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Calculation method for road traffic noise

Description of the calculation method NMPB

General comment on the similarities and differences of NMPB with the END and on the possible use as Interim Method for END

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NMPB-Routes-96 “Road Traffic Noise New French calculation method including meteorological effects (Bruit des Infrastructures Routiers Methode de calcul incluant les effets météorologiques)” describes a detailed procedure to calculate sound levels caused by road traffic in the environs of a road up to a distance of 800 m from the road (perpendicularly to the lane), at least 2 m above the ground. It has been prepared by a group of French experts.

In 2001 the French standard XP S31-133 (norme experimentale) “Acoustic - Road and railway traffic noise – Calculation of sound attenuation during outdoor propagation, including meteorological effects (Acoustique –Bruit des infrastructures de transports terrestres .- Calcul de l´atténuation du son lors de sa propagation en milieu extérieur, incluant les effets météorologiques) “ has been published. It describes the same calculation procedure as NMPB. In END in Annex II the French national computation method NMPB-Routes-96 and the French standard XP S 31-133 are recommended for the interim computation methods. In the following a description of the French calculation procedure in principle is given together with a discussion of similarities and differences with the END.

1 Noise indicator

In NMPB-Routes-96 and in the French standard “XP S 31-133” the basic quantity to describe the sound immission near roads is the long term equivalent continuous A-weighted sound pressure level. There are 2 time periods distinguished: day (6 – 22h) and night (22 – 6h).

The long term equivalent sound level takes care of the traffic flow over the year and the meteorological conditions (vertical gradient of the wind speed and vertical gradient of the temperature) prevailing over the year. The influence of the meteorological conditions with respect to a long term average sound level is dealt with in detail as well with the definition of 2 different types of sound propagation, yielding different sound levels, as well as with the description of the percentage of their long term occurrence represented in a map for (nearly) the whole area of France. In the standard XP S 31-133 the map is substituted by a table for 40 cities (regions).

In END according to Article 5 the noise indicators

- L_{den} (day-evening-night noise indicator)
- L_{day} (day-noise indicator)
- $L_{evening}$ (evening-noise indicator)
- L_{night} (night-time noise indicator)

as defined in Article 3 and further defined in Annex I shall be applied for the preparation and revision of strategic noise mapping.

L_{den} is calculated from L_{day}, $L_{evening}$ and L_{night} by

$$L_{den} = 10.\lg\frac{1}{24}\left(12.10^{L_{day}/10} + 4.10^{(L_{evening}+5)/10} + 8.10^{(L_{night}+10)/10}\right)$$

Equation 1

where

L_{day}, $L_{evening}$ and L_{night} are the long term average sound level as defined in ISO1996-2: 1987, determined over all the day periods or evening periods or night periods of a year.

In this ISO standard the long term average sound level is based on the equivalent continuous A-weighted sound pressure level.

According to ISO 1996-2 the averaging relates to variations in the source emission as well as to the variations in meteorological conditions influencing the sound propagation.

While variations in the source road traffic may easily be taken into account by the number of vehicles during a representative year, the variations in meteorological conditions and with these sound propagation can not be handled so easily.

ISO 1996-2 and ISO 1996-1, cited in ISO 1996-2 with respect to a meteorological adjustment, don't give detailed advice. These ISO standards, more than 10 years old, refer primarily to measurements and not to calculations. There is only written, that - with respect to the average over a range of meteorological conditions - measurement time intervals are chosen in such a way, that the long term average sound level is determined over the range of meteorological conditions found at the measurement position. Another possibility is given by measurements taken under carefully specified meteorological conditions, normally with the most stable sound propagation, that is with a significant positive wind component from source to measurement position, and applying a correction to the value obtained. There is no advice on the quantity of this correction or on the procedure how to determine it. So there is little said on the calculation for noise mapping.

In Annex II of END a special sentence emphasizes that the establishment of the average over the year requires special attention as variations in emission and transmission can contribute to fluctuations over a year.

Summing up the indicators in END are based on the equivalent continuous A-weighted sound pressure level, averaged over the year with respect to variations in sound source and meteorological conditions influencing the sound propagation.

So the basic quantity is the same in NMPB and in END; with respect to the indicator there are no difficulties to use NMPB for the calculations according to END.

Only the time periods used are different: day, evening and night in END and day and night in NMPB, but this does not influence the calculation model in general.

2 Immission point

In END the height of the immission point is prescribed with 4 m.

In NMPB there is only said, that the height of the receiver point above the ground has to be at least 2 m. So for calculations according to END the height of the immission point may be chosen with 4m.

