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Practical aspects of road noise mapping in Sweden using CNOSSOS-EU

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The mapping of road traffic noise using CNOSSOS-EU requires more detailed input data than the Nordic Prediction Method for Road Traffic Noise from 1996 (RTN96), which currently is the primary calculation method used in Sweden for the mapping of road noise. Among the differences may be mentioned: the emission model has more vehicle categories that needs to be adapted to Swedish conditions, road surface correction is handled differently, corrections for the use of studded tires can be applied, four instead of two ground absorption classes, and that meteorology can be taken into account. The article presents results from test calculations that were made with CNOSSOS-EU with the aim of producing Swedish recommendations for END noise mapping. Calculated sound levels are compared with corresponding results obtained with RTN96 and Nord2000. Level differences between the methods are moderate at short distances, provided that no screening is present, but increases at longer distances and in shielded positions. For the latter, CNOSSOS-EU and RTN96 often underestimates levels in comparison to predictions made with Nord2000 using realistic weather data.

1 Introduction

In accordance with EU's Environmental Noise Directive (Directive 2002/49/EC, short: END) and following instructions from the European Environment Agency (EEA) concerning strategic noise mapping, noise levels must be mapped in all larger municipalities (>100,000 inhabitants) and around major roads, railways and airports of each member state. As of January 1 2019, it is mandatory to use the new CNOSSOS-EU (Common Noise Assessment Methods in EU) assessment methods for the strategic noise mapping, where the impending mapping covers 2021 and the data must be reported to the European Commission by June 30 2022.

Up to now, Sweden have been using the Nordic Prediction Method for Road Traffic Noise, revised 1996 (RTN96), for both END and domestic mapping. As CNOSSOS-EU differs from RTN96 in several ways, adaptions to Swedish conditions (mainly concerning emission data of vehicle fleet and road surfaces) needs to be considered.

Presented in this article are some results from comparing calculations of road traffic noise, made with CNOSSOS-EU, RTN96, and Nord2000.

2 Method

Both source and propagation models differ in several significant ways between the three calculation methods. As there is a risk that a comprehensive parameter study may become unmanageably large, an approach using a full-scale model over a residential area was chosen. However, at a later stage, in-depth analyses of selected parts may need to be done using parameter studies, as well as studies in other types of areas. The Högsbo district in Gothenburg was found to be a suitable example in that it contains a variety of buildings, roads, noise screens, as well as varying terrain. L_{den} noise levels were calculated at 4 m above ground, as façade levels and noise contours. All calculations have been made with the software SoundPLAN, version 8.1.

The City of Gothenburg contributed with a section from their SoundPLAN model over the city, which was developed for the third END mapping round, and hence contains measured traffic data distributed over day, evening and night.

Figure 1: Part of the Högsbo district in Gothenburg. Noise levels have been calculated within the green area (30 Ha).

In SoundPLAN, each calculation method has its own set of attributes for the road and traffic data. The obtained SoundPLAN model included such data for RTN96 while the attributes of CNOSSOS-EU and Nord2000 were empty. Required input data also differs between the three methods at several points. For example, RTN96 use one category for heavy traffic while both CNOSSOS-EU and Nord2000 need two.

The existing RTN96 traffic data were exported to a shapefile, further processed for CNOSSOS-EU and Nord2000 respectively, and brought back into the SoundPLAN model. This is made possible since all road attributes that are relevant to the three methods (a total of about 200 attributes), and the information they contain, are stored in each shapefile's corresponding dBase file. As the attributes keep references to their corresponding road objects in the model, different variants of source emissions etc. can be tried out in a rational way by editing the attributes in the dBase table and importing them back into the model.

3 Correction factors

Initially calculated levels showed relatively large differences between the three calculation methods, even at short unshielded distances. However, these calculations were made using the default settings in SoundPLAN. For instance, vehicle emissions of CNOSSOS-EU and Nord2000 did not correspond to Swedish conditions. Neither CNOSSOS-EU nor Nord2000 related to the same road surface texture as RTN96, which uses stone mastic asphalt 0/16 (SMA16) as reference.

3.1 Vehicle emissions

Vehicle emissions of Nord2000 and CNOSSOS-EU were corrected according to the result of a Swedish measurement campaign carried out in 2015 [1].

