CNOSSOS-EU noise model implementation in Finland and experience of it in 3rd END round

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Summary

During the implementation process of the CNOSSOS-EU noise model, many questions has been raised. There are inconsistencies in the directive, but most of the questions are related to acquisition of initial values and their validity. CNOSSOS-EU default rolling and propulsion noise factors are not usable in Nordic conditions and the national factors had to be defined. The Nordic A and B coefficients for rolling and propulsion noise are based on measurements in Sweden and Finland and already implemented in Nord2000 noise model. Also, Nord2000 road surface correction can be converted to CNOSSSOS. CNOSSOS railway model implementation is more challenging and lots of work must be done before Finland has reasonable values for CNOSSOS source model. Without accurate and validated national source values only propagation was calculated with CNOSSOS and sound power levels had to be defined with current Nordic model. CNOSSOS calculated noise levels look quite different when compared to the current Nordic models' results. However, the most significant difference is related to the new assessment method and not for sound power level or propagation part.

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1. Introduction

In 2015, an update to the Environmental Noise Directive (END) [1] Annex II was published. According to the new Annex II [2], all the EU Member States (MS) are required to use Common NOise aSSessment methOdS in the EU (CNOSSOS-EU) from 31 December 2018 onwards. Finland decided to use CNOSSOS-EU model already in the 2017 END noise mapping. Before this decision Finland had national CNOSSOS-EU implementation project where essential values, calculation and modeling principles had been defined. At that moment there was only draft test version at commercial software where but there was a strong trust that those will be ready to use when actual noise calculation starts. In national implementation project CNOSSOS-EU propagation part accuracy or precisions wasn't at interest but 2017 END noise mapping were done with CNOSSOS-EU and old Nordic calculation methods [3][4]. This way we had better picture of how noise situation has been changed and we had lot of data how CNOSSOS-EU results differ from old Nordic model results.

In the CNOSSOS-EU requirements it is mentioned that variation in the input parameters of the emission part should have less than 2 dB effect on the calculation results [2]. Using wrong sound power levels as initial data may lead to significant inaccuracy and systematic errors in the calculation results. To avoid this, the essential values of the CNOSSOS-EU should be mitigated to the national conditions and values.

2. CNOSSOS-EU initial values

Finland national guidance [5] includes detailed modelling instruction, initial values and calculation configurations. Here are presented three most essential subject where national values differ remarkable from CNOSSOS-EU default values.

2.1. Road traffic noise

CNOSSOS-EU database for road traffic source is presented at the END directive Annex II appendix F. Most important values at that database are A and B coefficients for rolling and propulsion noise and α and β coefficients for surface correction.

In the Nordic countries the current road noise calculation method is Road Traffic Noise — Nordic

Prediction Method (RTN96) [3]. The RTN96 values are over 20 years old and unsuitable for the CNOSSOS-EU road model. Much more detailed and fresh measurements are made for the Nord2000 model [6] and this data is possible convert to CNOSSOS-EU model A and B factors.

In Figures 1 and 2 are presented calculated light (cat1) and heavy vehicles (cat2 and cat3) sound power levels as a function of speed with CNOSSOS-EU, Nordic models RTN96 and Nord2000 with different surfaces.

Light vehicles (cat1) rolling noise is determinative almost at whole speed range and with heavy vehicles (cat2 and cat3) propulsion noise. Figure 1 shows that in the Nordic models, the rolling noise increase in a steeper angle as a function of speed, and the overall level is much higher than in the CNOSSOS-EU.

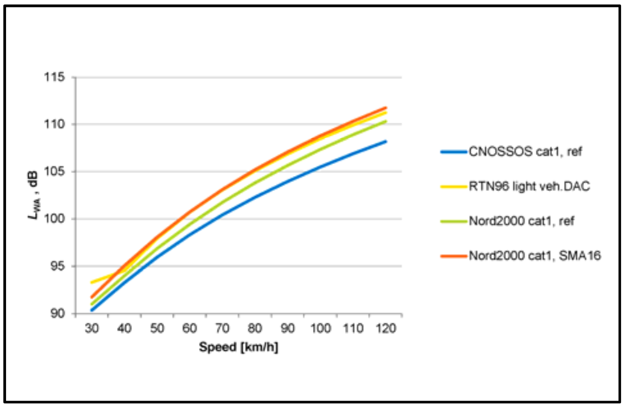

Figure 1 CNOSSOS, Nord2000, and RTN96 light vehicle L_{WA}

Figure 2 and table 1 shows that CNOSSOS-EU also has a lot smaller default values in propulsion noise. Frequency and speed depend rolling and propulsion noise correction can't be included to surface corrections α and β coefficients so national A and B coefficients for rolling and propulsion noise must be used.

