The Inclusion of Recreational Activities in Strategic Noise Maps

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Summary

Strategic Noise Maps in Europe are supported mainly by Directive 2002/49/EC and by Good Practice Guide for the preparation of Strategic Noise Maps. These documents address mainly four types of noise sources: Roads, Railways, Airports and Industries and was therefore not included Recreational Activities. This article seeks to justify the need for inclusion of Recreational Activities in Strategic Noise Maps, present some examples, and the main difficulties associated with, and present the main methods that can be used for characterization and modeling of this special type of noise source.

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1. Introduction

The definition of Environmental Noise in the Directive 2002/49/EC [1], often referred by END (Environmental Noise Directive), is the following one, in accordance with END, Article 3, paragraph a): "*... shall mean unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity ...*".

Although an explicit reference does not exist, it is clear that Recreational Activities noise can match the definition of "*unwanted or harmful outdoor sound created by human activities*", so should appear in Strategic Noise Maps.

Also note, in this regard, the provisions of END [1], Article 3, paragraph m): "*«quiet area in open country» shall mean an area, delimited by the competent authority, that is undisturbed by noise from traffic, industry or recreational activities*".

Notwithstanding the above, the European Good Practice Guide for Strategic Noise Mapping [2], often known by GPG (Good Practice Guide) states the following on page 50 of 129: "*It should also be noted that the END does not require the acquisition of data on recreational noise ...*".

Put in another way, the END [1] does not require that Strategic Noise Maps include Recreational Activities noise.

Of course, despite not being required by the END [1], it is possible, and in some cases it is necessary, to include noise of Recreational Activities in Strategic Noise Maps, as already indicated, for example, in references [3,4].

However, given the absence in GPG [2], about a standard methodology for the characterization and inclusion of Recreational Activities in Strategic Noise Maps, the methodologies can be different and without any framework of suitability.

So, the aim of this paper is alerting to the explained above, present examples of some Strategic Noise Maps that include noise of Recreational Activities and of some Strategic Noise Maps that do not include noise of Recreational Activities, and explain the main difficulties and methodologies for characterization and modelling of this type of noise source.

2. Noise Map Examples

One example of an Agglomeration Strategic Noise Map that includes Recreational Activities is the Strategic Noise Map of Lisbon [5]. One example of an Agglomeration Strategic Noise Map that does not include Recreational Activities is the Strategic Noise Map of Berlin [6].

Examples of other types of Noise Maps that include Recreational Activities are:

- Albufeira (Portugal) Noise Map [7].
- Belém (Brazil) Trade Zone Noise Map [8].
- Entertainment area in Brisbane (Australia) Noise Map [9].
- Ships, including Cruises, anchored in the port of Venice (Italy) Noise Map [10].
- Special Regime Acoustic Zone in Barcelona (Spain), mainly consisting of pubs, Noise Map [11].
- Acoustic characterization of pedestrian areas, related with tourism activities and entertainment, in León (Spain) [12].

3. Types of Recreational Activities

There are several Recreational Activities capable of producing noise with potential affectation of people who live or stay in its vicinity, but they can be divided into the following three broad categories that influence the type of characterization and modelling, as discussed in the next chapters:

- Open Air Recreational Activities: People socializing and strolling the streets, outdoor concerts, water sports, tourist areas, etc.
- Recreational Activities in Semi-open Buildings: Pubs that work with open door, concerts and games in stadiums, etc.
- Recreational Activities in Closed Buildings: Closed Discos and Pubs, etc.

4. Difficulties and Methodologies

4.1. Noise classes

One of the major difficulties of characterization of Recreational Activities, as mentioned in reference [4], relates to the possibility of different noise emission over time, for example, in areas of pubs, in the early evening may exist fewer people and less noise, but with the night "advance" the number of people and the pubs themselves can emit more noise. With specific regard to the Strategic Noise Maps, as they must correspond to an annual average, and since many Recreational Activities are seasonal, it is relevant to know the months and/or days of the week and/or hours of the day on which the Activity takes place to determine the necessary annual logarithm average of the noise emission.

