Location of the areas where the limits provided for by the Italian regulations are exceeded along the one thousand kilometers of the Lombardia State Roads

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This paper deals with the working out of a method suitable to locate the critical areas from an acoustic point of view inside the pertinence zones of the roads (250 meters from both sides). The sizes of the pertinent belts and their boundaries have been recently defined and regulated through a specific national law. We have applied our method to about one thousand kilometres of major roads managed by ANAS in Lombardia. The daily average traffic flow on this typology of roads ranges from a minimum of 2000 to a maximum of 60000 vehicles per day. By an upgrading of a Geographic Information System (GIS) we have been able to show, manage, process and file in digital georeferenced information concerning road layout, administrative borders, contour lines, ground typology as well as location of buildings or of any artefact. The procedure is based on the coupling a GIS with an acoustics simulation model. This has allowed to estimate the sound levels of the monitored roads and then to calculate the sound propagation in the environment. In order to characterize the noise sources in the prediction software it has been necessary to estimate in every significant section of the streets the day and night average fluxes of vehicles, the vehicle typology and their average velocity. This study started from a statistical analysis of the experimental data obtained by sound measurements and by counting the vehicle fluxes. As a result, we have obtained on a GIS the acoustics map of the whole Lombardia road network with information on where the noise limits classes are exceeded.

1 Introduction

The present work shows the results of the study carried out by Dipartimento di Scienze dell'Ambiente e del Territorio (DISAT) to identify the critical areas within the acoustical road boundaries of the public road network managed by ANAS in the Lombardia Region. The road network under study reaches an overall length of approximately 1000 km, crosses 10 districts and 352 towns. The type of roads are different and include either roads with two carriageways and three lanes for each way and roads with one carriageway and one lane for each way. The interested territory is quite heterogeneous and includes densely populated urban areas, flat rural areas and mountain areas.

The work was carried out with a GIS *(Geographic Information System)* and an acoustics numerical model *(Mithra 5.1.12, 01dB-Stell,CSTB).*

The work is characterized by the following phases:

- Basic data acquisition
- insertion of data into the GIS and the numerical model
- acquisition of the sound level data
- calibration of the numerical model
- measurement and estimate of vehicular fluxes
- estimate of noise levels with horizontal and frontal maps
- identification of critical areas.

The results obtained during the calibration of the model indicate the behaviour of the predictive model, thus its good reliability in particular conditions of traffic and sound propagation.

2 Identification of the critical areas

The integrated use of both GIS and the numerical model allowed an estimate of noise levels in wide non-easily monitored areas and the geo-referenced representation of such levels along with the identification of the critical areas. Such areas are labelled with three different range levels exceeding the enforced threshold (0-2.5, 2.5-5 and >5dB).

The procedure of characterization followed these phases:

- creation of a georeferenced database in order to manage and process the information regarding the territory (administrative boundaries, road network, acoustically influenced ranges) and to produce elements useful to characterize in the numerical model the environment where the sound propagates (height contours, land use, buildings).
- Field measurements (60 stations) performed by ARPA Lombardia in order to monitor the noise level and to evaluate the reliability of the numerical model.
- Measurement and estimate of the traffic fluxes and composition, expressed as hourly mean (vehicles/hour) during reference periods in day time conditions (06:00 to 22:00) and night time conditions (22:00 to 06:00).
- Calibration of the forecast model, i.e. analysis of the deviations between simulated and measured noise levels, in order to evaluate the reliability of the simulation tool.
- Estimate of the noise levels (Leq [dB(A)]) with the aid of the simulation software:

- characterization of the source through input data regarding the mean hourly vehicular flux, the road tarmac, the speed, the percentage of heavy vehicles and the kind of traffic flow (smooth, interrupted or accelerated);
- simulation of the environmental sound propagation characteristics through data of orography, topography and land use;
- model calibration through experimental data;
- computation of the expected noise levels at the receptors;
- plotting the acoustical maps for the reference periods during nighttime and daytime.
- Importing the acoustical maps into the GIS in order to compare the estimated values with the threshold values according to the Italian rules within the acoustically affected zones and in order to obtain a layer of the critical areas.

