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Fast Determination of the Acoustic Area of Influence of Roads, Railways, Airports and Industries

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Abstract
It is very important to know, as early as possible, what is the acoustic area of influence of a particular project, because this information has influence in other areas, e.g. the extension of cartography necessary. So, it is relevant to find fast and simple methods to determine the acoustic area of influence, based on European Interim Methods, for roads, railways, airports and industries.

Keywords: Fast prevision, road noise, railway noise, airport noise, industries noise.

1 Introduction

The Aim of this paper is to develop an expeditious methot for determination of the Acoustics Area of Influence of projects, based on European interim forecast methods set out in Directive 2002/49/EC [1]: Industries: ISO 9613-2: 1996 [2]; Roads: NF S 31-133: 2007 [3]; Railways: Standaard-Rekenmethode II: 1996 [4]; Airports: ECAC.CEAC Doc 29: 2005 [5].
It is understood by Acoustics Area of Influence, the area around the project where the sound levels are above a certain target.

2 Variation of noise levels with distance from the source

According to the European interim methods, changes in noise levels with distance from the source depend on the following variables:

1. Source type (geometric characteristics).
2. Geometric divergence (depends only on the distance to the source).
3. Atmospheric absorption (depending on the distance to the source, the source spectrum, temperature and relative humidity).
4. Effect of Soil (depends on the distance to the source, the source spectrum, the height of the source and receiver, and the sound absorption coefficient of the soil).
5. Barriers (depends on the difference between the direct path and diffracted path, and the source spectrum).
6. Favorable conditions (depending on the probability of ocorrence of positive vertical gradients of sound speed).

So, since the variation of sound levels with distance from the source depends on:

- the source type, the source spectrum, distance source/receiver, air temperature, relative humidity of air, source height, receiver height, the sound absorption coefficient of the soil, the difference between diffracted and direct path, and the probability of ocorrence of favorable conditions for sound propagation,

to determine the Acoustics Area of Influence of a given project, it is necessary to check the influence of these variables in noise levels with distance from the source.
The following chapters show the analysis for industries, roads and railways. For airports, and for other information associated with the fast prediction, should be consult the website www.schiu.com/FastPrevision.

2.1 Simplifications

For simplicity and applicability, we consider the following:

- Difracctions and reflections are disregard, i.e., it is considered that there are no obstacles between the source and receiver.
- All receivers are at a height of 4 meters.
- The average temperature and humidity is always 17 º C and 70% (annual mean values considered representative of Lisbon).
- In the case of roads and railways it is always only one very long straight track.
- For roads, there are considered only the continuous fluid flow and the horizontal skew.
- In the case of railways, there are disregard the existence of trains with braking system activated.
- For roads, we consider the effect of the pavement in overall terms and not by frequency bands.
- For the railways, the variation of noise due to different types of train, different speeds and different railway structures, are considered in global terms and not by frequency bands.

2.2 Reference Charts

In the case of industries, it is considered as reference the following:

- A point source, located at 4 meters high, with 3 distinct spectra [White Noise (variation of 3dB/octave), Brown Noise (variation of -3dB/octave) and Brown Noise (A) (variation of -3dB(A)/octave)][1].

In the case of roads, it is considered as reference the following:

- Movement of light vehicles on a normal asphalt pavement.

In the case of railways, it is considered as reference the following:

- Movement of a category C9 train on a railway structure of concrete sleepers in gravel and joinless rails.

It is presented in Figure 1 the reference chart for Industries, in Figure 2 the reference chart for Roads and in Figure 3 the refence chart for Railways, for distances between 100 and 1000 m (for other distances see www.schiu.com/FastPrevision; in the particular case of roads see [6]).
In all cases the graphics distinguish 3 sound absorption coefficients of soil (alpha = 0, alpha = 0.5 (50%) and alpha = 1 (100%)) and 3 probability of occurrence of favourable conditions for sound propagation (PO = 0%, PO = 50% and PO = 100%) (in industries the value assigned to constant C_0 was respectively as follows [7]: C_0 = 10 dB, C_0 = 0.7 dB and C_0 = 0 dB, which makes similar PO = 50% and PO = 100%, so the Figure 1 does not present PO = 50%; for similar reasons there are not shown Alpha = 50%].