So we can speak, at least, in two kinds of Noise Classes:

- Administrative Classes.
- Noise Emission Classes.

4.1.1. Administrative Classes

In Administrative Classes we can include the On/Off periods of the activities and the legal different periods, e.g.: day 7h-19h, evening 19h-23h and night 23h-7h (note that in some countries, e.g. Portugal, the national reference periods are different of European default periods presented).

For each period that we need to know the annual logarithmic average, if we have L_1 as the logarithmic average value of "On" period of the activity, and $L_2 = -\infty$ as the logarithmic average value of "Off" period of the activity, and T_1 as the duration time of the "On" period and T_2 as the duration time of the "Off" period, we have a global value L given by:

$$L = 10\log\left(\frac{T_1 10^{\frac{L_1}{10}} + T_2 10^{\frac{L_2}{10}}}{T_1+T_2}\right) \Leftrightarrow$$

$$L = L_1 + 10\log\left(\frac{T_1}{T_1+T_2}\right) \text{ [dB]} \qquad (1)$$

Assuming the following relation, is presented in Table I typical values of T_1, T_2 and k.

$$k = 10\log\left(\frac{T_1}{T_1+T_2}\right) \text{ [dB]} \qquad (2)$$

Table I. Typical values of T_1, T_2 and k.

T_1	T_2	k [dB]	T_1	T_2	k [dB]
T_1	$0{,}05T_1$	≈ -0,2	$0{,}9T_2$	T_2	≈ -3,2
T_1	$0{,}1T_1$	≈ -0,4	$0{,}8T_2$	T_2	≈ -3,5
T_1	$0{,}2T_1$	≈ -0,8	$0{,}7T_2$	T_2	≈ -3,9
T_1	$0{,}3T_1$	≈ -1,1	$0{,}6T_2$	T_2	≈ -4,3
T_1	$0{,}4T_1$	≈ -1,5	$0{,}5T_2$	T_2	≈ -4,8
T_1	$0{,}5T_1$	≈ -1,8	$0{,}4T_2$	T_2	≈ -5,4
T_1	$0{,}6T_1$	≈ -2	$0{,}3T_2$	T_2	≈ -6,4
T_1	$0{,}7T_1$	≈ -2,3	$0{,}2T_2$	T_2	≈ -7,8
T_1	$0{,}8T_1$	≈ -2,6	$0{,}1T_2$	T_2	≈ -10,4
T_1	$0{,}9T_1$	≈ -2,8	$0{,}05T_2$	T_2	≈ -13,2
T_1	T_1	≈ -3	$0{,}01T_2$	T_2	≈ -20

4.1.2. Noise Emission Classes

To note that the reference [13] chapter 3.1.6.3, discusses typical seasonal cases (daily, weekly, and monthly) and the overall results usually associated, warning that each case is unique and that sometimes certain assumptions based on preconceptions considered adequate reveal themselves wrong, after proper quantitative analysis.

According to reference [13] the main typical seasonal results, that permit characterize just L_H (higher value) or just L_L (lower value), are presented in next table (Table II).

Table II. Typical seasonal noise levels.

Higher emission		Lower emission		Global Value
Level	Typical Duration	Level	Typical Duration	
$L_H \le L_L+3$	3h	L_L	12-3=9h	≈ L_L
$L_H \ge L_L+15$	3h	L_L	12-3=9h	≈ L_H-6
$L_H > L_L$	5 days	L_L	7-5=2 days	≈ L_H
$L_H > L_L$	9 months	L_L	12-9=3 months	≈ L_H
$L_H \le L_L+3$	2 days	L_L	7-2=5 days	≈ L_L
$L_H \le L_L+3$	3 months	L_L	12-3=9 months	≈ L_L
$L_H > L_L+7$	2 days	L_L	7-2=5 days	≈ L_H-5
$L_H > L_L+9$	3 months	L_L	12-3=9 months	≈ L_H-6

According to references [4,11] the best way to determine the variations of noise will be the realization of 24 hours measurements on weekdays and on weekend, preferably near to receivers affected. However, these references do not specify the form of division of noise variations in different classes.

