Peer Review of Noise Modelling using ECAC Doc. 29 for Amsterdam Schiphol Airport

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Summary

A peer review has been undertaken on the Dutch aircraft noise calculation process as used in the Environmental Impact Assessment noise calculations for Amsterdam Schiphol airport.

The Dutch implementation of the calculation method in ECAC.CEAC Document 29 Volume 2 was deemed out of scope of this peer review. However, it is relevant to highlight that the Dutch implementation of ECAC Doc. 29 4th Edition was benchmarked by the ECAC's Aircraft Noise Modelling Technical Subgroup, AIRMOD alongside models from the UK, EUROCONTROL, Norway and the US and found to fully conform to the ECAC Document 29 4th Edition recommended practice on the calculation of aircraft noise. This benchmarking process verified the computer software's ability to generate three-dimensional flight trajectories from input ground tracks and flight profiles and the calculation of noise levels from the resulting segmented flight trajectories and ICAO ANP Noise-Power-Distance (NPD) information, along with verification of the various adjustments necessary for aircraft noise directivity and duration correction effects. Thus, for the same calculation inputs, the Dutch implementation of Document 29 4th Edition, gives the same calculated noise levels as other major implementations of Document 29 4th Edition.

The peer reviewed focussed on the inputs to the noise calculation process. The review was shown evidence of how the default flight procedures and profiles in the ICAO Aircraft Noise and Performance (ANP) database were adapted to reflect local operations at Schiphol airport and demonstrated how these changes produce larger noise footprints than the default ANP database profiles and would therefore lead to larger noise contours, had the adjustments not been made.

The degree to which differences in aircraft performance were represented by accounting for distinct take-off and landing weights and different noise abatement departure and arrival procedures was considered to far exceed best practice. Some aircraft types were represented by as many as 80 distinct flight profiles, in contrast to a maximum of 19 flight profiles provided in the ANP database.

The review found that the ANP noise performance information (Noise Power Distance data) have been used as provided in the ANP database (after taking account of any substitution adjustments required have been applied). The ANP NPD data therefore represent the single important aspect where formal validation has not been undertaken (in contrast to the adjustment of flight profiles for example). As there is not yet any international guidance on comparing noise calculations with measurements and on the adjustment of NPD data, this does not represent a deviation from best practice, however, it contrasts with the approach taken in other areas where, for example, aircraft performance has been calculated and compared in detail with radar data. Secondly, making comparisons with measurements not only allows the NPD data to be checked, but also a check of the cumulative effect of all elements of the noise modelling process, including assumptions on take-off mass and flight procedures. The review recommends that comparisons between calculated and measured noise levels (at the aircraft type level) are undertaken going forward. A separate report will be provided, giving guidance on comparing calculated and measured noise levels and on techniques to adjust flight procedure assumptions and/or NPD data to minimise any differences.

The software implementation in The Netherlands, uses ECAC Document 29 to calculate the Sound Exposure Level (SEL) for each aircraft type on each take-off or landing flight profile, on each flight track. The resulting SELs for each calculation grid point are stored (over 10,000 sets across thousands of grid points) and for an L_{den} calculation, the SELs are simply added together in accordance with the traffic scenario using a separate piece of software called DAISY. Because the DAISY programme is doing nothing more complex than logarithmic addition of grid-based SEL values for the assigned numbers of operations of aircraft types and flight paths, I am assured of the functions of DAISY without further detailed investigation.

Annual traffic information representing two Environmental Impact Assessment (EIA) scenarios was examined. The breakdown of flights between the day (0700-1900), evening (1900-2300) and night (2300-0700) periods required for L_{den} noise calculations closely matched that for London Heathrow airport. The distribution of aircraft types reflected the dominance of the home-based airline, KLM, with Boeing 737 aircraft being the most common aircraft type used.

The breakdown of operations by aircraft noise abatement departure procedure and landing flight profile reflected my understanding of the procedures used by KLM and in the case of landing, anecdotal evidence from UK pilots asked about landing at Schiphol airport.

Overall, the preparation of input data and the calculation process used for Schiphol airport’s EIA noise calculations goes beyond the best practice set out in ECAC Document 29 4th Edition. Although evidence was provided showing a good correlation between calculated noise levels and measurements, there is, nevertheless, a high degree of reliance on the industry provided ICAO ANP NPD information, which are central to the calculation of noise levels. It is therefore recommended that a routine programme of undertaking noise measurements is developed and implemented and that comparisons are made between measured and calculated noise levels, and where necessary adjustments to input assumptions and NPD data are made.

1 Introduction

The Dutch Transport Ministry has requested a peer review of the noise calculation process for Schiphol airport and in relation to the calculation process, a review of the inputs and outputs for two forecast scenarios.

The peer review commissioned and described in this report is not to undertake a repeat of the calculations undertaken for the Dutch Transport Ministry, but rather to review and report on the inputs for the EIA scenarios, the processes used to prepare the input data, the processes used to adapt the international Aircraft Noise and Performance (ANP database) to Schiphol airport and the calculated outputs. The computer software that performs the core noise calculations was scoped out of the peer review, however, information on the precision of the Dutch computer software is addressed in this report on basis of a separate international benchmarking exercise that was undertaken under the auspices of the European Civil Aviation Conference (ECAC).

In order to better understand the inputs required and the processes used in the calculation of aircraft noise it is first essential to understand what the important factors and why. Although it appears somewhat illogical, in trying to understand the challenges faced in the calculation of aircraft noise levels, it is helpful to understand the key factors that affect the calculation in comparison with similar factors for calculating road and rail noise.