3.2 Heavy vehicle categories

RTN96 has only one category for heavy vehicles while CNOSSOS-EU and Nord2000 both divide them into two different categories, *medium heavy vehicles* and *heavy vehicles*. The distribution between them depends on what type of road it is. As a first order approximation, heavy traffic was divided equally between the medium and heavy categories in the calculations.

3.3 Road surfaces

All calculations have been made for SMA16, which is a very common surface in Sweden, and also the reference surface of RTN96. The reference surface of both CNOSSOS-EU and Nord2000 is an average of dense asphalt concrete 0/11 and stone mastic asphalt 0/16. However, the Swedish correction for vehicle emission that have been applied to CNOSSOS-EU, is formulated as a road surface correction for SMA16, that includes adjustments to speed dependence. In order to correct Nord2000 for SMA16 a frequency independent correction factor was applied. The correction was determined to be +1,55 dB using a model presented in [2].

3.4 Other emission-related corrections

CNOSSOS-EU and Nord2000 can take occurrence of studded tires into account. Nord2000 also offers possibility to include probability for wet surface conditions (which early versions of CNOSSOS-EU also did). No correction for studded tires or wet roads has been made in the calculations.

4 Refraction

Meteorology influences sound propagation through refraction, atmospheric absorption and turbulent scattering. The effect that has the largest influence on L_{den} is refraction, a phenomenon where wind or temperature gradients influences the vertical sound speed profile, which in turn causes downward or upward curving of sound paths. When weather is causing downward curving, propagation conditions are said to be *favourable* as they may lead to higher sound levels. Accordingly, *unfavourable* propagation conditions correspond to upward curving, and *neutral* conditions is when there is no refraction (i.e. straight sound paths). The magnitude of the effect varies strongly with the weather conditions.

In the Harmonoise project it was found that the influence on L_{den} from refraction can be sufficiently good predicted by identifying different meteorology situations with unique propagation characteristics and their respective occurrences during a year, in analogy to what already is an established method within the field of air pollution computation. 25 different meteorological classes, ranging from very unfavourable to very favourable, were identified as important to include in order to ensure a determination of long-term average sound levels with an error of at most 2 dB at 1000 m [3]. Later research has proposed that it for noise mapping purposes is possible to reduce the necessary number of classes, and hence use less computational power. The IMAGINE project concluded that five classes would be enough for END noise mapping [4], and research in Denmark has found that nine, four or one should be used for Nord2000 calculations depending on what the application is [5].

Refraction has a small or negligible influence in unshielded positions at short distances between source and receiver. However, at longer distances, or when screening is present, the effect of favourable sound propagation can significantly increase noise levels relative to neutral or unfavourable situations.

Being an energy equivalent noise level, L_{den} is to a greater extent dominated by high levels than an arithmetic mean. As a consequence, noise that is emitted during favourable conditions will have a greater influence on L_{den}, than if the same noise is emitted during unfavourable or neutral conditions. Another factor that explains why the favourable conditions are more dominant is because they are more likely to happen during evenings and nights, when L_{den} includes a penalty of 5 and 10 dB respectively (compare with Figure 12). However, in Sweden the latter factor is only valid for END mapping since domestic assessments are made using L_{Aeq24h} instead of L_{den}.

The studied calculation methods have different abilities to include effects of varying refraction. Calculations according to RTN96 correspond to a fixed, slightly favourable condition, and the method lacks support for varying refraction [6].

Sound levels calculated with CNOSSOS-EU is the result from two calculations: one corresponding to a fixed, favourable condition and one that corresponds to a neutral condition. Actual meteorology is considered by calculating L_{den} as a weighted energy mean of these two results. The weighting factor, p_f, is the probability of occurrence of favourable conditions during a year, which can be determined from meteorological observations (there are no specific instructions available on how to do this for CNOSSOS-EU, but a guideline written for NMPB – 1996 could be found in [7]).

Nord2000 can compute noise levels for various uncomplicated weather conditions, and hence consider varying refraction. Very strong or varying wind gradients or layered atmospheric conditions cannot be handled though. Yearly average noise levels such as L_{den} is calculated by combining results from different weather conditions [8].