Having regard to the provisions of Chapter 6.5.1 of ISO 1996-2 [14], we have: "*The source operating conditions shall be divided into classes. For each class, the time variation of the sound emission from the plant shall be reasonably stationary in a stochastical sense. The variation shall be less than the variation in transmission-path attenuation due to varying weather conditions ... The time variation of the sound emission from the plant shall be determined from 5 min to 10 min Leq values ...*".

It is believed that, in the absence of other standard information, we should consider that a particular type of noise belongs to the same class if the associated variations are smaller than the variations due to weather conditions. Since according to Figure A.1 of ISO 1996-2 [14] the best value of Standard Uncertainty, due to weather conditions, is 1.5 dB, it can be considered that we have a single Noise Class if the standard uncertainty associated with different measurements (5 to 10 minutes for each measurement duration) is less than 1.5 dB. This means, in terms of standard deviation s_d and of the number n of measurements (assuming the relations of the chapter 4.2.4 of reference [15]):

$$\frac{s_d}{\sqrt{n}} < 1,5 \text{ [dB]} \quad (2)$$

For example, if we have the information that the activity has two kinds of noise, one with the duration of 1 hour and other with other duration of 1 hour, it is presented in the next graphic (Figure 1) one example of a case that, according with the previous statement and assuming 10 minutes for "each measurement" (2 hour ⇔ 12 measurements), can be simulated just with one source (just one noise class: $s_d < 1,5\sqrt{12} \approx 5,2$), and other example that must be simulated with at least two sources (at least two noise classes: $s_d >$ 5,2).

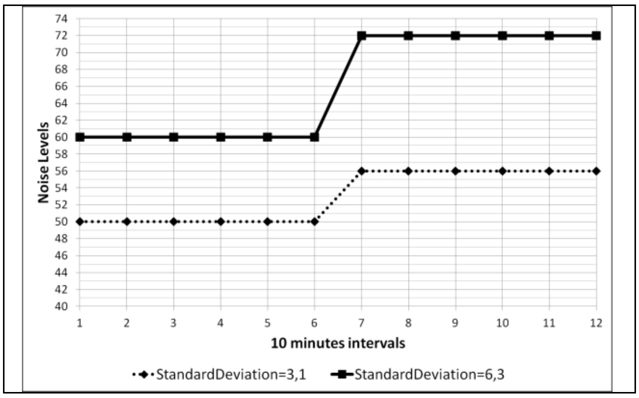

Figure 1. Examples with standard deviation higher and lower than 5,2.

4.2. Measurements around noise sources

Measurements of Sound Pressure Levels around noise sources, for characterization of Sound Power Levels associated with each Noise Class (determined in accordance with the previous subchapter), may follow, in adapted form, the provisions of ISO 8297 [16].

To note that, as stated in reference [17], at least under Strategic Noise Maps scope, is expected the necessity of using a simplified adaptation of ISO 8297 [16], namely the reference [18].

To note also that, despite the fact that ISO 8297 methodology is applicable to industrial areas, where most of equipment operates outdoors, it might be adapted to Open-air Recreational Activity.

In other cases, a more detailed characterization may be required, as noted in references [19,20].

The greater or lesser simplicity of characterization and modelling, and the method chosen, will depend primarily on the greater or lesser proximity of the receivers to the sources of noise.

Typically a greater proximity of receivers implies the need for characterization and modelling less streamlined and less proximity allows simplified characterization and modelling.