Although the end result is the calculation of long-term average noise levels, in this case based on the average annual day L_{den} and L_{night} noise indicators, the key input is the calculation of noise levels for an individual vehicle passing in relation to a point on the ground where we wish to calculate the noise levels associated with the vehicle passing by. Although not always the case, the maximum noise level will occur when the vehicle (aeroplane, car or train) passes closest to the point of interest on the ground.

In the case of a car or train, the precise location of the noise source is known, because of the constraints of following a road or railway line. In contrast, there is uncertainty about the location if the aeroplane. Laterally (x-y plane), whilst it often, but not always, it will follow a predefined flight path. Even then, an aeroplane is unable to follow a pre-defined flight path as precisely as a car follows a road or a train follows a railway line. In some situations, where Air Traffic Control (ATC) intervene to separate and sequence aeroplanes for landing, there is not always a predefined flight path so one must obtain knowledge and understanding of the actual flight paths flown and the variation from one flight to another. The speeds flown between different aeroplanes differ greatly and may cause different lateral flight paths to be flown, particularly during turning flight.

The vertical dimension is especially important for aircraft noise calculations, where the range of vertical movement is far greater than for cars or trains. Again, the height of aeroplane is not pre-determined, instead being affected by a number of factors. The most important factor is the aircraft take-off weight (more correctly it’s mass), which is strongly affected by the fuel load, which is related to the distance being flown. There is, however, no precise relationship between distance flown and fuel load, for short-haul flights, some airlines may fuel for two or more flights to reduce the turn-around time between flights. The take-off will also be affected by the passenger and cargo load. All of the factors related to the aircraft’s take-off mass are considered sensitive commercial information, rarely shared with the aircraft noise calculation community. Whilst an international hub airport will typically have at least 50% of flights operated by the home-based airline, there will be well over 300 airlines operating services, each with their own relatively unique operating characteristics.

Aircraft height on take-off will also be affected by atmospheric factors. Aircraft typically, but not always, take-off into a headwind, the stronger the headwind the greater the height that will be achieved at a point after take-off. Conversely take-off with a tailwind will cause a loss of height, compared to no wind and an even greater height loss than take-off into a headwind. As well as wind, temperature will affect take-off performance and height gained. Warmer air is less dense and requires aircraft to fly faster to generate the required lift, resulting in long take-off ground rolls along the runway and reducing height after take-off compared with lower temperatures.

The aircraft's onboard systems compensate for atmospheric effects, adjusting the take-off speeds required, and, in some circumstances, increasing engine thrust settings to maintain an adequate safety margin.

Aircraft height is also affected by how an airline chooses to operate its aircraft, in order to balance competing factors of cost, noise, local air quality and CO_2 emissions. Each airline sets communicate the procedures to its pilots through Standard Operating Procedures (SOPs), which for EU airlines are governed by EU regulations are set out in EU-Ops, which enforce ICAO Standards and Recommended Practices that govern flight safety and emphasise standardised methods of operating. Noise abatement departure procedures are incorporated in each airlines' SOPs, with an airline permitted no more than two departure procedures for each aircraft type in its fleet. These regulations also stipulate no pilot intervention after take-off until a minimum height is reached of 800ft above the aerodrome. Above 800ft, a pilot is granted some flexibility in how to climb and accelerate the aircraft.

Airline SOPs are particularly relevant to aircraft noise calculations, because they can significantly affect noise levels after take-off beyond the 800ft height point, with maximum differences occurring around 12-13km from start of take-off roll, they can affect the length and size of noise contours between 55-60dB L_{den}. SOPs are approved by the State of aircraft registration as part of overall safety oversight and are not published. An ICAO survey (Ref 1) of 19 airlines found 14 distinct noise abatement departure procedures.

For the calculation of landing noise, some of the factors important for take-off noise become less important, but other factors become important, making the calculation no less challenging. Closer to the landing runway, aircraft position becomes more precise because aircraft follow the Instrument Landing System (ILS) that precisely fixes the height and lateral position of a landing aircraft. However, beyond the ILS, there is likely to be greater variation in aircraft height and position as aircraft are directed by ATC in order to optimise the landing rate.

Aircraft mass is less important, as unlike take-off, it does not affect height, but it does affect the engine thrust required to fly a particular trajectory. For example, all other things equal, a heavier aircraft requires more engine thrust to maintain level flight. ECAC. Doc. 29 recommends a fixed landing mass assumption of 90% of maximum landing mass of all aircraft, which is conservative for long-haul aircraft.

Aircraft configuration, the position of high lift devices (flaps and slats) and the landing gear become much more important. Whilst flaps and slats will be deployed according to aircraft speed, which will largely be dictated by ATC, the point of landing gear deployment is typically related to an airline SOPs.

All the above related to the calculation of noise for a single aircraft operation. This process is repeated for all aircraft operations in order to generate estimates of long-term average noise exposure. In contrast to road noise calculations, where details on the number of vehicles operating and their precise types is seldom recorded, large airports have systems in place to record detailed information on each operation, which airline it was operated by, using what specific aircraft type, from/to which runway and which flight path was used.

The task of calculating noise exposure around an airport is therefore one of capturing as much of the variation in aircraft operation as possible in order to provide an estimate of long-term average noise exposure within reasonable budget and timescales. Crucially, apart from very specific circumstances and projects, it is not necessary to estimate the variation in noise between flights, since dose-response functions already represent reactions to aircraft noise obtained from surveys linked to long-term average noise levels.