3 Measurement campaign

The public road network maintained by ANAS in the Regione Lombardia was the object of a noise level measurement campaign carried out by the district departments of ARPA Lombardia.

The studied roads, 28 overall, display different typologies according to their functions and characteristics. The high variability of the characteristics of both the road network and the sound propagation made necessary a selection of the measurement sites according to the following criteria:

- environmental characteristics: in order to calibrate the numerical model in different environmental situations, the measurement sites were diversified according to density of urbanization (densely inhabited centres, building on one side of the road only, measurements on facades, open field measurements), land use (adsorbing terrain, reflecting surfaces) and orography of the area;
- analysis of the more exposed areas, usually included in the first 100 m belt off the carriageway for this kind of roads
- functional typology of the road (by-pass thoroughfares, inter-urban link roads, urban roads) and physical characteristics (number of lanes and carriageways**,** kind of tarmac, slope)
- homogeneous distribution over the regional territory: an additional criterion for locating the measurement sites was the desire to obtain information about all different zones of the region considering, in particular, all public roads.

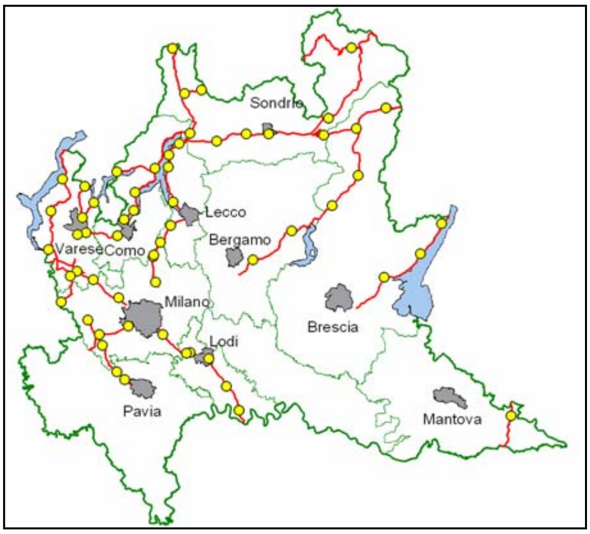

Figure 1: measurements sites distributions

Measurements have been conducted at several sites by using mobile noise monitoring terminals. Each one, set up for a long period not assisted monitoring, has been located at 3 up to 60 meters from the lane border.

To standardize the data acquisition procedure over the entire monitored area, a particular measurement protocol has been introduced by filling a proper form.

Taking into account a monitoring period ranging from 2 to 4 days, depending on the site, the following acoustical data have been recorded:

- 30 sec-interval A Weighted Equivalent Level Time History (L_{Aeq} 30sec)

- 1 hour interval A Weighted Equivalent Level (L_{Aeq})
- Hourly statistical index as L5, L10, L50, L90, L95

For every site, while discerning cars from trucks or motorcycles, the hourly vehicles flow was recorded with the aim to compare the measurement data with the output simulation model data.

Additionally each measurement form reports the average transit speed and the type of vehicle flow since the software can distinguish three types of traffic flow: smooth, interrupted and accelerating.

These information allow the validation of the simulation model for a number of real scenarios equal to the number of measurements sites. In these simulated scenarios the source (the road), the propagation's conditions and a receiver in the position of the measurement instrument are reproduced. Regarding the hourly measurements the validation shows a good reliability of the model (see fig. 2) with an average error of +1,2 dB and a standard deviation of about 1.5 dB.

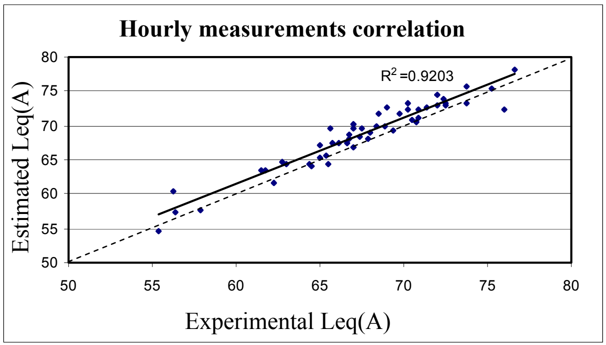

Figure 2: experimental versus estimated data

Using the average day/night vehicular flux as input (see paragraph 5), a check about the noise level measured during the day and night reference period and those estimated by the model was obtained. The overestimate by the validation procedure show a security range of error adopts in the valuation of the exposure noise level.

