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AIR TRAFFIC NOISE CALCULATION IN THE NORDIC COUNTRIES: MINIMUM REQUIREMENTS, TEST AND TOOLS

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1. SCOPE

The scope of this paper is to notify environmental authorities, planners, airports, and airport noise consultants of the existence of new Nordic guidelines for calculation of air traffic noise.

The guidelines define minimum requirements to the calculation methodology. Test examples and a single-point calculation method are also part of the Nordic guidelines.

2. BACKGROUND

For many years the environmental authorities in the four Nordic countries (Denmark, Finland, Norway, and Sweden) have cooperated on development, revision, and harmonization of calculation methods for road traffic noise, railway noise, and air traffic noise.

The Model Revision Group under the official committee on environmental issues of the Nordic Council of Ministers has supervised the accomplishment of the work reported in this paper.

The main objectives of the work were:

- To prescribe guidelines that ensure high quality air traffic noise calculations by specifying minimum requirements for calculation methodologies being in accordance with ECAC [1] and ICAO [2] recommendations. Called "the minimum requirements" the method defines which calculation principles will ensure a sufficient calculation accuracy, statisfactory to the environmental authorities (e.g. in Denmark as a basis of an application of environmental approval).
- To describe a test mandatory for consultants who use calculation programs deviating from DANSIM and INM3. Acceptable limits are defined.
- To describe a single point calculation method (a manual and a PC-version exist) that enables "non-professionals" to evaluate noise complaints, facilitate a test of consultants' calculations in single points, and decide whether a noise-sensitive building can be placed in a specific area.

3. NOISE RATINGS AND CALCULATION PROGRAMS USED IN THE NORDIC COUNTRIES

There are only minor differences between the air traffic noise ratings and the corresponding basic noise descriptors which are used in the Nordic countries as stated in Table 1

Country	Time-integrated noise rating	Based on descriptor	Maximum rating	Calculation program
Denmark	L_{DEN}	L_{AE}	L_{Amax}	DANSIM[1)]
Finland	L_{DEN}, $L_{Aeqnight}$, L_{Aeqday}	L_{AE}	L_{Amax}	DANSIM[1)]
Norway	EFN	L_{AE}	MFN (L_{Amax})	INM[2)] NORTIM[3)]
Sweden	FBN	L_{AE}	L_{Amax}	[4)]

Table 1 *[1)] DANSIM (Danish Airport Noise SImulation Model) [3]*
[2)] INM (Integrated Noise Model version 3) [4]
[3)] NORTIM (Norwegian Topography Integrated Model) [5]
[4)] Calculation programs comply with the Nordic minimum requirements.

To ensure a high quality of the calculation results, no matter what rating and calculation program is used, it is necessary that all relevant input data are available and that the consultant has a sufficient knowledge of acoustics in general, of aircraft noise in particular, and of the function of the calculation program in detail, and is capable of evaluating all necessary data which include traffic information, operational information, and noise and performance data.

4. MINIMUM REQUIREMENTS FOR CALCULATION METHODS

The requirements that air traffic noise calculation methods must fulfil in order that the results can be accepted by the environmental authorities in the Nordic countries are formulated in the minimum method [6].

The reason for defining a minimum method instead of an explicitly defined method is the wish to make calculations with more or less complex programs possible.

For each individual program it must be documented that the computational principles used are not inferior to the principles of the minimum method.

The minimum method applies to calculations based on both L_{Aeq} and L_{Amax}. The minimum method does neither concern the rating method nor the noise limit values. The principles of the minimum method are dealt with in the following.

Air traffic noise calculations are based on the following 4 groups of information:

a) Traffic information, e.g. number of operations distributed on aircraft types, time-of-day-, week-, and year-distribution.
b) Operational information, e.g. runway configuration, runway use, flight track system and horizontal dispersion, and traffic distribution on tracks.

c) Noise and performance data, e.g. dependence of the used noise descriptor L_{AE} or L_{Amax} on distance and engine power setting at a reference speed (L_{AE} only). Information of take-off and landing performance (altitude, speed, and power setting as a function of the distance to the runway).

d) Computational assumptions, e.g. the lateral attenuation model, directivity of the noise source, and whether topography is taken into account.

The minimum method defines a calculation procedure consisting of two steps: First the single-event noise contours (L_{AE} or L_{Amax}) are calculated for each individual type of aircraft and operation.

Second the noise from the total traffic is determined either as the maximum level contour from e.g. the most noisy aircraft adjusted to the flight track system or as the sound exposure contour based on an energy summation of the L_{AE}-contours from each individual operation on an average day (defined in the national methods).

During the single-event calculation the basic noise contours need a number of corrections which are specified in detail in the minimum method.