Noise calculations are often calculated for both historical and forecast purposes. Sometimes, because of the different amount and level of information available between historic and forecast scenarios, different approaches are employed. This is perfectly valid, it must be simply recognised that forecast scenarios will have greater uncertainty than historic ones.

2 ECAC.CEAC Document 29 and the ICAO Aircraft Noise and Performance (ANP) database

Guidance on calculating aircraft noise in the vicinity of an airport was first published in the 1980s. Today guidance is published by the European Civil Aviation Conference (ECAC) in ECAC.CEAC Document 29 4th Edition and ICAO Document 9911 2nd Edition.

Document 29 Volume 1 describes the important factors and encourages the person undertaking the calculations to ensure that the input data reflect local circumstances. Volume 2 provides a specific method and algorithms reflecting the internationally agreed recommended method for calculating aircraft using the ICAO ANP database. Volume 3 Part 1 provides reference calculation results based on the recommended method in Volume 2. Volume 3 Part 2 is planned guidance

ICAO Document 9911 replicates Document 29 Volume 2, the recommended calculation method, but provides no guidance on adapting the method to local circumstances.

The Dutch implementation of the calculation method in Document 29 Volume 2 was deemed out of scope of this peer review. However, it is relevant to highlight that the Dutch implementation of ECAC Doc. 29 4th Edition (Ref 2) was benchmarked by the ECAC's Aircraft Noise Modelling Technical Subgroup, AIRMOD alongside models from the UK, EUROCONTROL, Norway and the US and found to fully conform to the ECAC Doc 29 4th Edition recommended practice on the calculation of aircraft noise. This benchmarking process verified the computer software's ability to generate three-dimensional flight trajectories from input ground tracks and flight profiles and the calculation of noise levels from the resulting segmented flight trajectories and ICAO ANP Noise-Power-Distance (NPD) information, along with verification of the various adjustments necessary for aircraft noise directivity and duration correction effects. Thus, for the same calculation inputs the Dutch implementation of Document 29 4th Edition, gives the same calculated noise levels as other major implementations of Document 29 4th Edition.

The ICAO ANP database harmonised the provision of manufacturer supplied aircraft performance and noise information essential to the calculation of noise as set out in Document 29. As well as providing information on the aircraft aerodynamic, engine thrust and noise characteristics, it provides information on the variation of take-off mass with distance flown and noise abatement departure procedure information for two take-off noise abatement procedures. It provides a single landing approach procedure assume a 3 degree decelerating descent from 6,000ft. Take-off mass assumes a payload (passengers, bags and cargo) of 65% of maximum. Engine thrust settings are the maximum available take-off and climb thrust.

These do not reflect operations at major European hub airports, but, are provided as the only agreed way of providing standardised information. Whilst some States require that the ANP database is applied unadjusted, prioritising harmonisation of data used. Closer to the airport this may be acceptable, but further from the airport, i.e. beyond the 55dB L_{den} day to day operations deviate from the ANP database operating assumptions and thus it is necessary to adapt the database to reflect the local factors highlighted in section 1.

Above providing a guidance similar to in section 1 of this report, Document 29 Volume 1 provides no recommended approach for taking account of these local factors. Those undertaking the calculations are therefore left to identify how best to apply the guidance in Volume 1, when using the methods set out in Volume 2.

To what extent and how these adaptations have been done, forms the core aspect of this review. This task was broken down into three parts, reflecting the different inputs to the noise calculation process as described in section 1:

1. Input assumptions on how each aircraft type is operated that, in turn, define each aircraft's vertical flight profile on take-off and landing (height, speed and engine power setting at a given point in time)
2. Input assumptions on an aircraft's track over the ground
3. The aircraft performance and noise database that are used to calculate the vertical flight profiles (along with the assumptions defined in 1 above) and define the aircraft's noise characteristics

Items 1 to 3 are assessed in detail in Section 3.

For long-term average noise indicators such as L_{den} and L_{night}, values of L_{den} and L_{night} are calculated by determining the long-term average Sound Exposure Level (SEL), which is itself made up of calculations of SEL values for each aircraft type, operating on each flight path and each type of vertical flight profile defined. It is seldom possible or practical to calculate the noise levels of every individual flight on a flight by flight. Instead, each operation is typically allocated into a representative group or sample for a given combination of aircraft type, flight path and flight profile (flight procedure). The values of SEL for each unique grouping and calculated and combined with the number of operations of the grouping in order to determine the L_{den} or L_{night} values for each grouping.

Normally, such a calculation is implemented in a single step with the end result being the overall average L_{den} L_{night} values each location on the ground in the vicinity of the airport. However, the implementation in software in the Netherlands is slightly different to normal practice. First, calculations of the SEL values of each unique combination (over 10,000 for Schiphol) are undertaken and stored, rather than being used as temporary intermediate outputs. A separate piece of computer software then takes these intermediate SEL values for each unique

combination along with the numbers of operations of each combination to calculate the final L_{den} and L_{night} values.
The second piece of computer software is mathematically much simpler, since the aircraft performance and noise characteristics of each unique aircraft type, flight path and profile have already been calculated with the aircraft noise calculation. All the second piece of software is doing is decibel addition of large numbers of SEL values. Mathematically, the two approaches are identical. The benefit of this two-stage approach is that the calculation of alternative scenarios becomes much more rapid since the time-consuming calculation of SEL values is performed only once and is especially beneficial when the flight operations are broken down into a large number of combinations. Whereas for Schiphol airport, the operations are represented by over 10,000 combinations, for Heathrow airport around 1,500 are used. The disadvantage of such an approach is that a vast amount of intermediate SEL values much be stored after the first calculation is performed.