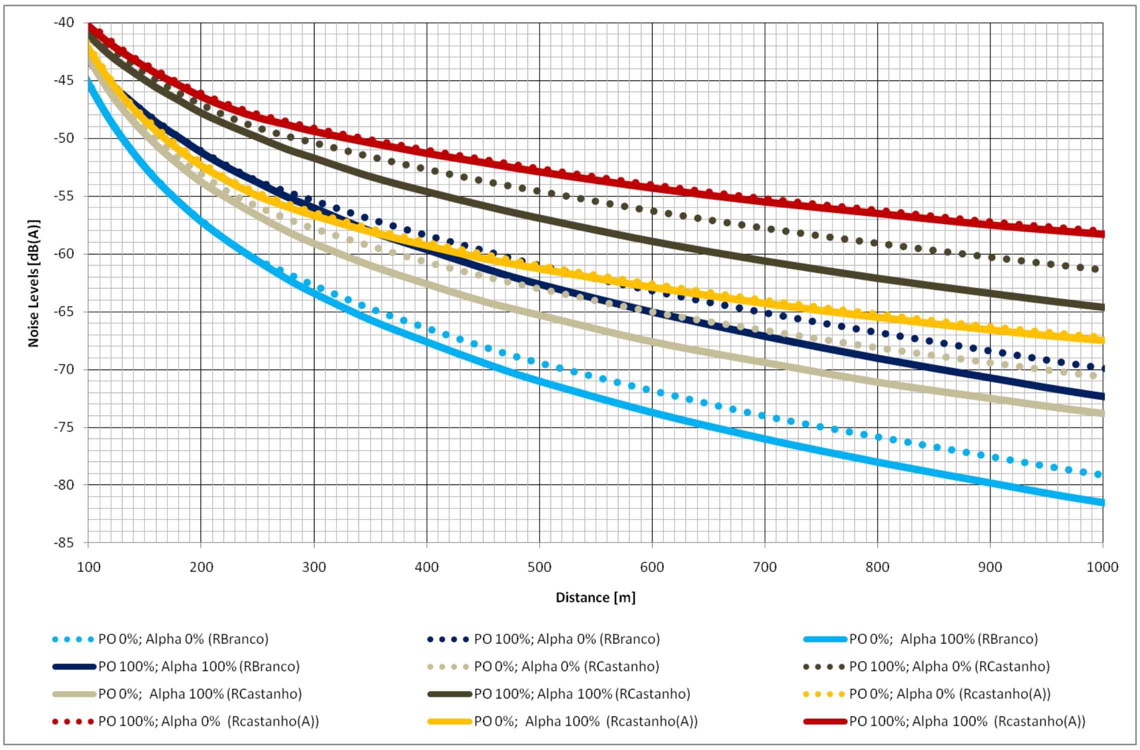

Figure 1 – Variation in noise levels with distance from the source (industries; point sources)

[1] According to the database Source dB V1.1, available through the site www.imagine-project.org, it was found that the 3 theoretical spectrum presented, are those that best represent, respectively, the real situations of the prevalence of low, medium and high frequencies.