In the following short introductions to the individual correction steps are given together with illustration of the influence on the basic noise contour (dotted line).

- Correction for duration (only of relevance for L_{AE}, not for L_{Amax}):

$$\Delta L_v = 10 \log \frac{V_{ref}}{V}$$

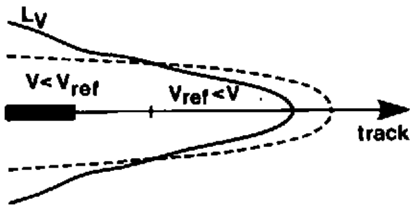


Fig. 1 Duration correction.

- Correction for lateral attenuation: As an example the model described in SAE AIR 1751 [7] is used for calm wind and flat terrain covered by short-cut grass. Ground-to-ground attenuation increases to max. 14 dB at a distance of 914 m or more. Air-to-ground attenuation is reduced gradually to zero at an elevation angle of 60°.

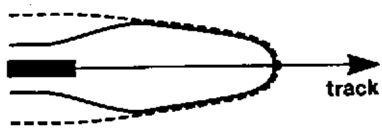


Fig. 2 Influence of lateral attenuation.

- Correction for change in power setting: As an example a sudden power reduction at x will change both an L_{AE}-contour and an L_{Amax}-contour. Δx is shorter for an L_{Amax}-contour than for an L_{AE}-contour.

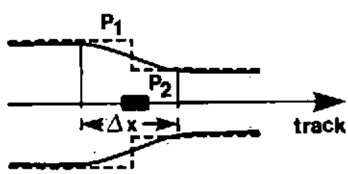


Fig. 3 Correction for change in power setting.

- Correction of noise during take-off ground roll is rather complicated: L_{AE}-contours are affected both by aircraft speed and by the flight effect. The total effect on L_{AE} is an increase of approx. 10 dB at start of roll compared to lift-off. For L_{Amax} the effect is approx. 5 dB.

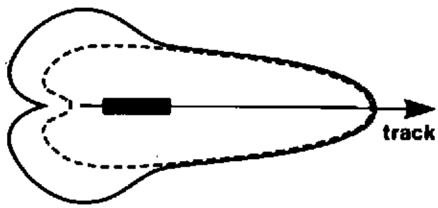


Fig. 4 Effect of flight effect only.

- Correction of noise during landing roll: L_{AE}-contours are affected by aircraft speed, whereas L_{Amax}-contours are not. The use of thrust reversers for aerodynamic braking action adds noise during landing roll.

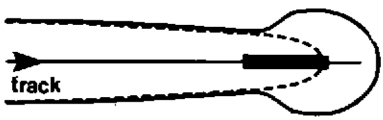


Fig. 5 Correction for thrust reversal.

- Correction for track geometry: If a flight track includes a turn, the sound exposure level will increase inside the turn and decrease outside the turn. Depending on the size of the turn and the calculation position corrections are in the range from +4 dB to -2 dB. No correction is added to L_{Amax}-contours.

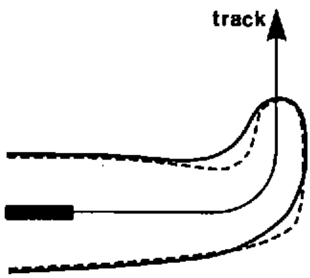


Fig. 6 Correction for turning flight track.

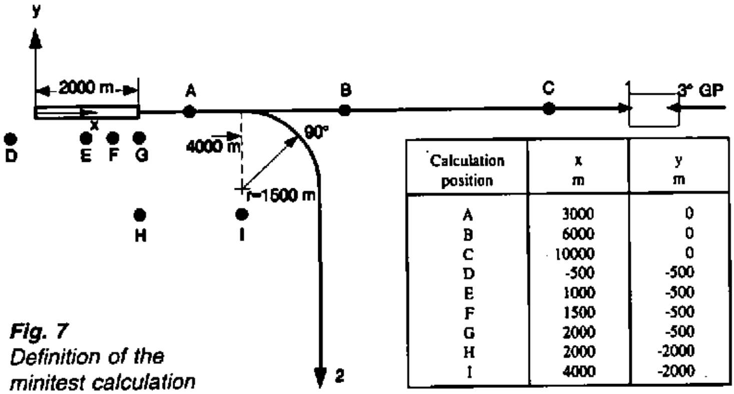
5. QUALITY TEST

To ensure an adequate quality of airport noise calculations in the Nordic countries it is mandatory that:

- the principles of calculation are documented as not inferior to the minimum method,
- a minitest has been executed using the calculation program under consideration,
- the calculation results from the minitest are within the limits specified in [8] if the principles of calculation deviate from the minimum method.