In Denmark, where Nord2000 is the official calculation method, weather statistics for noise calculations are published by authorities. Data sets with nine and four propagation classes are used, and some calculations are recommended to be performed using neutral weather conditions. [9]

5 Performed calculations

5.1 RTN96

Calculations of façade levels and noise contours were made with RTN96 without adding any corrections. Thus, the results represent a SMA16 road surface, a slightly favourable meteorological condition and only one heavy vehicle category.

5.2 CNOSSOS-EU

5.2.1 Emission correction

One initial calculation was made using the default road vehicle emission data and the reference road surface, while the rest of the calculations included corrections for a Swedish vehicle fleet and SMA16 road surface.

5.2.2 Meteorology

Three sets of calculations using different meteorological input were made, all of them using corrections for Swedish vehicle fleet and SMA16 road surface.

First, calculations were made using recommended default values of p_f, i.e. 50 % for day, 75 % for evening and 100 % for night. These values are compatible with guidelines of the Good Practice Guide, and are suggested to be used in absence of specific information on local meteorology [4]. The use of single values for p_f means that the same occurrence of favourable conditions is used in all directions. This is a simplification as many sites have varying sound propagation conditions in different directions when averaged over a year, such as that some wind directions occur more often than others.

In a second step two calculations of façade levels were made with p_f representing real meteorological statistics of two French cities, Nantes on the west coast and Montélimar in south-east [10]. The cities were selected because their statistics are distinctly different from the single values above, as well as from each other, see Figure 2.

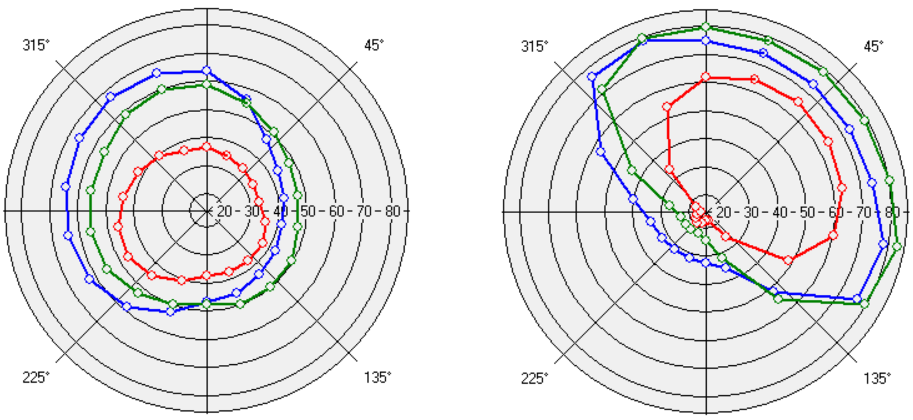

Figure 2: Weather statistics for Nantes (left) and Montélimar (right). The graphs show probability of occurrence of favourable conditions in different directions, p_f, for day 6–18 (red), evening 18–22 (blue) and night 22–06 (green) [10].

5.3 Nord2000

All calculations were based on emission data representing a Swedish vehicle fleet and road surface SMA16.

Three different meteorological input data sets were tested. Two artificial sets were compiled by the authors, while the third was a statistic set based on meteorological observations

5.3.1 Calculations using artificial meteorological data

The two artificial sets both used a 50/75/100 % mix of the two cases neutral and favourable sound propagation for day/evening/night, aiming at emulating similar input data sets as described in the case with CNOSSOS-EU using default meteorological data. The neutral case was identical in the two sets, while the meteorological condition representing favourable propagation were different.

In *artificial set 1*, the favourable meteorological condition was represented by a weak temperature inversion of +0.02 °C/m, which also have been used in a similar Norwegian comparison [11].

In *artificial set 2*, the favourable meteorological condition was represented by propagation class M 18 that was extracted from the Danish reduced data set with four distribution classes. Propagation class M 18 is a moderately favourable class (the other three classes in the Danish data set are: class M 8 which is unfavourable, class M 13 that is neutral and class M 24 which is very favourable) [9].

5.3.2 Calculations using meteorological statistics

Calculations were made with real meteorological input data consisting of the Danish dataset with four propagation classes [12].

6 Results

Facade noise levels were calculated at 4 m above ground in 548 calculation points at domestic buildings within the investigated area, and noise contours at 4 m above ground were based on calculations using a grid distance of 5 m. Results and comparisons of facade noise results are presented below as histograms together with respective arithmetic mean, median and standard deviation. Furthermore, two plots showing differences between noise contour calculations are presented. All presented differences are the result of point-to-point comparisons of two calculations.