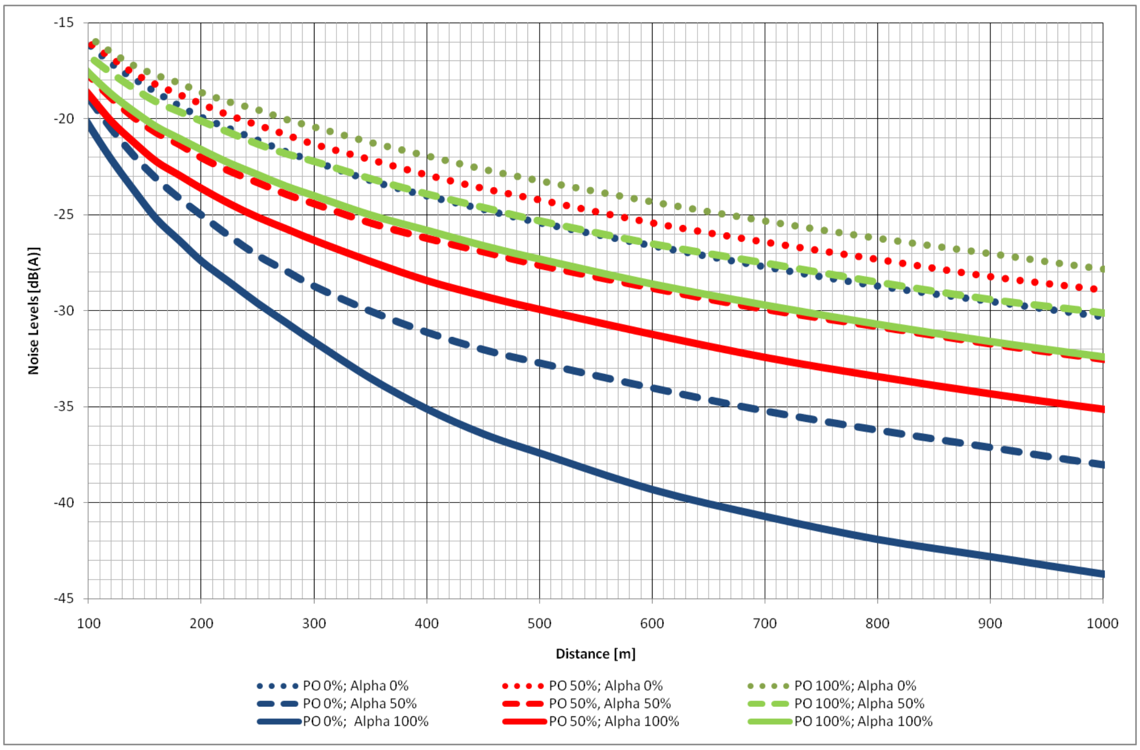

Figure 2 – Variation in noise levels with distance from the source (roads; very long straight track)

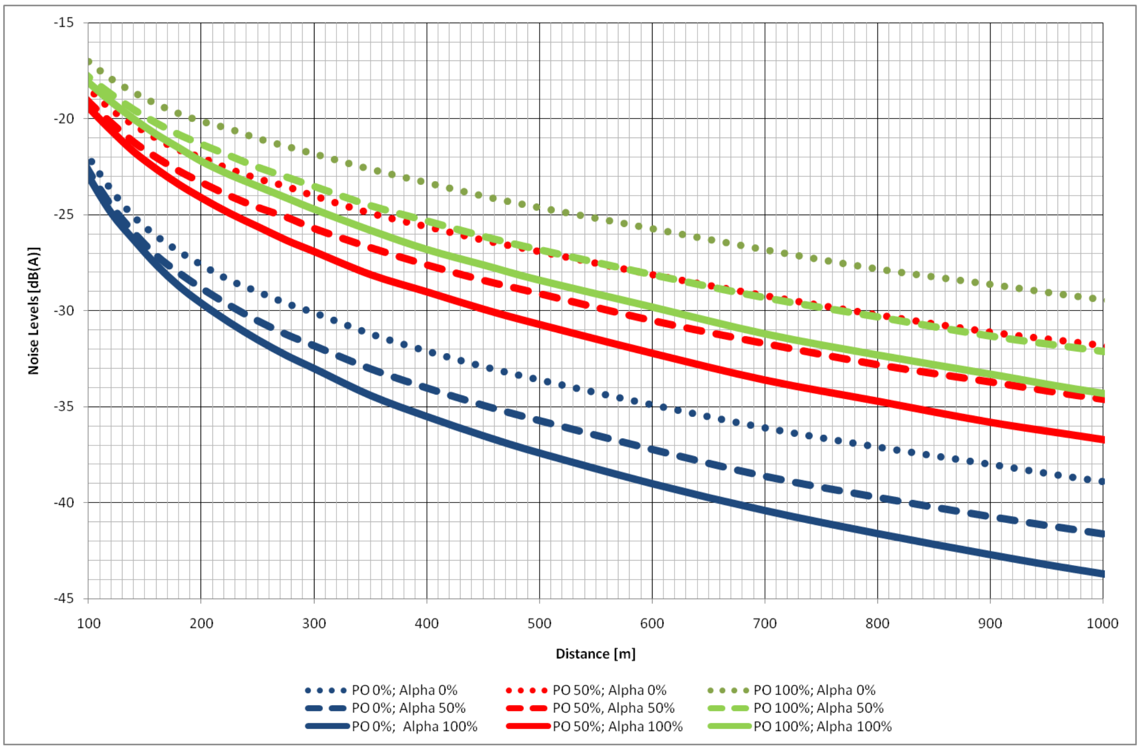

Figure 3 – Variation in noise levels with distance from the source (railways; very long straight track)