Table 1 Propulsion noise medium heavy vehicle (cat2) Nord2000 - CNOSSOS

	Speed, km/h					
Frequency, Hz	40	50	60	70	80	90
63	3.6	3.9	4.1	4.4	4.6	4.9
125	6.5	5.7	5	4.2	3.6	3
250	6.6	6.4	6.2	6	5.9	5.7
500	3.5	4	4.5	4.8	5.1	5.4
1000	0.8	2.1	3.3	4.2	4.9	5.6
2000	0.8	1.9	2.9	3.7	4.5	5.2
4000	1.7	2.5	3.3	3.9	4.5	5.1
8000	4.4	4.6	4.7	4.8	4.9	4.9
ΔL_{WA}	1.7	2.3	2.9	3.5	4	4.6

The basic values of the current Nord2000 model are given in third octave bands and therefor the values were converted to octave bands. The calculated A-factors in octave bands are the energy sum of corresponding third octave bands and the calculated B-factors are the average from corresponding third octave bands.

In Sweden new measurements has been made in 2015, and based on these measurements, new Nord2000 coefficients has been proposed [7] Differences between new [7] and older data [8] total sound power level L_{WA} is small (cat1 -0,5 … 0,08 dB and cat2 -1,4…-0,5 dB) and use of new coefficients would also require own national measurements so these new results wasn't take into account.