6.1 CNOSSOS-EU

6.1.1 Using default values of p_f, 50/75/100 % for day/evening/night

In Figure 3 the distribution of L_{den} façade levels calculated with Swedish vehicle emissions and SMA16 road surface is presented, together with a comparison of the results with a calculation of L_{den} using default CNOSSOS-EU emissions and the reference road surface as presented in [13]. Using data for the Swedish vehicle fleet and the rougher SMA16 road surfaces leads to a 2,3 dB higher L_{den} than with the default CNOSSOS-EU equivalents.

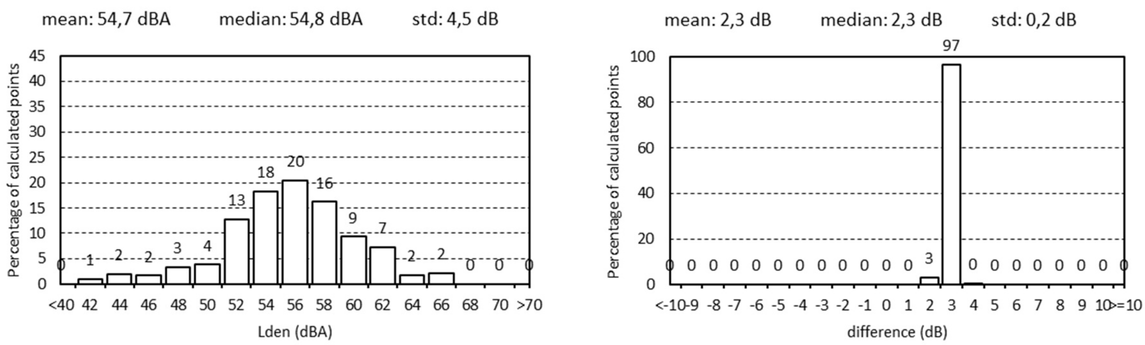

Figure 3: Calculation of façade levels with CNOSSOS-EU, p_f set to 50/75/100 % for day/evening/night. Left: Distribution of L_{den}. Right: Difference between two CNOSSOS-EU calculations – with correction for Swedish vehicle fleet and SMA16 road surface, minus with default vehicle fleet data and reference road surface according to [13].

6.1.2 Using meteorological statistics for two French cities

The distribution of L_{den} façade levels calculated using p_f representing meteorological statistics for the cities Nantes and Montélimar are presented in Figure 4. Their respective differences to the results presented in Figure 3 (using default p_f values) are shown in Figure 5. Calculations were based on Swedish vehicle emissions and SMA16 road surface.

In relation to the levels calculated using default values of p_f, statistics for Nantes results in 0–2 dB lower calculated levels (the arithmetic mean of all calculated levels is 0,6 dB lower, with a standard deviation of 0,4 dB), and statistics for Montélimar results in 0–4 dB lower values (arithmetic mean is +0,7 dB, with a standard deviation of 0,6 dB). The results suggests that the default values of p_f could be considered to be conservative.

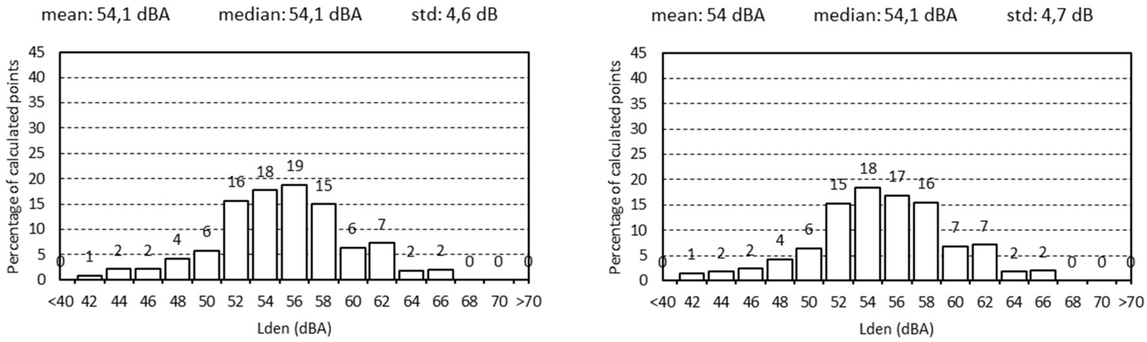

Figure 4: Distribution of L_{den} façade levels calculated with CNOSSOS-EU, using p_f that represents meteorological statistics for two French cities. Left: Nantes. Right: Montélimar.