Can also be used the called Relational Method, according to references [13,21], or the called Inverse Noise Modelling Method, according to reference [22]. In general, these methods make use of the emission, propagation and reception relations established in ISO 9613-2 [23], to construct a system of equations and determine, by solving the system of equations, the unknown values involved (usually the Sound Power Levels).

Given the particular importance and use of the ISO 8297 [16], are analyzed in the next chapter its main limitations.

4.2.1. Main Limitations of ISO 8297

The following are the main limitations of ISO 8297 [16]:

- Area: The Step 4 of ISO 8297 (section 10.4) defines a parallelepiped volume above ground witch surface area must be logarithmic "add" to the Sound Pressure Level in order to calculate the Sound Power Level. This approach means, in on one hand, the assumption of an acoustic reflector ground (not considering the imaginary volume below the ground), which may not be the case in many practical situations (possibility of a typical error of 3 dB in the calculation of the Sound Power Level), and secondly the parallelepiped surface area may deviate more or less from the hemisphere surface area that should be used to determine Sound Power Level of Point Source, depending on the horizontal and vertical dimensions in question (especially for horizontal dimensions higher than the 320 m limit established in the standard, and for not very lofty heights of measurement that do not comply with section 9.3 of the standard (which sometimes may be required), may occur a significant difference in areas that may lead to significantly erroneous determination of the Sound Power Level concerned).
- Proximity Correction: The Step 5 of ISO 8297 (section 10.5) defines an expression to correct the Sound Pressure Level measured at a distance less than twice the largest dimension of the source that may no longer be valid for higher dimensions that may be necessary to characterize (largest dimension of source higher than 320 m), as usually occurs in strategic noise mapping.
- Atmospheric attenuation: The values of Atmospheric Absorption Factors shown in Step 7 of the ISO 8297 (section 10.7) are based on ISO 3891 [24], which is a relatively old standard (1978) (note that new standard [25] does not have Atmospheric Absorption Factors), where the Factors considered are similar to those considered in ISO 9613-1 [26] (base standard of the European Interim method for Industries [23]), with the exception of 8000 Hz octave band, where the attenuation factors may be significantly different, and may subsequently lead to outcomes of Sound Power Level proportionally different.

For the reasons given is advised that the determination of the Sound Power Level through ISO 8297 [16] be accompanied by an auxiliary calculation of Correction Terms of passage of Sound Pressure Levels for Sound Power Levels, by using a software of outside acoustic modelling, using a prediction method appropriate (typically the European Interim method ISO 9613-2 [23]) instead of using the formulas of Steps 4, 5 and 7 of ISO 8297 [16]. So, such auxiliary calculation permit exceed the limit of 320 m for the largest horizontal dimension of the sound source and to enable the characterization of non-horizontal sound sources, such as the typical case of vertical sources in the buildings façades.

4.2.2. Example of software auxiliary calculation for ISO 8297

Locating correctly the Source in the software, and the Measurement Points, and given a general value of, e.g., 100 dB for L_w in the model, the foreseen values on the Measurement Points will be calculated with the following general equation (based in equations (3) and (6) of ISO 9613-2 [23]):

$$L_{fT} = L_w + D_c - A(DW) + C_{met} \text{ [dB]} \quad (3)$$

$$L_{fT} = 100 + D_c - A(DW) + C_{met} \text{ [dB]} \quad (4)$$

where L_{fT} is the equivalent continuous octave-band sound pressure level at a receiver location, D_c is the directivity correction, in decibels (for an omnidirectional point source radiating in free space we have $D_c = 0$), $A(DW)$ is the attenuation, in decibels, that occurs during propagation from the point sound source to the receiver for downwind conditions, and C_{met} is the Meteorological Correction.