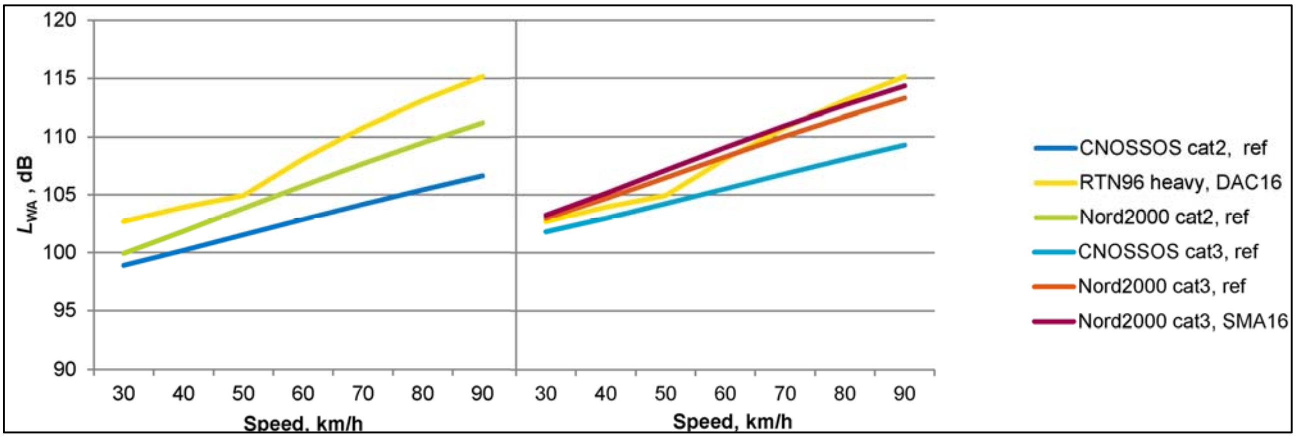

Figure 2 CNOSSOS, Nord2000, and RTN96 heavy vehicles L_{WA}

2.2. Railway traffic noise

CNOSSOS-EU railway model emission calculation is based on railway and wheel roughness and Finland have railway roughness data only at one point. It has also been shown that there might be even 10 dB errors [9] when sound power levels are defined purely with CNOSSOS-model. There are also no instruction how national measured emission values should or could be taking into account in CNOSSOS-EU railway model, for example how to fix wrong speed correlation. Railway roughness measurements take's lots of time and money and benefit of this approach is questionable if cost-benefit and modelling accuracy are considered (author opinion). Because of these challenge and lack of time and money Finland calculated CNOSSOS-EU railway octave band sound power levels with current Railway Traffic Noise — Nordic Prediction Method (NMT96) [4]. Propagation was calculated with CNOSSOS-EU railway model. With this "short cut" method all sound power is at +0,5 m height and higher sound source at +4 m height is lost. At higher sound source is only part of locomotive and aerodynamic sound so it has very small effect for results. According test calculation maximum small area local error is less than 0,5 dB in situation when train is behind barrier.

CNOSSOS-EU railway model sound source have horizontal and vertical directivity functions that must take into account with correction term so that calculated and measured sound levels are equal at emission measurement point.

CNOSSOS-EU model says that horizontal directivity is dipole according equation (1):

$$\Delta L_{W,dir,hor,i} = 10 \times \lg\left(0.01 + 0.99 \cdot \sin^2 \varphi\right) \quad (1)$$

and vertical directivity according equation (2):

$$\Delta L_{W,dir,ver,i} = \left(\left|\frac{40}{3} \times \left[\frac{2}{3} \times \sin\left(2 \cdot \psi\right) - \sin \psi\right] \times \lg\left[\frac{f_{c,i} + 600}{200}\right]\right|\right) \quad (2)$$

Train emission measurements are done in Finland at 7,5-25 m distance and at 1,2-2 m height of track. Calculated CNOSSOS-EU train directivity is -1,8…-2,2 dB in these measurement points so sound power level calculated with NMT96 was corrected with + 2 dB.

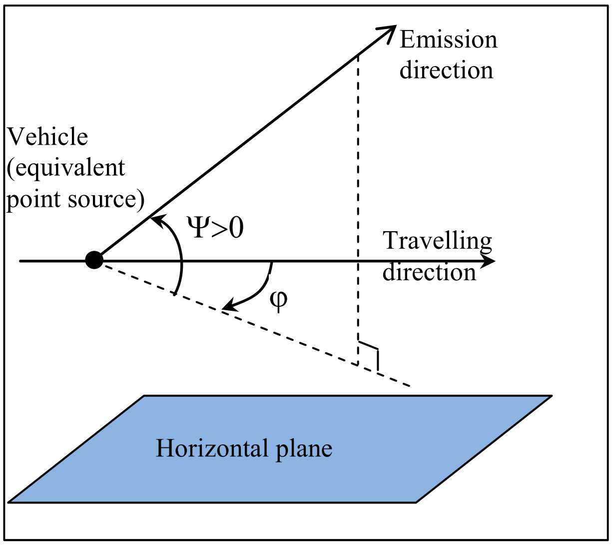

Figure 3 Geometrical definition of angles [2]

2.3. Weather correction

CNOSSOS-EU long-term sound level (L_{LT}) calculation requires data of probability of occurrence of favourable condition (p_f). Favourable condition means positive temperature gradient and/or down wind conditions. P_f values are given at 20 degrees steps for day-, evening- and night time. General default values for day/evening/night times are 50/75/100 % to all directions.

Use of default weather values increase noise levels and number of exposed people [10]. With default value number of exposed people might increase at daytime 10 - 20 % and 60 - 90 % at night time[11]. Afterward it has been found out that CNOSSOS-EU favourable condition propagation calculation has too high result in multiple diffraction situation so that there might be higher noise level with building versus situation without buildings. If this inconsistency is fixed it might change this conclusion.