The minitest specified in [6] includes the calculation of noise exposure contours $L_{Aeq,24h}$ = 35-50 dB for two different aircraft types each following two different departure routes and one straight approach. The noise exposure in nine specific positions specified in Figure 7 must prove to be within a specified interval ±1 dB relative to the interval formed by the values calculated with INM 3 and DANSIM. The DANSIM-calculated $L_{Aeq,24h}$ = 35-50 dB contours ±1 dB for a B767 taking off on flight track 2 and the corresponding values in A-I are shown in Figure 8.

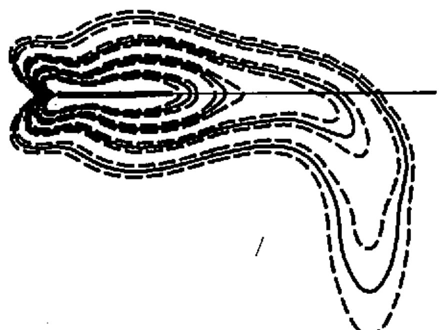
Use of the minitest ensures that the main calculation routines and the plotting routine satisfies the accuracy demands of the authorities.



Calculation position	x m	y m
A	3000	0
B	6000	0
C	10000	0
D	-500	-500
E	1000	-500
F	1500	-500
G	2000	-500
H	2000	-2000
I	4000	-2000

Fig. 7
Definition of the minitest calculation positions.

Fig. 8
Example of DANSIM-contours.



Calculation positon	Calculated $L_{Aeq,24h}$		
	DANSIM	Acceptance interval	INM3
A	44.9	43.9 - 47.0	46.0
B	31.4	30.2 - 32.4	31.2
C	12.5	11.5 - 13.7	12.7
D	41.3	40.3 - 43.1	42.1
E	45.8	40.6 - 46.8	41.6
F	47.0	44.9 - 48.0	45.9
G	46.1	45.1 - 47.4	46.4
H	28.7	27.6 - 29.7	28.6
I	29.9	28.7 - 30.9	29.9

Single-point values of $L_{Aeq,24h}$:
B767-300/PW 4060 take-off,
TOM: 265,000 lbs.

6. SINGLE POINT CALCULATION METHOD (SPM)

The single point calculation (SPM) method is a new calculation method developed at the request of the Nordic Council of Ministers. It exists both as a manual method and as a PC-program. The method is simple and enables a person without particular knowledge in the field of airport noise calculations to make calculations of noise from air traffic in a single point with a reasonable accuracy.

The SPM is a tool suited for e.g. environmental authorities and planners, who need to estimate noise exposure or the change in noise exposure in one or more points in the vicinity of an airport.

The SPM may be used in connection with:

- Considerations concerning placing noise-sensitive buildings near an airport.
- Evaluation of noise complaints.
- Control of large airport noise calculations in single points.

The manual SPM is based on precalculated noise levels for a straight flight track contained in immission data tables. Tables have been made for a number of aircraft types and for take-offs and landings separately. Corrections are made for the number of operations, the time-of-day distribution and, if necessary, for the flight track geometry and the lateral dispersion of the traffic around the flight tracks. The method covers both time integrating and maximum noise ratings used in the Nordic countries (see Table 1).

For each single point the method has in principle no limitations compared to the more advanced calculation programs. However, the manual procedure puts a limit to how many points it is possible to cope with. Approx. 25 aircraft types are contained in the immission database which is published on disks only, due to its considerable size. The database is usable both for the manual and for the PC-version of SPM.

The SPM fulfils the technical minimum requirements (Section 4). The PC-version of the method has the advantage that reading from immission data tables and calculation of corrections is made by the program. The accuracy of the SPM is comparable to that of more advanced calculation programs provided that the immission database is sufficient to describe the traffic under consideration.

References

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[2] ICAO, "Recommended Method for Computing Noise Contours around Civil Airports", CAEP/1 WP2, Appendix E, June 1986.

[3] Birger Plovsing & Christian Svane, "Aircraft Noise Exposure Prediction Model. Guidelines for the Methodology of a Danish Computer Program", Danish Acoustical Institute, Report No. 101, July 1983.

[4] M.C. Flythe, "INM, Integrated Noise Model Version 3, User's Guide - Revision 1", Federal Aviation Administration, Report No. DOT/FAA/EE 92/02, June 1992.

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[6] H.L. Nielsen, B. Plovsing & C. Svane, "Air Traffic Noise Calculation. Nordic Guidelines", Nord 1993:38.

[7] SAE Aerospace Information Report 1751, "Prediction Method for Lateral Attenuation of Airplane Noise during Take-Off and Landing", March 1981.