2.3 Reference values

The reference value corresponds to the value L_1 at 1 meter of horizontal distance from the source, considering the reference positions of the sources [Industries (White Noise and Brown Noise) (1), Industries (Brown Noise (A)) (2), Roads (3) and Railways (4)]:

$$L_1 = L_{Aw} - 11 + 3x(1 - \text{Alpha}) \tag{1}$$

$$L_1 = L_{Aw} - 9 + 2x(1 - \text{Alpha}) \tag{2}$$

$$L_1 = 78 \text{ dB(A)} \tag{3}$$

$$L_1 = 74 \text{ dB(A)} + 2x(1 - \text{Alpha}) \tag{4}$$

For Roads, the reference value corresponds to 1000 light veichuls per hour (Q_{ref}) running at 100 km/h (v_{ref}) on a normal asphalt pavement.
For Railways, the reference value corresponds to 20 trains of category C9 per hour (Q_{ref}) running at 100 km/h (v_{ref}) on a railway structure of concrete sleepers in gravel and joinless rails.

3 Corrections to charts and reference values

3.1 Quantity

The L_{1Q} value, associated with a quantity Q of sources different from the reference quantity Q_{ref}, is given by:

$$L_{1Q} = L_1 + 10\log\left(\frac{Q}{Q_{ref}}\right) \tag{5}$$

3.2 Height of source (Industries)

The correction C_h of the source height, applies only to industries (point sources).
The correction C_h of the source height is applied to the values contained in the chart of Figure 1, and this correction varies with the horizontal distance d to the source, in the following ratio, where h is the height of the source and h_{ref} = 4 m the reference height, and applies only to distances less than or equal to $3|h - h_{ref}|$.

$$C_h = 20\log\left(\frac{d}{\sqrt{d^2 + (h - h_{ref})^2}}\right) \tag{6}$$

In addition to that the fact that PO = 0% curve becomes equal to the curve PO = 100%, up to a distance equal to 10(*h* +4). From this distance the curve PO = 0% is equal to the curve PO = 100% corrected by the following value:

$$-10(1 - 10(h - 4))/d \quad (7)$$

Note that, according to database Source dB V1.1, available through the site www.imagine-project.org, the height of the sources ranges between 0.3 meters (different types of pumps) and 100 meters (flare).

3.3 Type of vehicle (Roads and Railways)

The correction of the type of vehicle, applies only to roads and railways.
The value L_{1T} associated with a type of vehicle different from the reference vehicles (light vehicles for Roads and Category C9 for Railways) is given by:

$$L_{1HeavyVehicle} = L_{1LigthVehide} + 9 \quad (8)$$

$$L_{1C1} = L_{1C9} + 4 \quad (9)$$

$$L_{1C2} = L_{1C9} + 5 \quad (10)$$

$$L_{1C3} = L_{1C9} + 1 \quad (11)$$

$$L_{1C4} = L_{1C9} + 6 \quad (12)$$

$$L_{1C5} = L_{1C9} + 7 \quad (13)$$

$$L_{1C6} = L_{1C9} + 1 \quad (14)$$

$$L_{1C7} = L_{1C9} + 3 \quad (15)$$

$$L_{1C8} = L_{1C9} - 1 \quad (16)$$

Based on the information given in reference [8] it can be established corrections for Portuguese trains.

3.4 Speed (Roads and Railways)

The speed correction C_v, applies only to roads and railways.
The value L_{1v} associated with a speed different from the reference speed (v_{ref}) is given by:

$$L_{1v} = L_1 + C_v \quad (17)$$

It is presented in Figure 4, Figure 5 and Figure 6, the values of C_v as a function of speed, respectively for Roads and Railways.