3 Source

In NMPB the source is defined with respect to geometry, but not with respect to the sound emission. With respect to the latter the data of Guide de bruit have to be used. The sound emission is described by the A-weighted sound power per m length with a prescribed octave band spectrum (according to EN 1793-3).

The position of the source is described in detail. The model is based on splitting up the road or the single lanes of the road into elementary sound point sources by equiangular splitting up (generally steps less or equal to 10o) or splitting up with a constant step (generally steps less than 20 m, at any rate less than half of the orthogonal distance between lane and receiver points). The point source is positioned in the middle of the respective step, 0,5m above the road surface.

Splitting up of the road into point sources is used in all national calculation models also.

The sound emission data are given in different ways in the different national calculation models and it will be necessary to describe the method to define the sound emission data to be used for the calculation with the NMPB model for the national vehicle fleet on the national road surfaces.

4 Sound propagation

In NMPB the calculation of the sound propagation is carried out in the octave bands from 125 to 4000 Hz.

The calculation method distinguishes two types of sound propagation due to different meteorological conditions and gives detailed advice in which areas of France which type of propagation has to be used in which proportion for day and night.

To use the NMPB method to calculate the indicators according to END it will be necessary to define the meteorological conditions and the type of sound propagation additionally for the evening period and to give the definitions for the types of sound propagation for all European countries.

In END is nothing special said on the calculation method to be used for the sound propagation. As in Annex II the French national computation method NMPB and the French standard “XPS 31-133” are recommended, it is clear, that this method has to be used.

The French method of course has to be separated from specialities, which can not be used for other European countries.

In the following the different steps of the calculation of sound propagation in NMPB are discussed. As several steps are different with respect to the meteorological conditions first the way in which the meteorological conditions are taken into account has to be described and discussed.

4.1 The influence of the meteorological conditions on the sound propagation

In the air above the ground always temperature and wind speed are different in different heights; the differences are given by the gradient in temperature, which may be positive or negative and the increase in wind speed with the height above ground. By these gradients in temperature and wind speed positive or negative gradients in sound speed are caused. In general 3 types of sound propagation are distinguished: conditions of propagation are homogeneous (sound rays are straight), conditions of propagation are favourable (positive vertical sound speed gradient i.e. down wind sound propagation, sound rays bent downwards), conditions of propagation are unfavourable (negative vertical sound speed gradient, sound rays bent upwards).

In reality a mass of combinations between thermal and aerodynamic effects are possible, variable in time and space, which lead to considerable sound level variations in greater distances from the source. Additionally the ground effect is influenced by the shape of the sound rays. In order to sum up the possible influences of meteorological conditions a double-entry grid is shown, which gives the qualitative variation of the sound level at long range, according to observable meteorological factors (see Annex 1).

To take into account these influences in calculating a long term sound level in NMPB the following approach is chosen: the sound levels are calculated for 2 conventional conditions of propagation: favourable conditions and homogeneous conditions. The 2 sound levels calculated with these 2 different conditions are combined to the average long term sound level, whereby the occurrence of the 2 different conditions is different for day and night and different for the source-to-receiver direction and different for different sites.

In NMPB 2 tables and 18 maps of France are added giving the percentage of long term occurrence for meteorological conditions favourable to sound propagation in steps of 20 degrees direction for day and night, based on the analysis of 40 meteorological stations spread out over France according to the criteria shown in Annex 1. In the standard XP S 31-133 only the tables without the maps are given.

In the general considerations in NMPB is said, that the effect of meteorological conditions is measurable as soon as the distance between source and receiver is greater than about 100 m. Further the "5 May 1995 French Decree" is cited, which imposes to take into account in road prediction studies real meteorological conditions for receivers located more than 250 m away from the road. However there is no clear statement for which distance the calculation has to take care of the favourable propagation. In the standard XP S 31.133 no specification is given on the distance when the favourable sound propagation has to be considered.

In both documents several conditions are given for the use of the data on occurrence of favourable sound propagation as:

- quite horizontal site with only a little high vegetation (isolated trees are accepted)
- ground covered with grass (optimal height of vegetation: 10 cm)
- no big water surface (lakes, rivers)
- clear propagation zone: no object of large size (surface or height) regarding to the dimensions of the propagation zone, and not a lot of small objects (some scattered objects are accepted)
- maximum altitude of the site: 500 m

It turns out from this, that the data, even when available, may not be used in a great number of cases.

