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The Acoustic Land Register of Umbria Region

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The great variety, the large number and the extremely widespread diffusion of noise sources in urban areas make the knowledge of the acoustic phenomenon in its various aspects extremely complex. It is difficult, for example, to characterize the specific noise emissions of the various sources, to evaluate their impact, to esteem the exposed population. The aim of the research described in the paper was to set up a methodology for a computerized Acoustic Land Register of the Umbria region. The register is both an acquisition instrument and a support for actions in the field of noise prevention and protection. The research work, which is the result of a collaboration between the University of Perugia and Arpa Umbria (the Regional Environmental Protection Agency), focused on the implementation of a code based on the environmental model DPSIR (Drivers, Pressure, State, Impact, Responses), proposed by the EEA (European Environmental Agency). The code allows the input, processing and consultation of the necessary data to carry out an acoustic analysis of a territory. Thanks to the employment of specific editing, it allows to summarize the punctual acoustic information through graphical representations and statistical analysis, so to identify critical areas as far as noise pollution. The reliability and functionality of this acoustic land register was tested in five municipalities of the Region, characterized by different noise sources and critical areas. The use of the code allowed to describe accurately the acoustical situation, to highlight critical points and to propose noise mitigation interventions.

1 Introduction

Noise is a kind of environmental pollution that is certainly worth of great notice. The diffusion of noise sources in industrial countries and their wide range make this phenomenon difficult to understand from different points of view: its emission features from the specific sources, the environmental impact evaluation and the calculation of the exposed population. Unlike other pollution sources, it is difficult to create information systems able to process data useful for law-makers, for local administrators and for the control institutions working on this matter, in order to detect critical situations, finalise control actions and choose mitigation strategies. Taking into account these problems, this research aims at setting an information system, based on a model of environmental analysis named DPSIR, and at creating a computerized Acoustic Land Register (ALR). This system should be a useful instrument for the description of acoustics in Umbria and, at the same time, to give support for the detection of the acoustic problems in this area. This research also reports a short description of the Acoustic Land Register structure and of the method used to study the acoustic problems in the area in subject, also proposing a methodology to calculate a priority index concerning critical acoustical situations.

2 The DPSIR model and the Acoustic Land Register of the Umbria region

The DPSIR (Drivers-Pressure-State-Impact-Responses) analysis model, developed within the EEA (European Environmental Agency) and EUROSTAT on the basis of the pre-existing PSR (Pressure-State-Response) scheme, is widely used by the OECD [1]. It is a general analysis scheme able to state a systematic and cyclic relationship between the definition of the environment quality status and the description of the events and the influencing factors, including processes and interventions carried out by private and public institutions (Fig. 1).

The DPSIR is a general instrument that can be used to survey all environment problems; it has been, therefore, revised to be adapted to environmental acoustics. The result was the NOISE [2] model, developed by the Department of Industrial Engineering of the University of Perugia. On the basis of this

model, a computerized system was created [3], able to process data concerning the main acoustic sources on the area, named Acoustic Land Register.

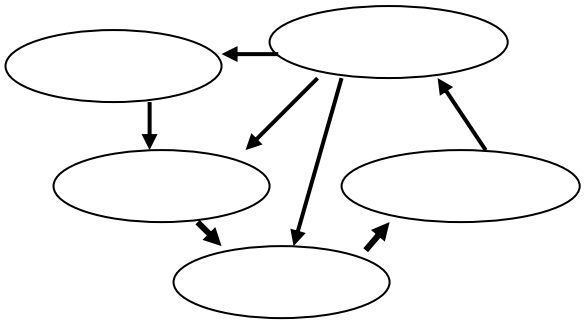

Figure 1 DPSIR layout

2.1 The Acoustic Land Register structure and the indicators choice

The Acoustic Land Register was obtained thanks to a software able to process and give access to a high number of data. The Access® (Windows Office) system seemed to be the most suitable one because it can be used together with special editing systems in Visual Basic and, at the same time, it is easy to use.

The database has been articulated in order to have two separated but interacting sections:

– the section reserved to the data input (accessible only by operators);
– the section reserved to the consultation (accessible by the institutions concerned and also by the citizens).

