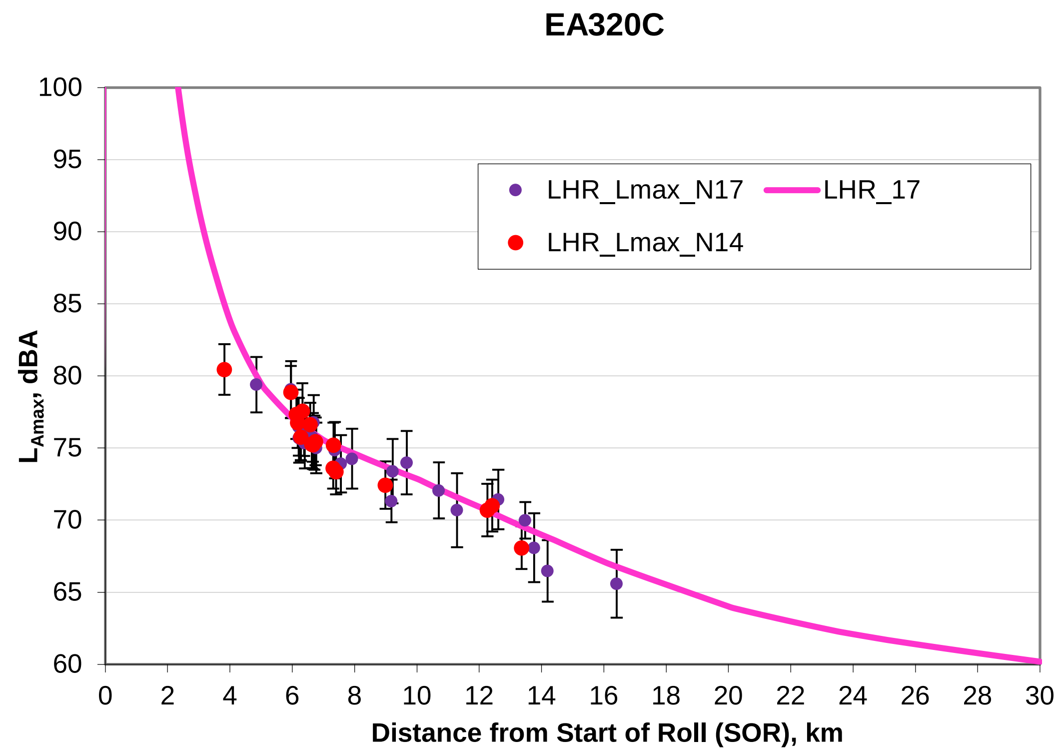

Figure 3: Noise calculations (L_{Amax}) with ANCON model along the extended runway centreline for year 2017 (magenta line) vs. noise monitor measurements (L_{Amax}) in years 2014 (red dots) and 2017 (purple dots) for the Airbus A320 (CFM56 engines) in Heathrow airport. Note that 'N' is short for NMT (Noise Monitoring Terminal).

1.2 Calculation and assignment of noise dose to SoNA respondents

Appendix B in the SoNA Peer Review scope document (attached) details the methodology for calculating and assigning noise dose data in multiple noise metrics (see below) to survey respondent locations.

The following file systems were reviewed in detail to check the robustness and accuracy of the calculation and assignment of noise dose to SoNA respondents.

- Traffic File (.TBS): 2-D Matrix with information on the number of operations on each day for varying track names and aircraft types. Comes from the airport radar data. This is cross-checked with the traffic control logs which are provided by the airports.

- RTA file: created by the in-house radar processing. The purpose of this file is to count flight tracks using gates where flights are tracked when passed through.

- Grid files: Although generally the grid sizes were set at $100m^2$ (i.e. 100 m by 100 m), it is possible to vary these grid sizes to account for noise contours shapes (of different airports).

- Postcode files (.csv): The purpose of this file is to comprise about 2 million postcodes from the grid interpolation with the measured noise metrics (e.g. $L_{Aeq,16h}$). There is a use of error codes to label postcodes that lie at the limits of the calculation grid, where locations beyond the calculation boundary are flagged.

- MNX files: Used for calculating the noise dose at the postcodes and accounting for grid rotation and receiver height corrections. Receiver IDs are tracked within the rows of the data in these files.

- The results files include metric results at grid points (a csv format file called $D2) or MNX points (a csv file called $D4), both of which are viewed and post-processed in Excel spreadsheets.

The calculation of the noise dose is carried out as follows:

- ANCON model performs the calculation of noise metrics using the following input files: traffic (numbers of aircraft on each route), route coordinates, vertical profiles for each model aircraft type on departure and arrival, ground terrain, the results grid or MNX points.

- Noise metrics are calculated using the MNX to provide this information at receptor locations, and also across a rectangular grid for plotting noise contours (the same results are given by both methods, as the same underlying noise calculation is used).

- The noise results (e.g. noise metrics) at respondent locations are obtained through interpolation (using a well-established tool that forms part of the ANCON noise model suite). A logarithmic interpolation is performed for energy equivalent metrics (e.g. $L_{Aeq,16h}$), and a linear interpolation is performed for Number above metrics.