3.5 More than one source

The global value associated with the existence of more than one source, is obtained by Energetic Addition ⊕:

$$L_A \oplus L_B = 10\log\left(10^{\frac{L_A}{10}} + 10^{\frac{L_B}{10}}\right) \quad (18)$$

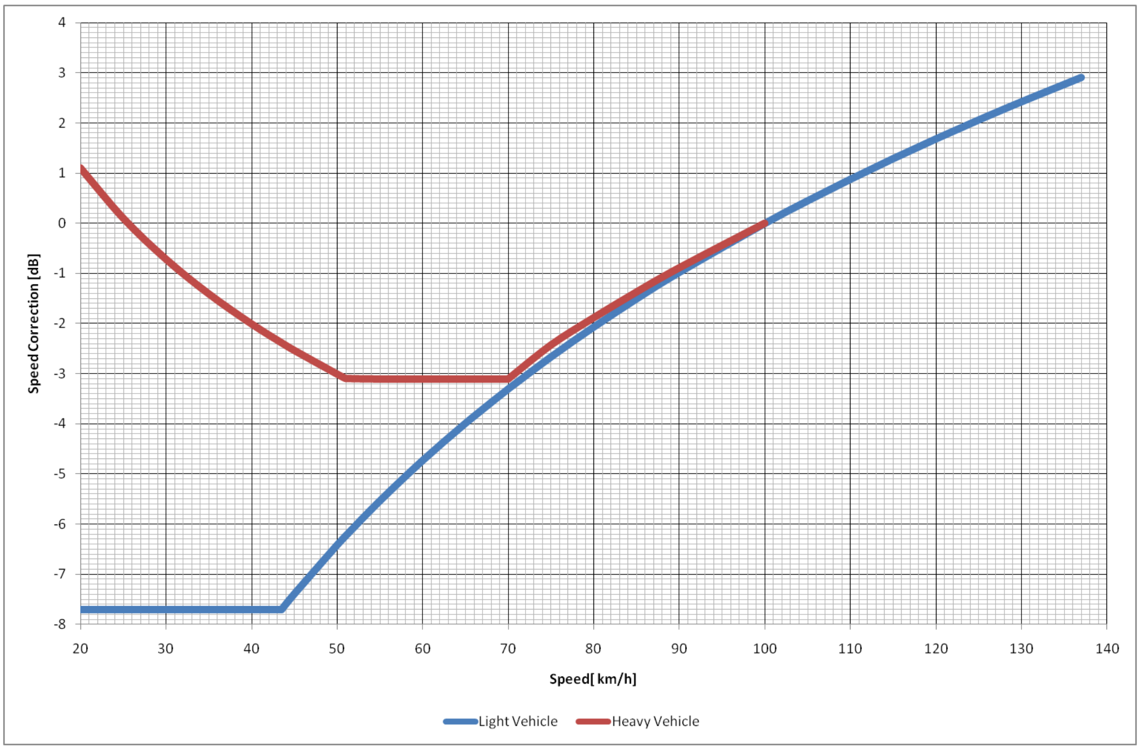

Figure 4 – Speed correction (Roads)