When a site is not in accordance with these criteria the following possibilities are specified:

- use local existing meteorological data; the work may be based on the grid shown in Annex 1 and needs specialists in micro-meteorology
- use local meteorological data got especially for the needs of the project; work more complex than the afore mentioned
- use overestimated inclusive values (fixed values); in this case the occurrence of favourable conditions is maximised, what will lead to overestimating the long term level (bringing a better protection to the people); the following values may be for instance chosen in any direction
    - 100 % of favourable occurrence for the night period
    - 50 % of favourable occurrence for the day time period

With respect to the use of the NMPB model to calculate road traffic noise for strategic noise mapping according to END definitions if and when and to which percentage favourable sound propagation has to be taken into account have to be laid down. From the afore described details on this question in the NMPB document it has to be considered

- the method shall only be used as interim method, so things should not be to complicated and expensive
- the meteorological data described in NMPB, only to be used for certain types of flat sites below 500 m can not be used at all in mountainous countries (like Austria or northern Italy, where all major transit routes lead through the Alps)

The best solution therefore would be to chose the method with "fixed values" for the END-interim method, i. e. do the calculations for

- 100 % of favourable occurrence for the night period
- 50 % of favourable occurrence for the daytime period

The evening period has to be taken into account additionally: as from the meteorological point of view the evening period is "night" in winter and "day" in summer it is proposed to calculate

- 75 % of favourable occurrence for the evening period.

The long term level $L_{longterm}$ is then calculated by summing on an energetic basis the levels LF calculated for favourable sound propagation conditions and LH calculated for homogeneous sound propagation conditions by

$$L_{longterm} = 10.\lg\left[p.10^{L_F/10} + (1-p).10^{L_H/10}\right]$$

Equation 2

where

p is the long term occurrence for meteorological conditions favourable for sound propagation.

The sound level with favourable conditions is calculated (for each octave band) for the path from one point source on the road to the receiver by

$$L = L_w - A_{div} - A_{atm} - A_{grd,F} - A_{dif,F}$$

Equation 3

taking into account the sound attenuation by divergence A_{div}, by air absorption A_{atm}, by ground effect under favourable conditions $A_{grd,F}$ and by diffraction under favourable conditions $A_{dif,F}$.

The sound level with homogeneous conditions is calculated (for each octave band) for the path from one point source on the road to the receiver by

$$L = L_w - A_{div} - A_{atm} - A_{grd,H} - A_{dif,H}$$

Equation 4

4.2 Geometrical divergence

The sound attenuation due to geometrical divergence A_{div} (decreasing of sound level due to propagation distance) is calculated in the general way (based on spherical propagation).

4.3 Atmospheric absorption

The sound attenuation due to atmospheric absorption A_{atm} is calculated in the general way. The air attenuation coefficient for a temperature of 15°C and a relative humidity of 70% is inserted in NMPB. These values are typical for France, but can not be used for all European countries.

To use NMPB for all European countries a table of the air attenuation coefficients according to ISO 9613-1 has to be given for several sets of temperature and relative humidity, typical for Europe, as shown in Annex 2. The relevant data have to be chosen from this table on a national basis.

4.4 Ground effect

The sound attenuation due to the ground effect A_{grd}, caused by the interference between the sound reflected on the ground and the sound propagating directly from the source to the receiver, is taken into account in two different ways, depending on the type of sound propagation which is caused by the meteorological conditions.

The attenuation for favourable conditions $A_{grd,F}$ is calculated according to the method given in ISO 9613-2,which is used in several European countries.

The attenuation for homogeneous conditions $A_{grd,H}$ is calculated according to a formula taking into account the ground coefficient G. If G = 0 (reflecting ground) $A_{grd,H}$ = - 3 dB.

In order to take into account the reality of the terrain relief along a sound propagation path the notion of an equivalent height which replaces the real height is introduced, which is a good solution for practice.

All the calculation procedures for the attenuation due to ground effect given in NMPB can be used for calculations according to END.

4.5 Diffraction

The calculation of the sound attenuation by diffraction is described in detail for the 2 types of sound propagation. In case a diffraction is effective, the ground attenuation has not to be taken into account as described in 4.4 but it is included in the calculation of the attenuation by diffraction. Also in this calculation the non flatness of the ground is taken into account using equivalent heights. The calculation procedure enables to treat the diffraction due to thin and thick barriers, buildings, natural or artificial mounds as well as edges of an embankment, cutting or viaduct.

In a first step it has to be considered, if a diffraction occurs. The path difference between the connection source – receiver and via the top of the obstacle has to be compared with the quantity - l/20 (l is the wave length for 500 Hz i.e. - l/20 = - 0,034 m); if the path difference is less, then there is no need to carry out a diffraction calculation.

Several sketches show how to calculate the path difference for homogeneous conditions (direct path source-receiver is straight) and for favourable conditions (direct path is curved).