- The master dataset calculates the doses in accordance with the modal split of the airport runway configurations, using fractional components. In this way, arrivals and departures for a particular direction to form the contribution of runway direction on receivers.

  (1) Firstly, the noise metrics are separated into bands, rather than using a numerical scale. This is due to the statistical analysis being carried out in a banded process. The size of the bands was considered for each noise dose metric, and was set in a way to distribute the results evenly over a reasonable number of bands.

  (2) The noise parameters used for the dose calculations were the A-Weighted:
    - 16- and 8-hour L_{Aeq}
    - L_{den} and L_{night}
    - 16- and 8-hour N60, N65 and N70

  (3) With each parameter calculated for both easterly and westerly airport operational conditions and as a function of a 7-day, 30-day and 92-day (summer) average period. Not all airports had all dose metrics, as shown in Table 1.

Table 1: Noise metrics calculated and assessed at the receptor points at the airports listed:

Airport	$L_{Aeq,16h}$	$L_{Aeq,8h}$	L_{den}	N60	N65	N70
Birmingham[1]	Y					Y
East Midlands[3]	Y					Y
Gatwick[1]	Y	Y	Y	Y	Y	Y
Heathrow[1]	Y	Y	Y	Y	Y	Y
London City[3]	Y					Y
Luton[2]	Y					
Manchester[1]	Y					Y
Newcastle[3]	Y					Y
Stansted[1]	Y	Y	Y	Y	Y	Y

[1] Noise measurements taken in 2014
[2] Noise measurements taken in 2013
[3] Noise measurements taken in 2012

- Modal Split averaging:

  In order to understand the overall effect of the individual runway directions on these noise doses, logarithmic parameters, such as L_{Aeq} and L_{den} are averaged logarithmically, whereas the Number Above (N60, N65 and N70) metrics were averaged arithmetically.

Both averages shared the same principle which is outlined below.

$$Noise\ Dose\ =\ (Easterly\ metric * Fraction\ of\ Easterly\ operation) \\ +(Westerly\ metric\ *\ Fraction\ of\ Westerly\ operation)$$

- Results are visualised using ArcGIS, where the noise contours may be inspected spatially with respect to all receptors.

The full process described above was covered in detail in peer review meetings with CAA.

1.2.1 Sources of uncertainty

- The interpolation of noise levels at grid points to calculate noise dose at the SoNA respondents may lead to a certain degree of uncertainty. The ERCD Report 0306 studied the agreement between the noise levels calculated with two grid sizes: 100m x 100m (used for calculating noise dose at SoNA respondents) vs. 10m x 10m. This ERCD's report concluded a good agreement between the results calculated with both grid sizes (with differences in calculated noise metrics < 0.5 dB). Also, in the ERCD's report it is found that the interpolation from the 100m by 100 m grid may only be problematic at the airport boundary, where there are no residential properties. For this reason, the uncertainty associated with this interpolation process can be assumed negligible for the calculation of the noise dose at SoNA respondents.

2. Review of master dataset

The master dataset is structured such that results can be grouped by airports, receiver ID's and other configurations. The file contains all social survey responses along with the acoustic parameters used in the model to understand the exposure-response relationship from the data. In addition to the receiver ID's, the spatial grid data and postcodes are present.

2.1 Integrity of social survey output data

- The integrity of the master data set is supported through supplementary sheets which provide visual representations of the data and other ancillary information for setting up the calculations.
- Furthermore, the 'Variables' sheet provides a reference to the definitions of each variable within the whole dataset. The separate sheet 'values' provides the explanation of the possible responses from the social survey.
- Social survey responses are encoded numerically and are represented depending on the survey question. For example, 'yes' or 'no' questions are represented in binary, whereas

questions that have indiscrete answers are accounted for using scales, such as the ICBEN 5- or 11-point scales[3].

2.2 Parsing and categorisation of noise modelling results (dose) data into master dataset

- Noise dose data is structured in rows for each respondent location ID number and follows a logical separation in to easterly and westerly modes for each specific time period.
- Following their calculation, the noise metrics are banded into metric value categories.
- The master dataset spreadsheet was covered in full detail through peer review meetings with the CAA
- Formulae used for the modal-split averaging were missing from the spreadsheet cells, due to the requirement of a hard-coded version needed to transfer the data into SPSS. However, CAA provided explanatory guidance on how results were calculated, and duplicate columns were produced during peer review meetings by the CAA with the initial formulae used.
- This provided the CAA with the opportunity to show the reviewers that the dataset correctly matched the data from the formulae.
- The reviewers have verified the low-level details of the formulae and are satisfied that the calculations are robust and accurate.

3. Recommendations

This reviewing team makes the following recommendations for future work:

- Investigate the uncertainty associated with the logarithmic average of SEL(A) and L_{Amax} metrics to define vertical profiles for each aircraft model type, monitor and runway combination. For instance, compare to a stratification of aircraft movements with different Maximum Take-Off Weight (MTOW).
- Expand the measurement campaign, with monitors at a wide range of distances from SOR (departures) or to Threshold (arrivals), to validate the noise calculations of novel aircraft entering into service.

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[3] Fields et al. (2001): J. Sound Vib., 242 (2001), pp. 641-679 (https://doi.org/10.1006/jsvi.2000.3384)