Because the peer-review scope also covered reviewing the L_{den} and L_{night} calculation results for two EIA scenarios, it was necessary to briefly review the second computer programme (called DAISY) used to calculate aggregate values of L_{den} and $L_{night.}$ Section 3 briefly reviews the computer programme DAISY used to aggregate the noise levels of individual aircraft types together in order to generate long-term average noise exposure levels used to generate noise contours and noise maps.

Section 4 of this report reviews the information specific to review of the EIA scenarios and the calculation of the EIA noise contours.

3 Noise Calculation

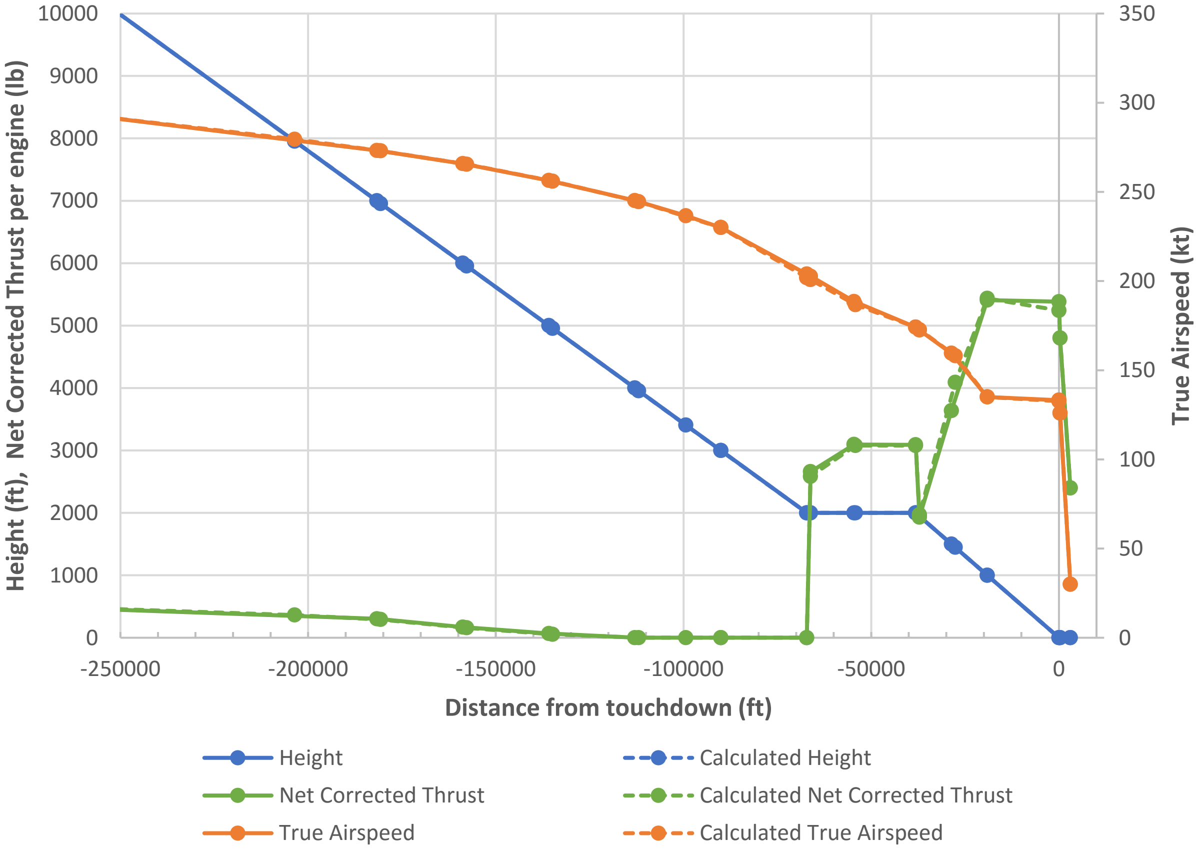
3.1 Calculation of Flight Profiles

The Dutch implementation of ECAC Doc. 29, utilizes the ICAO Aircraft Noise and Performance (ANP) database, to calculate the vertical flight profiles based on a series of assumptions as to how aircraft are operated into and out of Amsterdam Schiphol airport. The flight procedure assumptions have been developed from knowledge of and surveys of key airline operators and validation of flight procedures against observed aircraft flight profiles derived from radar data. This represents best practice.

As many as 80 unique flight profiles have been defined for each aircraft type, in order to encompass the wide range of aircraft distances flown and different arrival and departure flight procedures used. In practice, the number of unique flight profiles assigned to daily operations is much smaller (up to 20). This definition of flight profiles goes well beyond ECAC Doc. 29 best practice guidance, where the accompanying ANP database provides up to a maximum of 18 departure flight profiles for long-haul aircraft, up to 10 departure flight profiles for short-haul aircraft types and just a single landing flight profile for each aircraft type.

Unlike road or rail noise calculations, a unique aspect of aircraft noise calculations is that the source noise emission is based on engine thrust settings that are directly related to the aircraft trajectory flown. In order to check the calculation of engine thrust settings for the flight profiles developed for Schiphol airport, engine thrust settings were calculated for a single landing flight profile for the most common aircraft, the Boeing 737-700. The calculation requires application of the ANP database information on the aerodynamic characteristics of the Boeing 737-700 and the determination of when flaps/slats and landing gear are deployed. The results are presented in Figure 1, which shows aircraft height and speed at points prior to landing along with the calculated engine thrust settings associated with this flight profile. Height and speed (blue and orange lines) are deliberately identical in order to replicate the selected landing flight profile. However, the resulting calculated engine thrust settings (solid and dashed green lines) are also almost identical and hard to distinguish in Figure 1. This gives assurance that the flight profiles have been calculated correctly from the ANP database and that the source noise emission reflects the calculated performance of each aircraft type.