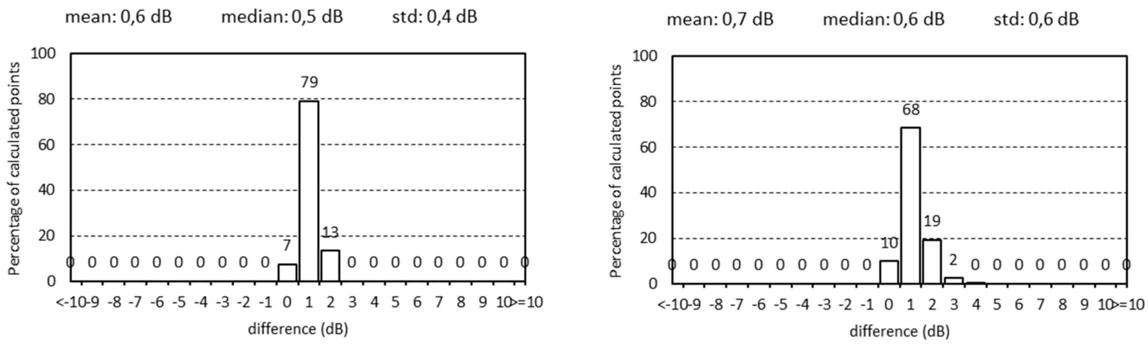

Figure 5: Difference between two CNOSSOS-EU façade noise calculations – using default values of p_f, minus using p_f representing meteorological statistics for two French cities. Left: Nantes. Right: Montélimar.

6.2 RTN96

In Figure 6 the distribution of L_{den} façade levels calculated with RTN96 is presented together with a comparison with values calculated with CNOSSOS-EU using a Swedish vehicle fleet and SMA16. As a mean over all façade points, L_{den} calculated with RTN96 is only 0,1 dB higher than when calculated with CNOSSOS-EU. However, according to the difference histogram and the standard deviation of 1,3 dB, differences are larger in most of the calculated points.

In Figure 7 corresponding noise contour differences are presented. At short and unshielded distances to roads, differences are limited, although not negligible. As a whole, large parts of the noise contour map show differences of more than ±1 dB. The arithmetic mean of the individual differences in all calculated points of the noise contour difference map is +1,1 dB (RTN96 levels are higher), with a standard deviation of 1,5 dB. Close to major roads RTN96 predicts higher values than CNOSSOS-EU, indicating that the in 2015 updated Swedish emission could be lower than the rather old emission data of RTN96.

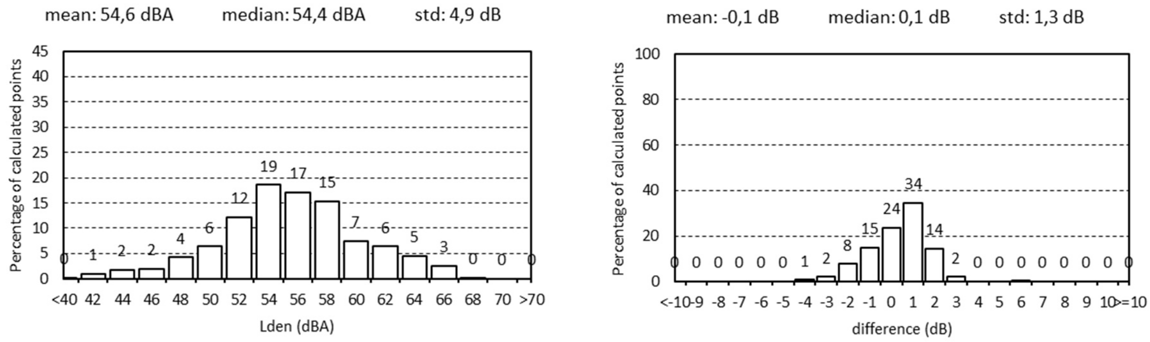

Figure 6: Calculation with RTN96. Left: Distribution of L_{den}. Right: Difference between two calculations – a calculation made with RTN96 (left figure), minus a CNOSSOS-EU calculation using the default values of p_f (Figure 3).