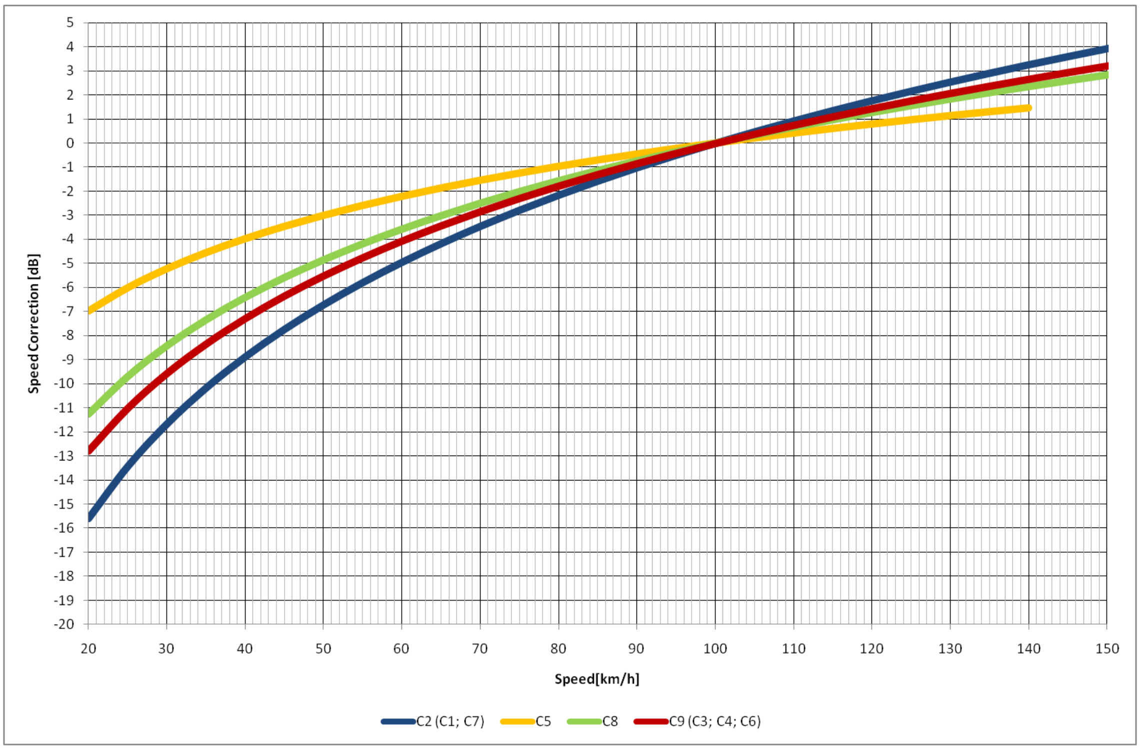

Figure 5 – Speed correction (Railways; 20 to 150 km/h)

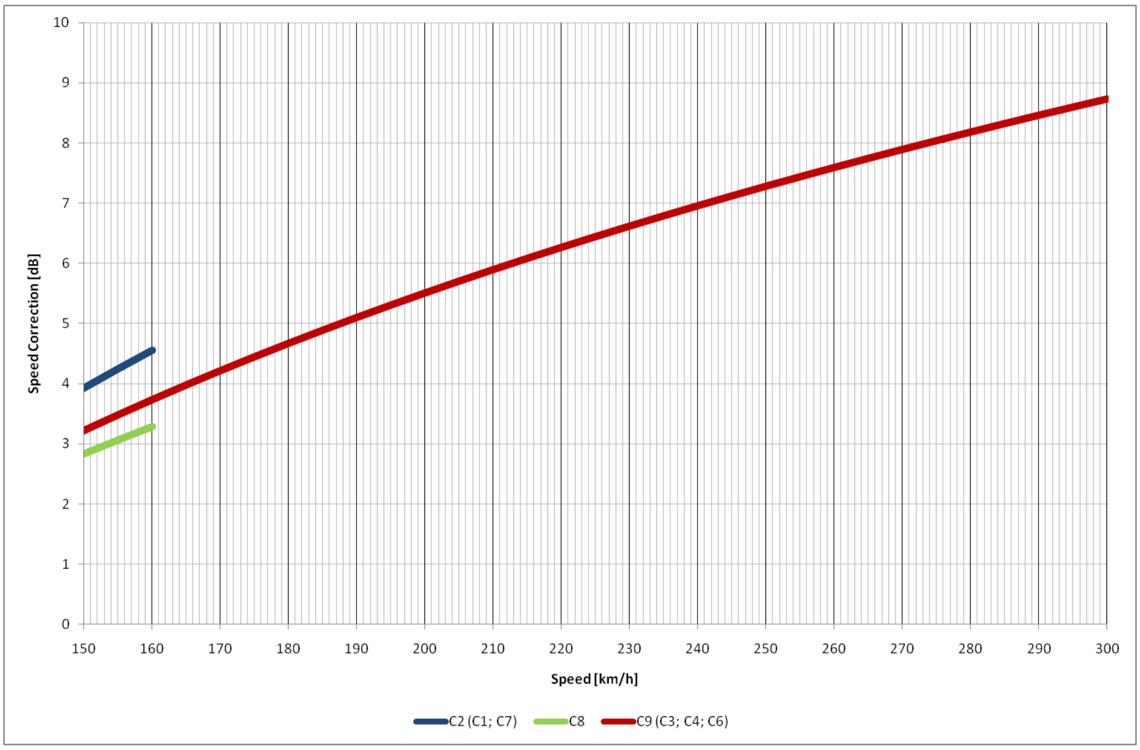

Figure 6 - Speed correction (Railways; 150 to 300 km/h)

3.6 Type of pavement and type of railway structure (Roads and Railways)

There are considered 5 types of pavement and 5 types of railway structure: Very Little Noisy (correction -6 dB), Little Noisy (-3 dB), Normal (0 dB), Noisy (3 dB) and Very Noisy (6 dB).