2.2 Data input

The compilation of the sources land register is articulated in three main groups, as shown in Figure 2, which are:

– production activities (industries , crafts);
– civil services (services, trade, recreational activities);
– mobility (roads, railways).

Each source situated in the examined area belonging to one of these three groups is input in the database by means of a classification code and described by a series of parameters contained in the DPSIR model.

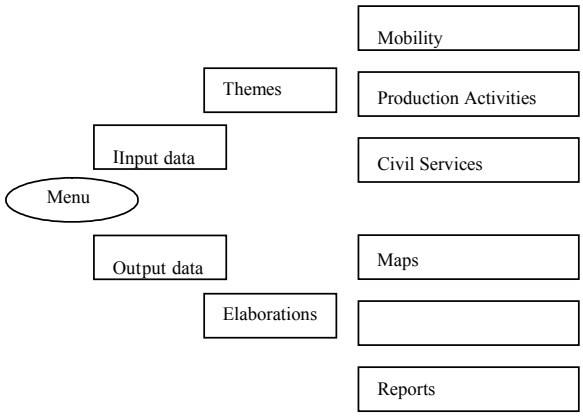

Figure 2: Structure of the Acoustic Land Register

Figure 3 shows an example of a schedule related to the transportation section concerning roads and streets.

The operator can fill in all the fields that describe this issue taking into consideration the area and the acoustic characteristics. Some of the indicators describing the various sources are reported in table 1.

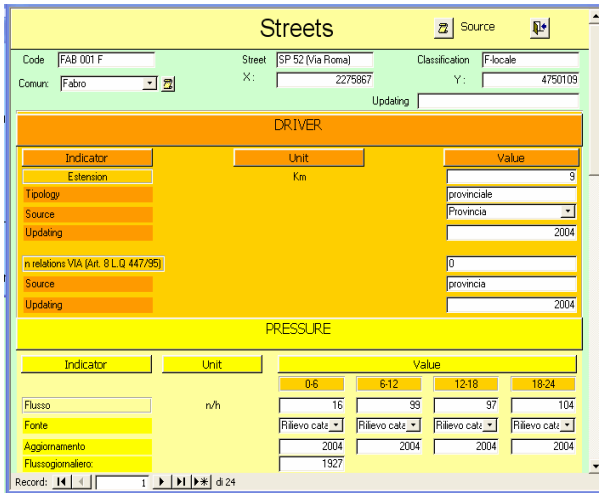

Figure 3: Data input for streets

2.3 Access to data

Many more people can have access to the second structure of the database which allows to analyse the area, both regarding single sources under study and the municipality area alike. This analysis takes place

through suitable synthesis parameters related to the different groups. Indeed, the study of the area was carried out on the basis of some algorithms allowing to synthesize, representatively, the data concerning each source into values able to describe satisfactorily the acoustic situation of a given area.

Table 1: Indicators chosen for the Acoustic Land Register

	Indicators	
	Mobility- Streets	**Production activities - Industries**
D	- Net extention - Tipology	- Surface - Tipology
P	- Traffic Flow - Tipology of Flow	- Electric Power Installed - Number of workers
S	- People in pertinence area - LeqA D/N	- % worker in Lep class - LeqA D/N
I	- N° of Complaints - N° of Petitions	- N° of Complaints - N° of Petitions
R	- N° of mitigation actions - N° of Monitorings	- N° of mitigation actions - N ° of Monitorings
	Civil Services	**Production activities - Crafts**
D	-Surface -Sensible receivers	- Surface - Tipology
P	-Number of users	- Number of workers
S	- LeqA D/N	- % Workers in Lep class - LeqA D/N
I	- N° of Complaints - N° of Petitions	- N° of Complaints - N° of Petitions
R	- N° of mitigation actions - N° of Monitorings	- N° of mitigation actions - N ° of Monitorings

Moreover, printed geographical references were provided for each acoustic source under study and a special set of symbols described its main features (Figure 4).

In order to check the technical and the economical suitability, the computerized structure of the Acoustic Land Register was tested on 5 municipalities taken as samples of Umbria region: two municipalities whose population was below 5,000 inhabitants (Piegaro, Fabro), two which ranged from 5,000 to 20,000 inhabitants (Trevi, Narni) and one with more than 20,000 inhabitants (Gubbio).

