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IMAGINE
Improved Methods for the Assessment of the Generic Impact of Noise in the Environment

Determination of Lden by calculation - definition of meteorological classes –

extra document

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1 Introduction

In the HARMONOISE project it was shown how noise levels are influenced by meteorological conditions such as wind speed, wind direction and thermal inversion effects. For the determination of long term averaged noise levels, short term levels, valid under specific meteorological conditions, must be weighted according to their frequency of occurrence. Even in case of long time monitoring some corrections may be required in order to take into account seasonal variations of traffic flow or atmospheric absorption. The IMAGINE project worked out an operational scheme linking the HARMONOISE propagation model to a statistical (climatologic) description of local meteorology.

2 Meteorological classes

For validation purposes, the Harmonoise project relied on 200 *meteorological* classes (8 wind directions, 5 wind speed classes and 5 stability classes). In order to limit the calculation efforts needed for the estimation of long term averaged noise indicators, it was proposed to reduce this problem by sampling all possible lin-log sound speed profiles down to 25 *propagation classes.*

The final aim of the engineering methods, however, is to provide a pragmatic and unified prediction scheme to be used for noise mapping according to END. In view of this, the Imagine project developed a methodology that further reduced the complexity of the problem to the calculation of 4 *propagation* classes, defined in terms of equivalent linear gradients. This classification of propagation conditions applies to prediction models as well as to measurements. From either or both, long term averaged L_{den} and L_{night} values are obtained by considering the frequency of occurrence of each propagation class over a (climatologically) relevant year.

In order to calculate a value for the long term L_{den} it is first necessary to be able to evaluate the propagation of noise levels for a variety of meteorological conditions and then determine the frequency of occurrence of those meteorological over a yearly period. In certain circumstances particular meteorological conditions will affect the source level eg winter conditions requiring the use of chains on road vehicle tyres or the operation of aircraft in different wind conditions.

3 Classification variables

For the development of this methodology, it was first noted that, in any given situation, the importance of meteorological effects on sound propagation can be assessed by the single dimensionless parameter $\boldsymbol{D}/\boldsymbol{R}$, the ratio of the (horizontal) propagation distance relative to the equivalent curvature parameter as defined above. Using this parameter, the meteorological effects (excess attenuation relative to free field) may then be quantified using a limited number of propagation classes, as indicated in the table below.

Propagation class[1)]	D/R Range	D/R Representative value	Verbal description	Typical values of wind speed component [2),3)] m/s
M1	< - 0.04	-0.08	Unfavourable	< 1 (day) < -1 (night)
M2	-0.04 … 0.04	0.00	Neutral	1-3
M3	0.04…0.12	0.08	Favourable	3-6
M4	> 0.12	0.16	Very favourable	> 6 (day) [~~3~~4)] ≥ -1 (night)

Notes:

[1] Propagation Class M0 has been removed from the propagation class calculation because it is very unfavourable and unlikely to influence the year long average noise level.
[2] The wind speed component is the projection of the wind speed vector on the direction of propagation. Negative values represent upwind conditions, blowing from the receiver to the source. The wind speed should be determined at 10 m high in a sufficiently large open space between the source and the receiver.
[3] The values given in the table are only indicative and were obtained assuming moderate thermal effects. Clear sky conditions may change the estimation one class up (night time) or down (day time).
~~3) I~~4)t may be difficult to carry out reliable measurements under such conditions.

4 Calculation of D/R

The first stage is tho determine the metrological profile parameters, friction velocity (u*), Inverse Monin-Obukhov length (1/L) and the Temperature Scale (T*)

These can be obtained from tables of wind speed classes and stability classes. The Harmonoise project proposed the following simplified classification scheme as appropriate for the purpose of characterising meteorological effects on outdoor sound propagation.

wind speed classes

Wind speed class	Wind speed at 10 m above local ground
W1	0 – 1 m/s
W2	1 – 3 m/s
W3	3 – 6 m/s
W4	6 – 10 m/s
W5	> 10 m/s

stability classes

Stability class	Cloud cover (in octants)
S1	Day 0/8 – 2/8
S2	Day 3/8 – 6/8
S3	Day 7/8 – 8/8
S4	Night 5/8 – 8/8
S5	Night 0/8 – 4/8

The meteorological profile parameters associated with wind speed classes and stability classes are given in the following tables.