Figure 7: Differences between two noise contour calculations – a calculation made with RTN96, minus a calculation with CNOSSOS-EU using default values of p_f. Arithmetic mean of all calculated points is +1,1 dB, median +1,1 dB, and standard deviation 1,5 dB. Noise protection walls are shown as black-yellow dashed lines.

6.3 Nord2000

With exception for the meteorological data, all prerequisites were identical in the three Nord2000 calculations below.

6.3.1 Using artificial meteorological data

The distribution of L_{den} façade levels calculated with Nord2000 using artificial meteorological data are presented in Figure 8. Their respective differences to the CNOSSOS-EU results are presented in Figure 3 using default p_f values are shown in Figure 9.

Results obtained using artificial meteo data set 1 show large differences to the CNOSSOS-EU results. The arithmetic mean of the differences in all calculated points is 3,3 dB lower with Nord2000 than with CNOSSOS-EU, and standard deviation is 2,4 dB. The use of meteo data set 2 leads to smaller differences, with a mean of 0,5 dB lower façade levels when calculated with Nord2000 (standard deviation 1,2 dB).

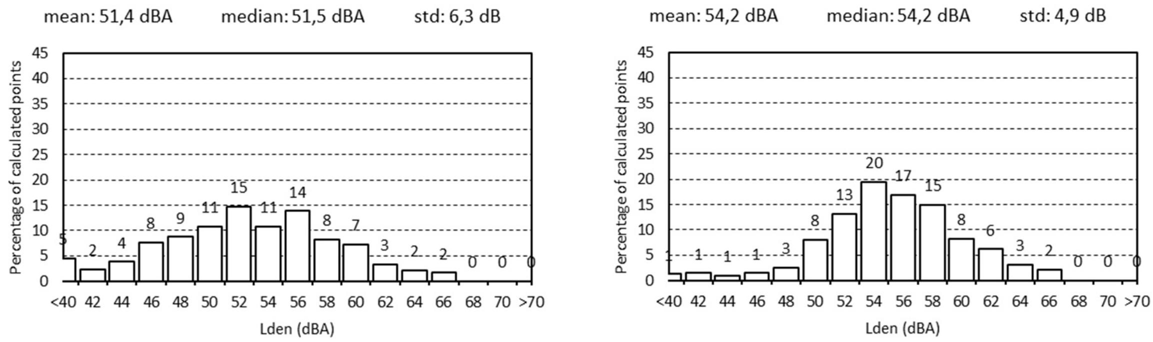

Figure 8: Distribution of L_{den} façade levels calculated with Nord2000 using artificial meteorological data. Left: artificial meteo data set 1 (with +0.02 °C/m representing the favourable condition). Right: artificial meteo data set 2 (with propagation class M 18 representing the favourable condition).

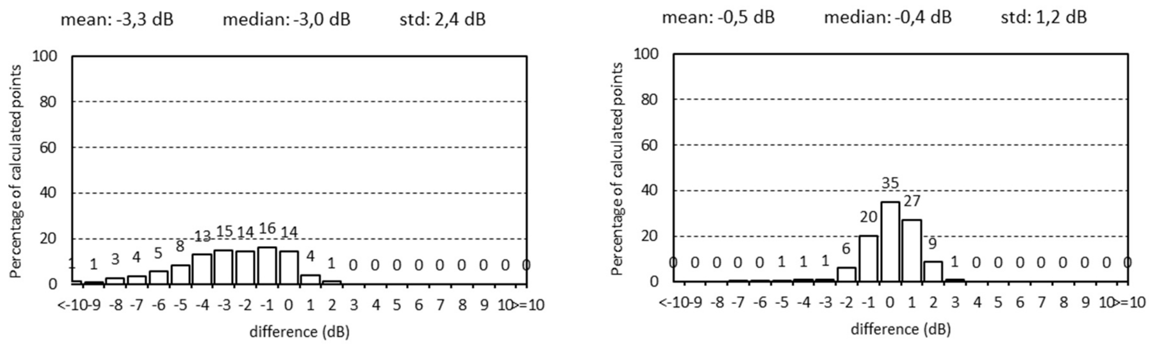

Figure 9: Difference between two façade noise calculations – calculation made with Nord2000 and an artificial meteo data set, minus a CNOSSOS-EU calculation using the default values of p_f. Left: artificial meteo data set 1. Right: artificial meteo data set 2.