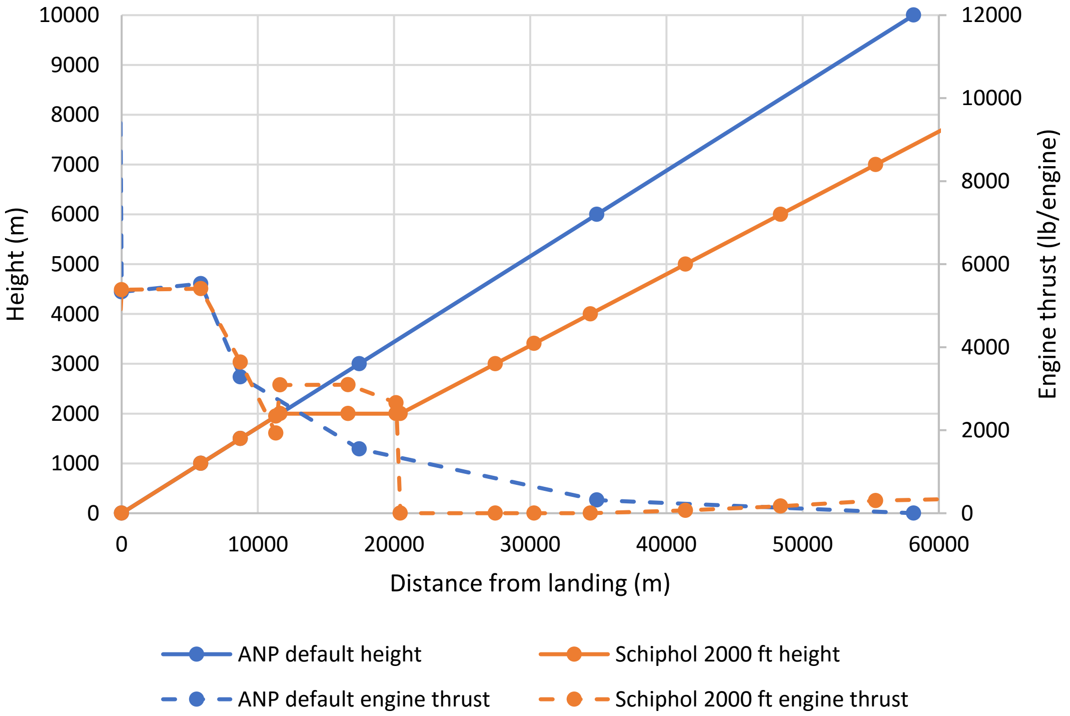
Figure 1: Validation check of supplied and calculated landing flight profile for a Boeing 737-700



3.2 Consequences of adjusting flight profiles

Figure 2 compares the Boeing 737-700 default ANP landing profile against the 2,000 ft intercept flight profile verified in Figure 1 and assigned to 39% of Boeing 737-700 landing operations in the traffic scenarios provided.

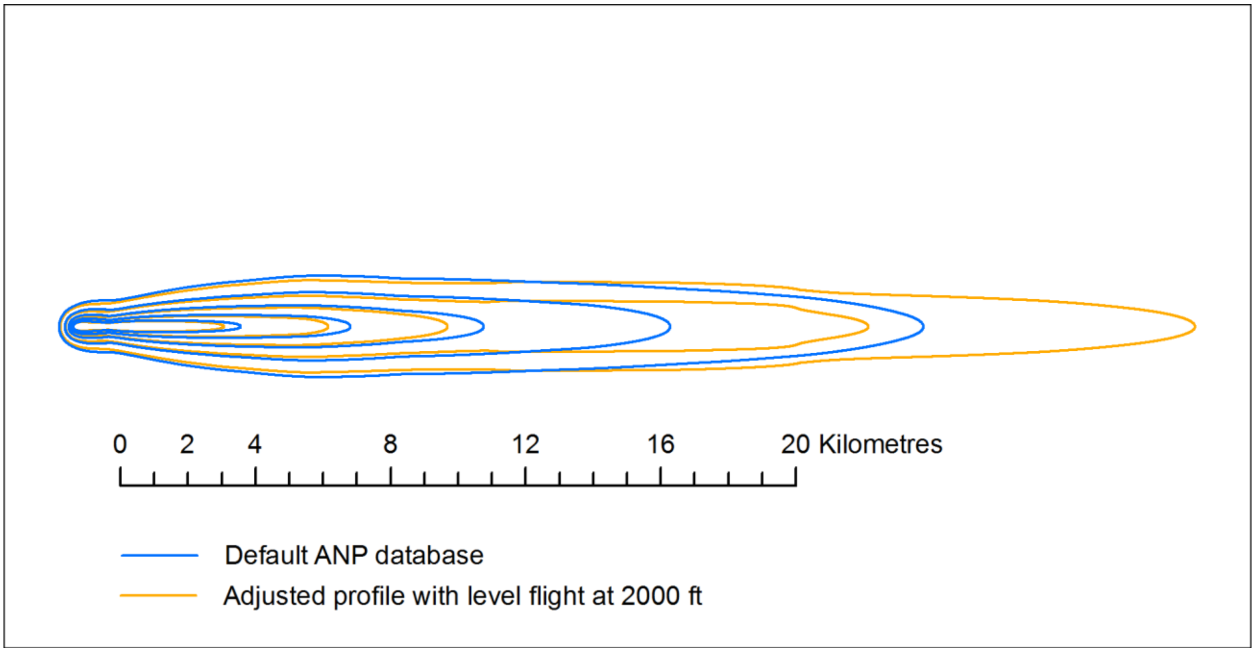
Figure 2: Comparison of Boeing 737-700 ANP landing profile and Schiphol adjusted 2,000 ft intercept profile



The 2,000 ft intercept profile incorporates a portion of level flight between 10 and 20 km from landing, which lowers the aircraft height relative to the ANP default profile and increases the engine thrust required to fly in level flight. Consequently, the flight profile is also lower than the ANP default for the preceding descent all the way out to 10,000 ft.