Estimated friction velocity u* as a function of wind speed class

Wind speed class	Friction velocity u* (m/s)
W1	0
W2	0.13
W3	0.3
W4	0.53
W5	0.87

Estimated inverse Monin-Obukhov length 1/*L* as a function of wind speed and stability class

1/L	S1	S2	S3	S4	S5
W1	-0.08	-0.05	0	0.04	0.06
W2	-0.05	-0.02	0	0.02	0.04
W3	-0.02	-0.01	0	0.01	0.02
W4	-0.01	0	0	0	0.01
W5	0	0	0	0	0

Estimated temperature scale T* as a function of wind speed and stability class

T*	S1	S2	S3	S4	S5
W1	-0.4	-0.2	0	0.2	0.4
W2	-0.2	-0.1	0	0.1	0.2
W3	-0.1	-0.05	0	0.05	0.1
W4	-0.05	0	0	0	0.05
W5	0	0	0	0	0

It should be noted that the proposed values are only indicative for propagation over flat, dry ground in an almost flat environment. Effects of wet land, large water surfaces, relief, forests or dense built-up areas are not taken into account and these situations may require a more detailed micro-meteorological study in order to derive more representative profile parameters.

The radius of curvature of the propagating ray is obtained from the following equations

$A = A_T + A_W$ and

$B = B_T + B_W$

where

$$\begin{cases} A_W = \dfrac{u^*}{k\,L} \\ A_T = \left(\dfrac{1}{2}\dfrac{c_0}{T_0}\right)\left(0.74\dfrac{T^*}{k\,L} - \dfrac{g}{c_p}\right) \end{cases} \qquad during\ day\ (stability\ classes\ S_1, S_2\ and\ S_3)$$

$$\begin{cases} A_W = 4.7\,\dfrac{u^*}{k\,L} \\ A_T = \left(\dfrac{1}{2}\dfrac{c_0}{T_0}\right)\left(4.7\,\dfrac{T^*}{k\,L} - \dfrac{g}{c_p}\right) \end{cases} \qquad during\ night,\ (stability\ classes\ S_4\ and\ S_5)$$

$$\begin{cases} B_W = \dfrac{u^* \cos\varphi}{k} \\ B_T = \left(\dfrac{1}{2}\dfrac{c_0}{T_0}\right)\left(0.74\,\dfrac{T^*}{k}\right) \end{cases}$$

The other parameters in the formulae are constants:

$k = 0.4$ the Von-Karman constant

g = 9.81 m/s² Newton's gravity acceleration

c_p = 1005 J kg^{-1} K^{-1} the specific heat capacity of air at constant pressure

c_0 = 331.4 m/s the sound speed at reference temperature

T_0 = 273 K the reference temperature

!/R is determined from from A and B as follows:

$$\frac{1}{R_A} = \frac{A}{c_0}$$

$$\frac{1}{R_B} = \frac{8}{D_{sr}}\sqrt{\frac{B}{2\pi c_0}} \qquad if\ B > 0$$

$$\frac{1}{R_B} = \frac{B}{c_0 Z_{sr}} \qquad if\ B \le 0$$

$$\frac{1}{R} = \frac{1}{R_A} + \frac{1}{R_B}$$

In case B > 0, the equivalent gradient has to be corrected for source and receiver height. The corrected value $1/R'_B$ is calculated from:

$$Z_B = \frac{D_{sr}{}^2}{8 R_B}$$

$$Z'_B = \sqrt{Z_B{}^2 + \left(\frac{Z_{sr}}{2}\right)^2} - \frac{Z_{sr}}{2}$$

$$\frac{1}{R'_B} = \frac{8 Z'_B}{D_{sr}{}^2}$$

Where:

Z_s, Z_r the height of the source and the receiver above local ground;

$Z_{sr} = (Z_s + Z_r)/2$ the averaged height of the propagation path above ground

D_{sr} the distance from the source to the receiver as measured in the horizontal plane

Note: in case of propagation over a deep valley or from an elevated road or railway, it may be more appropriate to calculate Z_{sr} as the averaged height of the straight ray path above the terrain profile.

5 Calculation of long term L_{den}

Once the equivalent noise level in each meteorological class has been determined, these values shall be combined together based on the frequency of occurrence of each class during a relevant average year:

$$L_{DEN} = 10\log\sum_{i=1}^{5} p_i 10^{L_{eq,i}/10}$$

The frequency of occurrence of each propagation class can be derived from meteorological data records, including wind speed, wind direction and cloud coverage (or other ways for determining stability) over a sufficiently long period. Except in mountainous area where local effects may be dominant, the frequencies of occurrence are stable over large areas and data from the nearest weather station or airport can be used. It may even be possible to provide generic values that can be used within the main climatologic regions covering Europe. Frequencies of occurrence must be determined separately for day, evening and night period. More information can be found in report IMA03TR-060610-CSTB01 (ref. [1]).

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[1] IMA03TR-060610-CSTB01 : Processing of meteorological data and determination of long time averaged noise indicators L_{den} and L_{night}.