6.3.2 Calculations using meteorological statistics

In Figure 10 the distribution of L_{den} façade levels calculated using real Danish meteorological input data is presented together with a comparison with the CNOSSOS-EU results using default p_f values from Figure 3. Arithmetic mean of the differences in all calculated points is +1,5 dB, i e higher level with Nord2000 than with CNOSSOS-EU (standard deviation 1,6 dB).

A corresponding noise contour difference map is presented in Figure 11. In general, differences are small at short and unshielded distances to roads, but in large parts of the investigated area differences are more than ±1 dB. Arithmetic mean of the individual differences in all calculated points is +0,8 dB (higher levels with Nord2000), with a standard deviation of 1,5 dB. In shielded positions deviations become larger, with up to 8 dB higher Nord2000 levels.

A likely explanation is that the inclusion of propagation class M 24, which represents weather situations with very favourable propagation conditions, is the cause of the increased L_{den} values when calculated with Nord2000. Probability of occurrences of M 24 for day, evening and night, are shown in Figure 12.

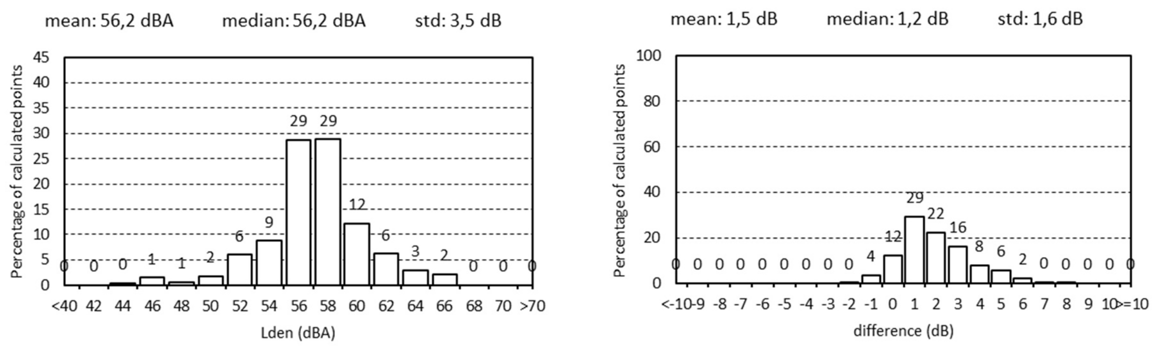

Figure 10: Calculation with Nord2000 using real meteorological input data consisting of a Danish reduced dataset with four propagation classes. Left: Distribution of L_{den}. Right: Difference between two calculations – result from Nord2000 calculation (left figure) minus a CNOSSOS-EU calculation using the default values of p_f (Figure 3).