From the path difference the attenuation due to diffraction is calculated by a series of formulae.

The calculation procedure is the same in NMPB and in XP S 31-133. There is only one difference: A note on how to calculate the diffraction on vertical edges in NMPB is a separate new paragraph in XP S 31-133.

The calculation procedure for the attenuation by diffraction can be used in all European countries without any change or addition; as the recent standard contains a note on vertical edges from the (elder) NMPB as full text, the note should also be taken as full text in the END interim method.

4.6 Reflection

The reflections on vertical obstacles are treated with the help of image-sources, as this is used in several national calculation methods. An obstacle is taken as vertical when its incline regarding to a vertical direction is less than15o. If the reflections on strongly inclined obstacles are needed then the present method has to be applied in 3D. Obstacles whose dimensions are small regarding to the wavelength have to be neglected in the calculation of reflection. The sound power level of the image source has to take into account the absorption coefficient of the reflecting surface. There are no examples given for absorption coefficients like they are given in some national guidelines.

The method to calculate the effect of reflections can be used in the END interim method without any change or addition.

5 Summary

The differences and similarities between NMPB and END found and necessary amendments or additions are summarized in the following table.

subject	result of comparison - action
noise indicator	A-weighted long-term average sound level determined over the year taking into account variations in emission and transmission identical periods day, evening, night have to be introduced
Immission point	4m above ground according to END may be used, o.k.
source	source data have to be established or better the method to define the sound emission data to be used for the calculation with the NMPB model for the national vehicle fleet on the national road surfaces has to be described prescription of splitting up the road into elementary point sources can be used, o.k.
propagation ▪ influence of meteorological conditions ▪ ▪ geometrical divergence ▪ atmospheric absorption ▪ ground effect ▪ diffraction	 2 types of propagation: homogeneous and favourable define percentage of occurrence of favourable conditions; general proposal 50 % for day, 75 % for evening, 100 % for night o.k. table with air attenuation coefficient versus temperature and relative humidity typical for European regions has to be inserted and relevant data have to be chosen on a national basis o.k. o.k., add note on vertical edges as full text acc. to XP S 31-133
reflection	o.k.

It has to be emphasised, that the method to calculate sound propagation according to NMPB and the identical French standard seems quite practical and seems to be reliable in practice because the method edited in 1996 has been taken over into a French standard 2001. However it is not identical with ISO 9613-2, which is recommended as interim computation method for industrial noise.

If the method is used to calculate the propagation of road traffic noise then it should be also used to calculate the propagation of railway noise and to calculate the propagation of industrial noise. It does not seem reasonable to calculate the propagation of sound of different sources with different propagation schemes (as all sources are split up into point sources for the calculation of sound propagation).

Annex 1: Double-entry grid showing the qualitative variation of the sound level at long range, according to observable meteorological factors

U1: strong wind (3 to 5 m/s) upwind to direction emitter-receiver	T1: day and strong radiation and dry surface and calm wind
U2: average to calm wind (1 to 3 m/s) upwind or strong wind, slightly upwind	T2: same conditions as T1 but at least one does not apply
U3: zero wind or any crosswind	T3: sunrise or dawn or (overcast and windy and not too humid surface)
U4: average wind slightly downwind or strong wind almost not downwind (≅45°)	T4: night and (cloudy or wind)
U5: downwind	T5: night and open sky and calm wind

The combination of the conditions U_i and T_i gives the following classes of conditions of sound propagation. The grey parts correspond to impossible meteorological cases.

	U1	U2	U3	U4	U5
T1		– –	–	–	
T2	– –	–	–	Z	+
T3	–	–	Z	+	+
T4	–	Z	+	+	+ +
T5		+	+	+ +	

– –	Heavily upward-curved sound rays cause a very strong attenuation (“unfavourable” situation)
–	Upward-curved sound rays cause a relatively strong attenuation (“unfavourable” situation)
Z	Sound rays propagate in straight lines with no meteorological effects interfering (“homogeneous” situation)
+	Downward-curved sound rays cause moderate increase in sound level (“favourable” situation)
++	Strongly downward-curved sound rays cause relatively strong increase in sound levels (“favourable” situation).