Assuming that we have a Directivity value (D_c), a Attenuation value ($A(DW)$) and a Meteorological Correction (C_{met}) in the software model that represents correctly the reality of the measurement (L_{wR}), the measurement results (L_p) are given by the following expression:

$$L_p = L_{wR} + D_c - A(DW) + C_{met} \text{ [dB]} \quad (5)$$

So we can write:

$$L_{fT} - L_p = 100 - L_{wR} \text{ [dB]} \quad (6)$$

$$L_{wR} = 100 + L_p - L_{fT} \text{ [dB]} \quad (7)$$

For example, if we measured in a point around the facility 40 dB, in a specific frequency band, and if we simulate this source with L_w = 100 dB and the result in the model related point is, e.g., 50 dB, the "real" L_{wR}, at this frequency band, is obtained from the following equation:

$$L_{wR} = 100 + 40 - 50 = 90 \text{ [dB]} \quad (8)$$

4.3. Measurements inside buildings

For Recreational Activities in Semi-open Buildings or Closed Buildings, may be appropriate the characterization of the sound pressure levels inside, not only to meet these values and compare them with good practice limits, for the protection of workers and audience [27], but also with the purpose of characterizing the Façade Sound Emission of these buildings, according to EN 12354-4 [28].

A practical example of the use of this methodology is located in reference [11], considering that the sound radiation occurs primarily through open doors and windows. The general equation applicable for determination of Sound Power Level corresponds to the combination of equations (2) and (3) of EN 12354-4 [28], i.e.:

$$L_w = L_{p,in} + C_d - R' + 10\log(\frac{S}{S_0}) \text{ [dB]} \quad (9)$$

$$R' = -10\log\left[\sum_{i=1}^{m}\left(\frac{S_i}{S_0}10^{\frac{-R_i}{10}}\right) + \sum_{i=m+1}^{m+n}\left(\frac{A_0}{S}10^{\frac{-D_{n,e,i}}{10}}\right)\right] \text{ [dB]} \quad (10)$$

Where prevail propagation openings (Recreational Activities in Semi-open Buildings) R' tends to zero [11]. Where not prevail propagation openings (Recreational Activities in Closed Buildings) will be necessary, using this methodology, know the applicable values of R', or perform measurements of sound pressure levels inside-outside (insulation measurement), for infer the values of R'. For both cases, an extra effort will be needed for getting representative indoor noise levels of recreational activities, including the development of innovative methodologies for measuring during full capacity operations.

4.4. Typical Database

In line with the provisions of the GPG [2], may be used, for Strategic Noise Maps, a less precise method, which makes use of default values for typical situations. In this case it is considered of particular interest the values provided in VDI Guide 3770 [29]. Are presented in Table III examples of default values given in VDI 3770.

In the particular case of water sports, it is also considered of particular interest the limit values of the reference [30] (Directive 2003/44/EC), presented in Table IV. For amusement park attractions, the sound level data are given in reference [31].

It is also highly relevant the given sound power data of human communication noises, useful for pedestrian streets and touristic areas, and some references of emission level of discos, open-air concerts and other facilities with music, applicable to noise mapping of this type of activities.

Table III. Examples of VDI 3770 default values .

Source in Recreational Parks	Sound Power Level L_{WA}	Source in Recreational Parks	Sound Power Level L_{WA}
Music express	98	White water ride	89
Chairoplane	100	Saurian (loudspeaker)	91
Roller coaster	102 to 107	Swing boat	102
Stage (presenter)	105	Circus (children)	99

Table IV. Directive 2003/44/EC limit values.

Single engine power in kW	Maximum Sound Pressure Level L_{pASmax}
$P \leq 10$	67
$10 < P \leq 40$	72
$P > 40$	75

5. Conclusions

It is easy to understand, that in certain cases, assume particular relevance the inclusion of Recreational Activities on Strategic Noise Maps, although this kind of noise source is not mandatory to include in Strategic Noise Maps. The authors wish that this paper could help those looking to include Recreational Activities on Noise Maps and could contribute also, in its proper measure, for the path that must be drawn in the direction of future harmonization – one of the objectives of Directive 2002/49/EC [1] – to use the most effective and appropriate methods for characterization and modelling of Recreational Activities.

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