In order to understand the compilation status of the Acoustic Land Register, Table 2 shows the number of the sources under study assigned to the three main groups with reference to each examined municipality.

24 road and railway infrastructures were input into the Acoustic Land Register, as well as 335 production activities and 36 civil activities. The filling in of the ALR is continually under progress.

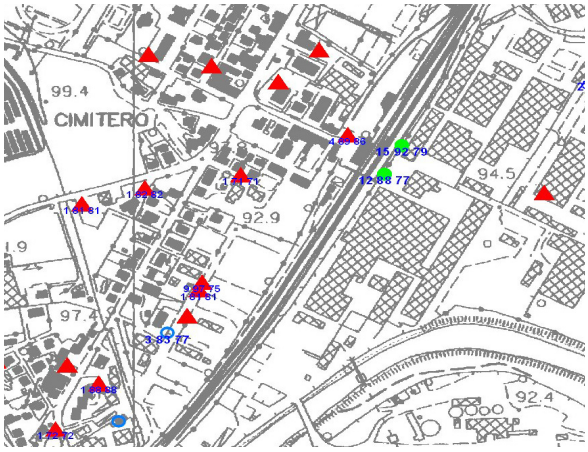

Figure 4: Geographical references the Acoustic Land Register

3 Individuation of the territory acoustic problems

The compilation of the Computerized Acoustic Land Register allows to obtain information that can be used as input in a calculation model aiming at determining the most critical areas from the acoustic point of view. On the basis of the data given by the Acoustic Land Register, it is possible to set a method allowing to obtain an "I" criticality index related to the examined area. In order to define this index, data concerning the exposed population (Pe) and the noise sources (transport infrastructure (T), industrial (AP) and service activities (S)) were taken into consideration. Each one of these parameters was evaluated in a given area whose surface was equal to 1 km^2. Therefore the "I" index can be obtained by means of the following relation according to the mentioned parameters (eq. 1):

$$I = f(P_e, AP, T, S, A) \quad (1)$$

3.1 Exposed population (P_e)

This data is important not only for the evaluation of the population's health, but also for its remarkable social

and economical consequences. The municipal registry of births, marriages and deaths supplies, with high accuracy, the distribution of the exposed population all over the area. This registry actually shows the number of people living in each building and, even, in each apartment. Regarding the population exposed to noise, it should be enough to know the number of people living in each building. This data can be obtained in form of:

– exact values, that is, as numerical values obtained by studying the registry of the births, marriages and deaths in a given area;
– values estimated through a careful analysis of a given area.

Table 2. Compilation status of the Acoustic Land Register (number of sources under study)

Municipality	Habitants	Thematic	Number
Fabro	**2.796**	Mobility	**8**
		Production Activities	**41**
		Service Activities	**12**
Piegaro	**3.626**	Mobility	**3**
		Production Activities	**16**
		Service Activities	**13**
Trevi	**7.773**	Mobility	**5**
		Production Activities	**22**
		Service Activities	**1**
Narni	**19.725**	Mobility	**8**
		Production Activities	**199**
		Service Activities	**14**
Gubbio	**30.453**	Mobility	**12**
		Production Activities	**57**
		Service Activities	**14**

In general, the evaluation can be carried out starting from the data concerning the number of people living in an area of the Municipality under study. This value can be extrapolated from the General Town Plan of the studied Municipality, from the section concerning the subdivision of the area into macro-areas (in conformity with the decree no. 1444, April 1968). Starting from the number of people resident in each macro-area, it is possible to give a rough estimate of the people living in the selected area and, on the basis of special calculations, of the people living in each building.

3.2 Noise sources (AP), (T), (S).

Regarding the punctual acoustic sources, thanks to the data collected in the Acoustic Land Register, it is possible to calculate the number and the types of acoustic sources in the area under study and their output levels [4],[5]. Afterwards, a calculation method was set allowing to correlate these values with the data concerning the exposed population. This calculation allows to obtain a criticality index related to industry, craft and services activities.