Day-, evening- and night time yearly average favourable condition percentages was calculated from 10-year hourly weather data to 26 areas in Finland. Massive 10 years hourly weather data calculation was done with Matlab-code that was originally developed for Nord2000 weather class calculations. The meteorological conditions are divided into stability classes and furthermore in 25 classes with different sound speed profiles. These 25 classes were reduced to favourable conditions and to homogenous conditions. Homogenous condition includes all unfavourable conditions. Required input values was: temperature, wind direction and velocity, cloudiness, and declination of the sun (derived from time and date). Used method is described in Harmonoise WP3 [12]

3. Calculation results comparison between CNOSSOS-EU and NPM 1996

When END calculations are made with new CNOSSOS-EU model one question is that are these calculation results somehow comparable to previous calculation round? Could there be some factors/coefficients that could be used when comparing results between END calculation round with different calculation model so it would be possible to estimate how noise situation has been changed in five years?

Finland 3. END calculation round calculation was made with both CNOSSOS-EU and Nordic models and with two assessment method old and new (according to new Annex II). In old assessment method, all inhabitants are at façade highest noise level and in new method if at residential house has more than one apartment
inhabitants are distributed to façade according VBEB[2][13].
From Table 2 we can see that total number of exposed people with CNOSSOS-EU road model and RTN96 are almost same at day time and a little higher at night time in Helsinki. But if we look at distribution in noise zones we can see that at higher noise levels CNOSSOS-EU model will give more exposed people. Main reason in this case is that in Helsinki is a lot of residential buildings near traffic lights where CNOSSOS-EU model has a correction for acceleration and deceleration and in Nordic model traffic flow is constant. From same table we can also see that new assessment method has huge effect (about -50%) to number of exposed people.

Table 2 Roads and streets in Helsinki, day- and night time L_{Aeq}

Helsinki	2017 (CNOSSOS-EU, new method)		2017 (CNOSSOS-EU, old method)		2017 (Nordic, old method)	
	L_{Aeq} (7-22)	L_{Aeq} (22-7)	L_{Aeq} (7-22)	L_{Aeq} (22-7)	L_{Aeq} (7-22)	L_{Aeq} (22-7)
50-54 dB	-	48410	-	116670	-	98930
55-59 dB	56340	15950	104990	44930	102340	43720
60-64 dB	30070	8490	85740	26340	81820	23700
65-69 dB	12250	440	37900	1890	40310	685
70-75 dB	4520	0	14160	0	8550	0
yli 75 dB	80	-	669	-	0	-
Total	103200	73300	243500	189800	233000	167000

CNOSSOS-EU railway model have horizontal and vertical directivity and NPM96 is an omnidirectional. That will cause that noise in CNOSSOS-EU barriers near railway track block noise more efficiency. Also, if there is a tunnel opening and/or calculation points are upward direction then we will have lover noise levels and less exposed people.

Noise zones differ mostly at long distance at lower levels (< 55 dB).
In multiple diffraction case, noise level at building agglomerations are relatively much higher than in Nordic model. If we look at figure 4 we can see that behind the railway barrier noise levels are smaller (blue color -1…-6 dB) because of directivity and at longer distance noise levels are higher (yellow and red colors 1…6 dB) because of favourable condition and built up area multiple diffraction effect.

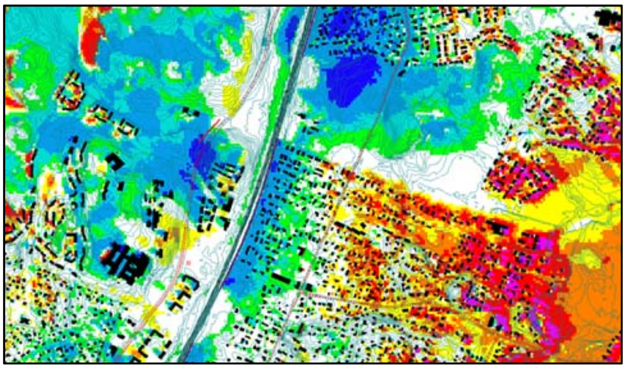

Figure 4 CNOSSOS-EU – NMT96 ($L_{Aeq,7\text{-}22}$)

These example shows that when CNOSSOS-EU calculation are done for first time with END noise mapping there must do calculation also with current calculations models and assessment method. Otherwise it is impossible to estimate how real noise situation has changed between END calculation rounds.
There seems to be quite big difference in CNOSSOS-EU software implementation. When compared two commercial software production it seems that other software implementation is done more like according noise directive and other one more realistic (build up areas don't increase noise levels as much). In figure 5 are shown buildings effect for sound propagation with CNOSSOS-EU road noise L_{den} calculation. Noise models and calculation configuration are same so only difference is with CNOSSOS-EU software implementation. Software implementations are tested with official test cases. Probably part of problem is that test cases are too simple and error or differences in real world complex situation doesn't reveal. It might be good if complex test case could be more like grid type calculation where interest are in accuracy and not in specific points results precisions.