The consequences of the lower flight profile are shown in Figure 3, which shows the landing SEL noise footprints for the same two profiles. The noise footprints are plotted are the 70, 75, 80, 85 and 90 dB SEL. Beyond 10km from landing, the adjusted Schiphol profile is clearer much noisier than the default ANP flight profile with the 75 and 70 dB footprints extending much further out from landing.

Figure 3: Boeing 737-700 landing noise footprints for ANP default profile and Schiphol 2,000 ft intercept profile



3.3 Flight Tracks

For the implementation of ECAC Doc. 29 noise calculations are performed using individual flight tracks obtained from radar data, rather than using a statistical representation calculated from the radar flight tracks. This removes the need to check the statistical methodology used to group or cluster radar tracks together (since no grouping is performed) and goes beyond ECAC Doc. 29 best practice guidance.

3.4 Use of ANP database

Each aircraft operation must be assigned to an aircraft type in the ANP database. The ANP database contains the most common variant(s) for each aircraft type, but does not contain aircraft performance and noise information for every variant. For example, the ANP database contains information only one variant of the Boeing 737-800. In contrast, Issue 30 of the EASA Approved Noise Levels database (Ref 3), contains 1,524 distinct certified variants of the Boeing 737-800. ECAC Doc. 29 4th provides guidance on assigning different variants to the single entry in the ANP database and the ICAO ANP database includes a substitution list based on the method describes in ECAC Doc. 29.

The presentation of the method used in The Netherlands (Ref 3) confirmed that the guidance in Document 29 on aircraft substitution is followed, according with best practice as described in Document 29.

The ANP noise performance information (Noise Power Distance data) have been used as provided in the ANP database (after taking account of any substitution adjustments required have been applied). The ANP NPD data therefore represent the single important aspect where formal validation has not been undertaken (in contrast to the adjustment of flight profiles for example). Although the ICAO noise certification process from which the ANP data are derived, is a rigorous one, it tests only a relatively small aspect of the landing and take-off flight performance of an aircraft and under very strict test conditions, in the case of landing, at very low speed, with full flaps, landing gear down and close to the airport. Under normal operation, conditions may differ considerably, and noise must be calculated over a much greater proportion of the landing and take-off flight envelope.

As there is not yet any international guidance on comparing noise calculations with measurements and on the adjustment of NPD data, this does not represent a deviation from best practice, however, it contrasts with the approach taken in other areas where, for example, aircraft performance has been calculated and compared in detail with radar data. Secondly, making comparisons with measurements not only allows the NPD data to be checked, but also a check of the cumulative effect of all elements of the noise modelling process, including assumptions on take-off mass and flight procedures.

A draft report on the comparison of calculated noise levels against measurements (Ref 5) was provided and indicated good correlation between (trends in) calculated and measured levels. A separate report (Ref 6) has been provided, giving further guidance on comparing calculated and measured noise levels and on techniques to adjust flight procedure assumptions and/or NPD data to minimise any differences. In light of the fact there is no internationally agreed and published validation on the ANP NPD data that is fundamental to the noise calculations it is recommended that comparisons between calculated and measured noise levels (at the aircraft type level) are undertaken going forward.

4 Calculation of noise for multiple flights

4.1 DAISY

The policy objective in the Netherlands is to calculate noise exposure for an average annual 24h day using the L_{den} noise indicator which gives greater weight to flights operating during the evening (1900-2300) and the night (2300-0700). The majority of international noise models calculate the noise of each operation and add the contributions of each aircraft type and flight path as they go. If this approach is taken when calculating the noise using every individual flight track, the calculation could take weeks or even months. To improve the efficiency whilst calculating noise for every flight track, the noise exposure associated with each aircraft type on a given SID or arrival flight path (itself made of potentially thousands of individual flights) is stored as the representative Sound Exposure Levels (SEL) for that aircraft type and flight path.

A separate computer programme called DAISY is then used to add the relevant SEL values together, based on the EIA forecast scenario in order to calculate the average annual L_{den} noise exposure. Computationally, this is an efficient process and mathematically gives an identical result to the conventional approach of calculating L_{den} directly from the individual SEL values in one go.

Because the DAISY programme is doing nothing more complex than logarithmic addition of grid-based SEL values for the assigned numbers of operations of aircraft types and flight paths, I am assured of the functions of DAISY without further detailed investigation.

5 Environmental Impact Assessment scenarios

5.1 Review of overall scenario traffic information

Annual traffic information was provided for two Schiphol scenarios. The traffic information provided the number of flights by aircraft, landing or take-off flight procedure, take-off stage length, runway, landing or take-off flight path and time period (day, evening or night).

An integrity check was performed on the data as follows. The proportion of traffic for the first provided scenario in the day, evening and night periods is compared with that for London Heathrow from 2016 in Table 1.