Concerning linear sources and, in order to determine the criticality index, the data obtained from the Acoustic Land Register and from the town plan in conformity with the European Directive no. 2002/49/CE [6] were used, together with the data related to the exposed population.

The sum of the two indexes, duly corrected according to the amount of the sensible receptors situated in the area under study, allowed to determine a global criticality index (I_c). The index was calculated in daytime ($I_{c,d}$) and in nightime ($I_{c,n}$)

3.3 Methodology

Equation 2 explains the dependence of the acoustic criticality index I from the various parameters:

$$I = \frac{AP(P_e) + M(P_e) + S(P_e)}{A} + K \qquad (2)$$

where:

AP is the acoustic criticality index due to production activities

$$AP = \sum_i \alpha_i \cdot Pe_i \qquad (3)$$

where:

α_i is a coefficient depending on the emission level of the i-th production activity inside the examined Area A (table 3).

Table 3: values of coefficient α in eq. 3

	Emission level		
	L_e<55dBA	55<L_e<70dBA	L_e>70dBA
α	5	10	15

Pe_i is the population resident in the pertinence area of the i-th source

M is the acoustic criticality index due to transportation infrastructures:

$$M = \sum_i \alpha_i \cdot Pe_i \qquad (4)$$

S is the acoustics criticality index of Service Activities :

$$S = \sum_i \alpha_i \cdot U_i \qquad (5)$$

where:

U_i is a value in function of the users of i-th civil activity ;

K is correction factor of the I index to take into account the presence of sensibile receptor :

$$K = \sum_i \beta_i \cdot U_i \qquad (6)$$

with:

β_i is the weight of i-th sensible receptor (table 4)

Table 4: values of coefficient β in eq. 6

β_i	Typology of sensibile receptor
15	Hospitals - Clinics
10	Schools - Churches
5	Cemeteries – Parks

The acoustic criticality index has been evaluated separately in daytime ($I_{,d}$) and night time ($I_{,n}$), since the noise limits are different in the different periods.

Finally, the obtained index was normalized on a base of 100, both for day and night time, so that the sum of the two normalized indexes varies from 0 to 200. Four groups with different acoustic criticality were defined:

1. Low criticality (0-50) ;
2. Medium-low criticality (50-100);
3. Medium-high criticality (100-150);
4. High criticality (150-200).

4 Results

The proposed method was applied to the five mentioned different areas included in the Municipality in order to understand its simplicity and the correct correspondence between the obtained index and the acoustic criticality level as it was actually perceived.

The same method was applied in some areas of the Municipality of Perugia, whose criticalities are known, since they had been already studied when planning the acoustic zoning, so that it was possible to adjust accordingly the evaluation scale of the criticality level.

Table 5 shows the results of the analysis.

Table 5: Acoustic Criticality Index

Municipality	**I** ($I_{,d} + I_{,n}$)	**Criticality**	
Trevi	**14**	Low	
Piegaro	**15**	Low	
Gubbio	**49**	Low	
Narni	**102**	Medium-high criticality	
Fabro	**111**	Medium-high criticality	
Perugia	**180**	High	

The study carried out on the application of the above described method on the groups with the acoustic criticality allowed to ascertain the correct correspondence with the level of acoustic discomfort that can be objectively found in the same area.

5 Conclusions

The main problems concerning the environmental noise pollution are surely connected with the difficulty of placing at the disposal of the local administrations and the controlling institutions expert systems able to detect the acoustic criticalities in an area, to check and mitigate them.

This activity was aimed at creating a Computerized Acoustic Land Register easy to be implemented and able to process the acoustic information arising from the area. The Land Register, based on the DPSIR environmental model, was implemented on Access; various indicators were chosen to describe from an acoustical point of view the territory of a municipality. The code was filled in for five different municipalities of the Umbria Region, considered representative of the various realities of the region.

Furthermore, a methodology to evaluate the acoustical criticality of an area, basing on the information contained in the Land Register, was proposed. The method was tested in the five municipalities and also in the city of Perugia, and it gave encouraging results.

The future development of research will focus on the spread of such method to others municipalities of Umbria region how the easy application of such methodology allows to the Acoustic Land Register to became a powerful tool for territory administration.

6 References

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[6] Directive 2002/49/EC of the European parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.