Annex 2:
Atmospheric-absorption attenuation coefficients in dB/km versus temperature and relative humidity

temperature	rel. humidity	Frequency (Hz)					
oC	%	125	250	500	1000	2000	4000
0	40	0,43	0,92	2,63	9,00	29,8	75,2
	50	0,41	0,82	2,08	6,83	23,8	71,0
	60	0,40	0,78	1,78	5,50	19,3	63,3
	70	0,39	0,76	1,61	4,64	16,1	55,5
	80	0,38	0,76	1,51	4,06	13,8	48,8
	90	0,37	0,76	1,45	3,66	12,1	43,2
5	40	0,47	0,92	2,10	6,48	22,7	72,5
	50	0,46	0,89	1,82	5,08	17,5	60,2
	60	0,44	0,89	1,69	4,29	14,2	50,2
	70	0,42	0,90	1,64	3,80	12,0	42,7
	80	0,39	0,90	1,63	3,50	10,5	37,0
	90	0,37	0,90	1,64	3,31	9,39	32,7
10	40	0,52	1,04	1,98	5,07	16,8	59,0
	50	0,49	1,05	1,90	4,26	13,2	46,7
	60	0,45	1,05	1,90	3,86	11,0	38,4
	70	0,41	1,04	1,93	3,66	9,66	32,8
	80	0,38	1,02	1,97	3,57	8,76	28,7
	90	0,35	1,00	2,00	3,54	8,14	25,7
15	40	0,54	1,23	2,18	4,51	13,1	45,7
	50	0,48	1,22	2,24	4,16	10,8	36,2
	60	0,43	1,18	2,31	4,06	9,50	30,3
	70	0,38	1,13	2,36	4,08	8,75	26,4
	80	0,34	1,07	2,40	4,15	8,31	23,7
	90	0,31	1,02	2,41	4,25	8,07	21,7
20	40	0,52	1,39	2,63	4,65	11,2	36,1
	50	0,45	1,32	2,73	4,66	9,86	29,4
	60	0,39	1,23	2,79	4,80	9,25	25,4
	70	0,34	1,13	2,80	4,98	9,02	22,9
	80	0,30	1,04	2,77	5,15	8,98	21,3
	90	0,27	0,97	2,71	5,30	9,06	20,2

Noise of road transport infrastructure

Comparison of emission data for road traffic noise in guide de bruit and in the German (RLS 90) and the Austrian (RVS 3.02) calculation model

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In guide de bruit the emission is described by

$$E = L_W - 10 \lg V - 50 \quad \text{in dB(A)}$$

where

L_W *sound power level in dB(A)*

V *speed in km/h*

The emission data from RLS 90 and from RVS 3.02 can be transformed to this quantity by the basic formula from guide de bruit as follows:

$$(L_W)_m = E + 20 \quad \text{in dB(A)}$$

where

$(L_W)_m$ *sound power level per m length*

E + 20 is also this quantity, which has to be inserted for the emission in the basic calculation formula in 5.2 in NMPB.

$$L_{eq}(1/h) = L_W - 10 \lg (d.V) - 38 \quad \text{in dB(A)}$$

where

$L_{eq}(1/h)$ *equivalent sound level in dB(A) from 1 vehicle per hour passing in distance d in m with speed V in km/h*

From this

$$L_{eq}(1/h,1m) = L_W - 10 \lg V - 38 = E + 12 \quad \text{in dB(A)}$$

and from this

$$E = L_{eq}(1/h,1m) - 12 \quad \text{in dB(A)}$$

With this formula the basic values from RVS 3.02, which are the L_{eq} in 1m distance for 1 vehicle/h can be transformed to E-values to be compared with guide de bruit.

In RLS 90 the basic emission value is the equivalent sound level in 25 m distance $L_m^{(25)}$ for vehicles driving by with 100 km/h. According to DIN 18005-1 from this the sound power level per m length can be calculated by

$$L_{W'} = L_m^{(25)} + 17,6 \quad \text{in dB}$$

and from this

$$L_{W'} = E + 20$$

and from this

$$E = L_m^{(25)} + 17,6 - 20 = L_m^{(25)} - 2,4 \quad \text{in dB(A)}$$

With this formula the basic values from RLS 90 can be transformed to E-values to be compared with the values in guide de bruit. As RLS 90 does not contain separate emission values for light and heavy vehicles (but a mixture of both) and also a mixture of the speed of light and heavy vehicles it is a little complicated to find E-values for the different types of vehicles for different speeds.

The best possibility to compare the data is to draw a diagram similar in scale to this in guide de bruit, which printed on a transparent sheet of paper may be placed over the diagram in guide de bruit and show more or less coincidence.

One can see, that the data in guide de bruit are as good and valid as the data in RLS 90 and in RVS 3.02,which both models are still in use. Sound level measurements alongside roads in Austria show a good agreement between calculated values and measured values.

E–values calculated from the German (RLS 90) and from the Austrian (RVS 3.02) road traffic noise calculation model for the comparison with E–values in guide de bruit