4 Examples

It is considered for all the examples a reference value of 55 dB (A), to limit the Acoustics Area of influence.

4.1 Industries (point source)

4 Point Sources with L_{Aw} = 101 dB(A), h = 100 m, with a spectrum where prevails low frequency (Brown (A)), a absorbent soil (alpha = 1), assuming PO = 100%.
Taking the equation (2) we have: L_1 = 101 – 9 + 0 = 92 dB(A).
Taking the equation (5) we have: L_{1Q} = 92 + 10log (4) ≈ 98 dB(A).
Analyzing the Figure 1, it appears that for a distance of 100 meters to the source we have, for this example, a correction of - 40 dB. Adding this correction to the correction of the equation (6) $20\log\left(\frac{100}{\sqrt{100^2+(100-4)^2}}\right)\approx -3$ dB, we have: 98 - 40 - 3 = 55 dB (A), i.e., the Acoustics Area of the Influence of the example is about 100 meters around the sources.

4.2 Roads

Traffic of light Vehicle: 2000 vehicles per hour.
Traffic of heavy Vehicles: 100 vehicles per hour.
Speed of light vehicles: 100 km / h.
Speed of heavy vehicles: 90 km / h.
Pavement Type: Normal (0 dB).
PO = 0% e Alpha = 100 %.
Taking the equation (3), we have: L_{1Light} = 78 dB(A). Taking the equation (8) we have: L_{1Heavy} = 87 dB (A). Taking the equation (5) we have: $L_{1QLigth}$ = 78 +3 = 81 dB (A) and $L_{1QHeavy}$ = 87 - 10 = 77 dB(A). Analyzing the Figure 4 we have: $L_{1QvLight}$ = 81 + 0 = 81 dB (A) and $L_{1QvHeavy}$ = 77 - 1 = 76 dB(A).
Energetic Addition (18): 81 ⊕ 76 ≈ 82 dB (A).
From the Figure 2, it appears that for a distance of 200 meters to the source we have, for this example, a correction of -27 dB, so we have 82 - 27 = 55 dB (A), i.e., the Acoustics Area of Influence of the example is about 200 meters around the road.

4.3 Railways

Traffic of Category C1: 10 trains per hour.
Traffic of Category C6: 20 trains per hour.
Speed of C1: 80 km/h.
Speed of C6: 100 km/h.
Type of Railway Structure: Very Noisy (6 dB).
PO = 50% and Alpha = 0%.
Taking the fequations (4) (9) and (14), we have: L_{1C1} = 76 +4 = 80 dB(A) and L_{1C6} = 76 +1 = 77 dB (A). Taking the equation (5) we have: L_{1QC1} = 80 - 3 = 77 dB (A). Analyzing the Figure 5 we have: $L1_{QvC1}$ = 77 - 2 = 75 dB (A).
Energetic Addition (18): 75 ⊕ 77 ≈ 79 dB(A).
Railway structure: 79 +6 = 85 dB(A).
From the Figure 3, it appears that for a distance of 800 meters to the source we have, for yhis example, a correction of -30 dB, so we have 85 - 30 = 55 dB (A), i.e., the Acoustics Area of Influence of the example is about 800 meters around the railway.

5 Conclusions

It is considered that using the simple method explained, in the early stages of plans and projects, it will be of great utility in the prior determination of the Acoustics Area of Influence of a particular project, and for the important process of decision, in terms of prior comparative analysis of alternatives, and in terms of coverage area of study where 3D cartography will be necessary in subsequent phases, for a more accurate prediction of sound levels.
It is also considered that the simple method presented can be used in the gauge of the adequability of complex models, where the probability of error is high.
For a more proficient use of the method, we developed a computer application, which is available to all interested people at the following address:
http://www.schiu.com/FastPrevision
We look forward for comments and criticisms to the method and its applicability.

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