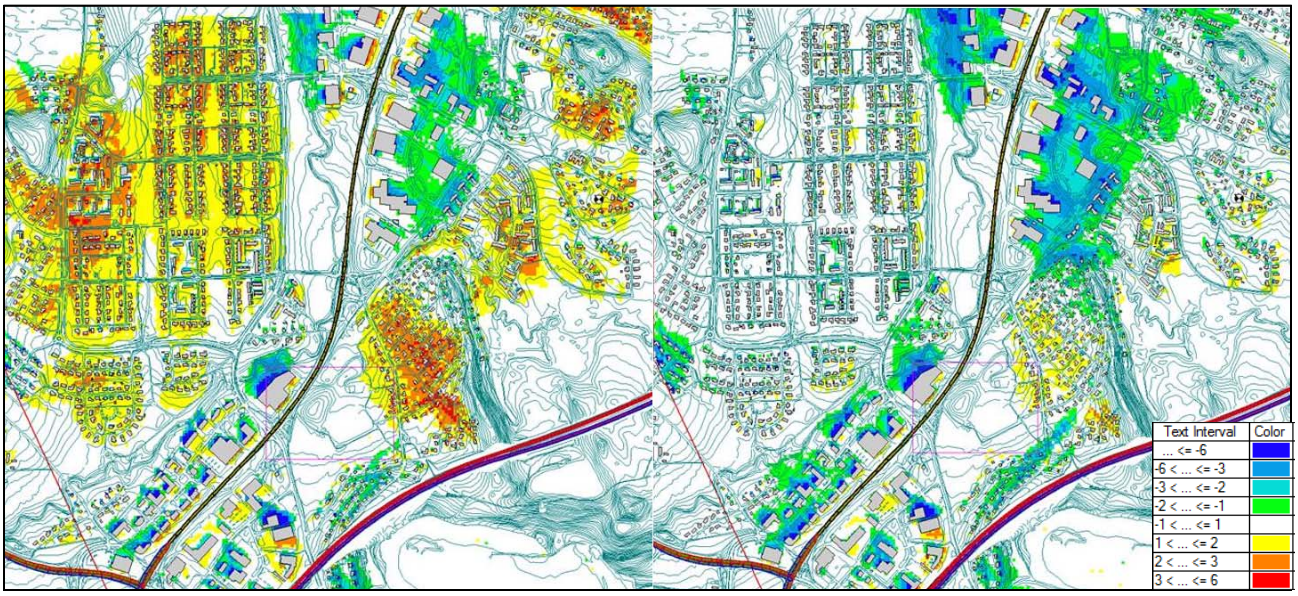

Figure 5 With building - without building L_{den} calculation with two software, yellow-red colours higher levels and green-blue colours lower noise levels.

Conclusions

The implementation process of the CNOSSOS-EU framework requires a lot of work at the national level. The guidance given in the new Annex II of the Environmental Noise Directive contains a number of deficiencies, and it is not fully consistent.

CNOSSOS-EU Road model is usable after implementation of national coefficients. Railway model input values needs lots of work if sound power levels are calculated with CNOSSOS-EU instead of current Nordic model.

Use of default weather values increase the immission levels and the number of exposed people. It is not recommended to use default weather values.

The new exposure assessment method has significant effect on the number of the people exposed to noise.

CNOSSOS-EU favorable condition is more favorable than NPM1996. Daytime values are close NPM1996 values.

CNOSSOS-EU is at commercial software are still as a test version and noise directive need some clarification. Testcases should also include some complex situation, curved road, built up areas etc.

Acknowledgement

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