Table 1: Day, Evening and Night flight distribution

	Day	Evening	Night
Amsterdam Schiphol scenario no. 1	72.4%	21.2%	6.4%
London Heathrow	73.0%	20.9%	6.0%

5.2 Allocation of traffic to flight profiles

A presentation (Ref 3) was provided describing how each flight is assigned to a set of flight procedures that are in turn used to calculate the vertical flight profiles. For departures, information is obtained on the Noise Abatement Departure Procedure (NADP) used by each airline, take-off mass as a function of distance flown and take-off engine power settings. These flight procedure parameters are used to calculate departure vertical flight profiles which are checked against observed flight profiles determined from radar data. This approach is best practice.

For landing aircraft, vertical ‘gates’ are used to assign aircraft radar flight profiles to different flight procedures, e.g. those aircraft that intercept the ILS at 2,000 ft, those that intercept at 3,000 ft and those that intercept in a Continuous Descent. Matching flight profiles are then calculated using the ANP database aircraft performance data in order that aircraft airspeed (which cannot easily be determined from radar data) and source emission (engine power setting) can be estimated. This approach is best practice.

Table 2 presents the distribution of landing flight profiles provided for the first EIA scenario. The distribution accords with anecdotal information provided by UK pilots questioned about operating into and out of Schiphol airport. Although the information in Table 1 was not broke down by airline (that information is not relevant to the noise calculation), it was found that a higher proportion of quieter Continuous Descent Approaches (CDA) were observed for a type where KLM is the dominant operator (B737-800) and a lesser proportion was found for aircraft types not operated by KLM. This is consistent with the fact that home-based airline will naturally have a higher proportion of quieter CDAs as its pilots will be more familiar with Schiphol airport flight procedures and local ATC services. This further indicates that the flight profile allocation is representative of expected practice.

Table 2

Approach Profile	**Percent of arrivals**
ILS intercept @ 2000ft	44%
ILS intercept @ 3000ft	19%
CDA	37%
Total	**100%**

Table 3 presents the percentage of landing operations assumed to use reduced landing flap and full flap. All aircraft are designed and certified with two possible landing flap settings. The reduced landing flap setting sets the flaps at a shallower angle, resulting in less drag, requiring less thrust and reducing noise during the final 8-10km of the landing approach, at the expense of a slightly higher landing speed, which for the long runways at Schiphol is of no consequence. Reduced landing flap is common practice since, as well as being a noise mitigation measure, it reduces fuel burn and reduces aircraft maintenance cost by reducing fatigue on flap components. Most of the 2% of operations assumed to use full flap were general aviation aircraft which may not always have two landing flap options and will also tend to land on the shorter runway at Schiphol.

Table 3

Approach Profile	**Percent of arrivals**
Reduced flap	98%
Full flap	2%
Total	**100%**

5.3 Calculation Grid spacing

Noise calculations are performed over a grid of points covering the vicinity of the airport. The annual average L_{den} noise exposure level is calculated at each grid point from the contribution of every combination of aircraft type, flight profile and flight path. A finer grid spacing entails more grid points and a longer calculation time – a halving of grid spacing in both dimensions will result in a four-fold increase in calculation time.

Noise contours, lines of constant noise level are calculated by interpolating across the calculation grid. If the grid spacing is too large, it will distort the shape of the calculated noise contour. Calculations for Schiphol airport use a 250m x 250m grid spacing. This is acceptable for the key policy noise contours, 48dB and 58dB L_{den}. In the UK 100m x 100m calculation grids are used for Heathrow airport noise calculations, where it has been found necessary to use a 100m x 100m grid spacing to more precisely calculate exposure levels of above 65dB L_{den} which cover smaller areas close to the runways.

6 Overall Conclusions

A peer review has been undertaken on the Dutch aircraft noise calculation process as used in the Environmental Impact Assessment noise calculations for Amsterdam Schiphol airport. The peer reviewed examined the inputs to the noise calculation process:

1. Input assumptions on how each aircraft type is operated that, in turn, define each aircraft's vertical flight profile on take-off and landing (height, speed and engine power setting at a given point in time)
2. Input assumptions on an aircraft's track over the ground
3. The aircraft performance and noise database that are used to calculate the vertical flight profiles (along with the assumptions defined in 1 above) and define the aircraft's noise characteristics

The review was shown evidence of how information on how the height and speed of aircraft during landing and take-off are determined from radar data and used to calculate aircraft performance, specifically engine thrust settings that relate to the observed radar data, rather than relying default assumptions provided in the ICAO Aircraft Noise and Performance (ANP) database. The implementation fully reflected guidance provided in ECAC Document 29 Volume 1, whilst utilising and respecting the aircraft performance calculation method described in ECAC Document 29 Volume 2. The degree to which differences in aircraft performance were represented by accounting for distinct take-off and landing weights and different noise abatement departure and arrival procedures was considered to far exceed best practice. Some aircraft types were represented by as many as 80 distinct flight profiles, in contrast to a maximum of 19 flight profiles provided in the ANP database. The review highlighted how the adapted flight profiles produce larger noise footprints than the default ANP database profiles and would therefore lead to larger noise contours, had the adjustments not been made.

In many States the different ground tracks flown by arriving and departing aircraft are first grouped together and represented by a nominal flight track and a statistical representation of the variation in track flown using 3 or 5 tracks positioned either side of each nominal track. The Dutch implementation of Document 29 in the content of the EIA scenarios, dispenses with the statistical grouping of tracks and instead calculates noise exposure for every flight track operated as determined from radar data. Again, this goes beyond the best practice described in ECAC Document Volume 1.