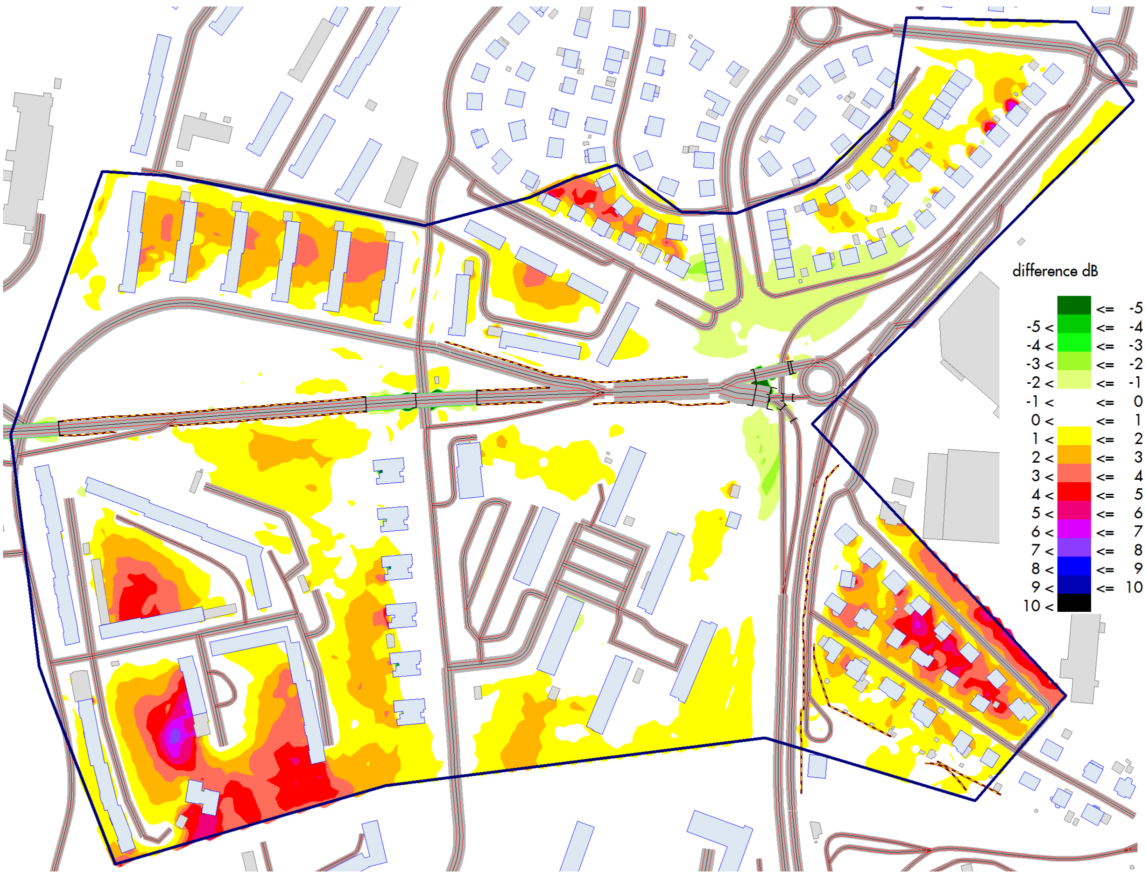

Figure 11: Differences between two noise contour calculations – a calculation made with Nord2000 using Danish weather statistics with four classes, minus a calculation with CNOSSOS-EU using default values of p_f. Arithmetic mean of all calculated points is +0,8 dB, median +0,7 dB, and standard deviation 1,5 dB. Noise protection walls are shown as black-yellow dashed lines.

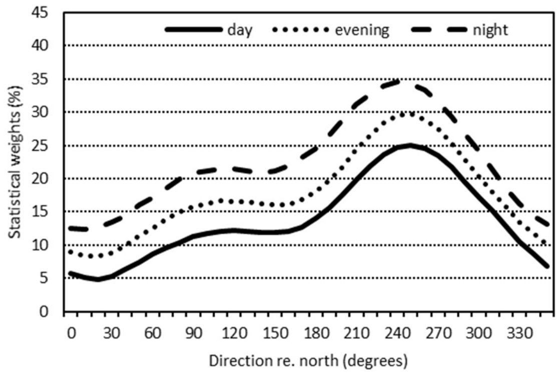

Figure 12: Statistical weights for propagation class M24 in the Danish dataset with four propagation classes [12].

7 Summary

The calculation methods CNOSSOS-EU, RTN96 and Nord2000 have been compared with road noise calculations in a model of the Högsbo district in Gothenburg.

The three methods give similar results as long as the distance to the dominating source is short, provided receivers are in unshielded positions. At greater distances and in shielded positions predicted sound levels differ more.

It is also in situations with screening or large source-receiver distances that weather influence can be of great importance. Tests with Nord2000 using different meteorological data sets suggests that in such situations it is necessary to include a propagation class representing very favourable sound propagation conditions in order to accurately predict a yearly averaged L_{den}, something that is not possible to do with RTN96 or CNOSSOS-EU. In comparison to levels calculated with Nord2000 using real weather statistics, both CNOSSOS-EU and RTN96 predictions are too low in these situations. Even when using conservative meteo statistics, CNOSSOS-EU calculations underestimates L_{den} with up to 8 dB in comparison with NORD2000 using realistic weather statistics.

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