The Dutch implementation of the calculation method in Document 29 Volume 2 was deemed out of scope of this peer review. However, it is relevant to highlight that the Dutch implementation of ECAC Doc. 29 4th Edition was benchmarked by the ECAC's Aircraft Noise Modelling Technical Subgroup, AIRMOD alongside models from the UK, EUROCONTROL, Norway and the US and found to fully conform to the ECAC Document 29 4th Edition recommended practice on the calculation of aircraft noise. This benchmarking process verified the computer software's ability to generate three-dimensional flight trajectories from input ground tracks and flight profiles and the calculation on noise levels from the resulting segmented flight trajectories and ICAO ANP Noise-Power-Distance (NPD) information, along with verification of the various adjustments necessary for aircraft noise directivity and duration correction effects. Thus, for the same calculation inputs the Dutch implementation of Document 29 4th Edition, gives the same calculated noise levels as other major implementations of Document 29 4th Edition.

Sometimes the aircraft variant for which noise calculations are being performed is not in the ICAO ANP database. For such circumstances, Document 29 provides guidance on how to perform an appropriate substitution, which is implemented into a Substitution List provided alongside the ICAO ANP database. Information provided confirmed that the guidance in Document 29 on aircraft substitutions is followed, according with the best practice described in Document 29.

The ANP noise performance information (Noise Power Distance data) have been used as provided in the ANP database (after taking account of any substitution adjustments required have been applied). The ANP NPD data therefore represent the single important aspect where formal validation has not been undertaken (in contrast to the adjustment of flight profiles for example). Although the ICAO noise certification process from which the ANP data are derived, is a rigorous one, it tests only a relatively small aspect of the landing and take-off flight performance of an aircraft and under very strict test conditions, Under normal operation, conditions may differ considerably, and noise must be calculated over a much greater proportion of the landing and take-off flight envelope. Secondly, making comparisons with measurements not only allows the NPD data to be checked, but also a check of the cumulative effect of all elements of the noise modelling process, including assumptions on take-off mass and flight procedures.

As there is not yet any international guidance on comparing noise calculations with measurements and on the adjustment of NPD data, this does not represent a deviation from best practice, however, it contrasts with the approach taken in other areas where, for example, aircraft performance has been calculated and compared in detail with radar data. A draft report on the comparison of calculated noise levels against measurements (Ref 5) was provided and indicated good correlation between (trends in) calculated and measured levels. A separate report (Ref 6) will be provided, giving guidance on comparing calculated and measured noise levels and on techniques to adjust flight procedure assumptions and/or NPD data to minimise any differences. In light of the fact there is no internationally agreed and published validation of the ANP NPD data that is fundamental to the noise calculations it is recommended that comparisons between calculated and measured noise levels (at the aircraft type level) are undertaken going forward.

The software implementation in The Netherlands, uses ECAC Document 29 to calculate the Sound Exposure Level (SEL) for each aircraft type on each take-off or landing flight profile, on each flight track. The resulting SELs for each calculation grid point are stored (over 10,000 sets across thousands of grid points) and for an L_{den} calculation, the SELs are simply added together in accordance with the traffic scenario using a separate piece of software called DAISY. Because the DAISY programme is doing nothing more complex than logarithmic addition of grid-based SEL values for the assigned numbers of operations of aircraft types and flight paths, I am assured of the functions of DAISY without further detailed investigation.

Annual traffic information representing two Environmental Impact Assessment (EIA) scenarios was examined. The breakdown of flights between the day (0700-1900), evening (1900-2300) and night (2300-0700) periods required for L_{den} noise calculations closely matched that for London Heathrow airport. The distribution of aircraft types reflected the dominance of the home-based airline, KLM, with Boeing 737 aircraft being the most common aircraft type used.

The breakdown of operations by aircraft noise abatement departure procedure and landing flight profile reflected my understanding of the procedures used by KLM and in the case of landing, anecdotal evidence from UK pilots asked about landing at Schiphol airport.

Noise calculations must be performed at a wide number of locations in the vicinity of the airport. Though always necessary, it is routine practice to carry out calculation of a regular grid of points with a uniform grid spacing. If the grid spacing is too large, it will distort the shape of the calculated noise contour. Calculations for Schiphol airport use a 250m x 250m grid spacing. This is acceptable for the key policy noise contours, 48dB and 58dB L_{den}. In the UK 100m x 100m calculation grids are used for Heathrow airport noise calculations, where it has been found necessary to use a 100m x 100m grid spacing to more precisely calculate exposure levels of above 65dB L_{den} which cover smaller areas close to the runways.

Overall, the preparation of input data and the calculation process used for Schiphol airport's EIA noise calculations goes beyond the best practice set out in ECAC Document 29 4th Edition. Although evidence was provided showing a good correlation between calculated noise levels and measurements, there is, nevertheless, a high degree of reliance on the industry provided ICAO ANP NPD information, which are central to the calculation of noise levels. It is therefore recommended that a routine programme of undertaking noise measurements is developed and implemented and that comparisons are made between measured and calculated noise levels, and where necessary adjustments to input assumptions and NPD data are made.

7 References

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3. "Nederlandse gebruiksafspraken Doc29", Dick Bergmans, Expert Meeting Doc. 29, 8 February 2017.
4. Issue 30, EASA Jet Aeroplane approved Noise levels, 21 June 2018
5. Trendvalidatie van Doc.29 berekeningen, NLR-CR-2017-371, draft report.
6. Guidance on comparing calculated aircraft noise levels with measurements, Rhodes, Darren, UK CAA, September 2018.