4 Digitalization

In order to carry out the projects aimed at calibrating the simulation model the following data have been introduced or implemented in the model:

a) Road's location and dimensional characterization
The roads provided with georeference data have been introduced in the simulation software through GIS converting the road's linear themes (file *.shp) to CAD formatted file (file *.dxf). Then the data relevant to the structural characteristics of the roads have been implemented adding the number of carriageways, the number of lanes for each carriageway, the carriageway width, the width of the emergency lanes, the width of the median strip and the direction of traffic.

b) Characterization of the noise source
The sound power level of the source is determined by the parameters relevant to the vehicular traffic and to the covering of the State roads (simple or drainage asphalt). This information concerns the traffic fluxes referred to the night or day time (number of vehicles per hour), the percentage of heavy vehicles, the average velocity and the traffic flux condition (smooth, interrupted or accelerated).

c) Buildings
Buildings have been reproduced by transferring manually into the GIS the polygonal digitalized themes. The standard values of the model have been attributed to the buildings main parameters (number of floors, floors height, ground floor height, reflecting and diffracting vertical surfaces): ground floor height 2.5 meters; height of each floor 3.5 meters, reflecting and diffracting walls.

d) Orography
The reproduction of the surface altitudes in the simulation software has been performed by introducing contour lines. The level lines, at 10 meters spacing, have been obtained from the GIS.

e) Ground covering
The information on the typology of the ground covering has been introduced by the polygonal theme relevant to the ground utilization. The area which are indicated as forested area have been introduced in the model as adsorbing surfaces (*ground factor* G=1. The *ground factor* G is a parameter relevant to the ground absorption and it affects the amount of reflected energy from the surface under consideration). A *ground factor* 0,68 has been attributed to the remaining area, as this is the standard value automatically attributed by the model; it correspond to the covering of a grassland.

5 Vehicular flow's estimate

The number and the kind of vehicles are the main parameters characterizing a road as a noise source. In order to define such parameters data from the following different sources have been utilized:

- records of the 'Traffic and Infrastrucures of the Lombardy Region' (multi-weekly data 2003-2004);
- traffic measurements from INEMAR project (ARPA Lombardia);

- weekly measurements carried out by the Laboratorio di Fisica Ambientale (DISAT) by means of magnetic plates;
- vehicle hourly counts by ARPA Lombardia.

By utilizing the counts over a long period of time, the percentage distribution of the daily traffic on 13 census sections have been obtained.
The results have been obtained by means of the following procedure:

- acquisition of the hourly fluxes on different days and in different periods of the year;
- calculation on the data sample of the hourly fluxes averaged on different periods of the year for the seven days of the week;
- from averages computed in different days, the behaviour of the hourly fluxes on weekdays and holidays has been calculated for an hypothetical average weekday and holiday. Subsequently on this behaviour has been re-calculated and expressed as hourly percentage flux with reference to the daily total (from 00.00 to 24.00);
- a daily percentage distribution has been obtained by combining the results from weekdays and holidays.

We have utilized this distribution as a characteristic hourly flux distribution for each census section as requested by the Italian regulations. Actually the fluxes averaged on a weekly basis are requested by the regulations in order to evaluate the noise produced by a road. Looking at the weekly average distribution it is evident a strong increase in the evening and night results due to the impact of holidays. This result has allowed us to estimate the vehicular fluxes with a precautionary method (instead of taking into account the weekdays fluxes only) and therefore to estimate the noise of night hours (night time being the critical time for the limitations overcoming).

The traffic percentage distribution plots have allowed us to allocate the average day and night values of the vehicular fluxes starting from the hourly experimental counting performed by ARPA on some of the road under consideration. From the counted number of vehicles within a fixed period, if the percentage with respect to the total number is known, it is possible to get the total number of daily transits and consequently, if the respective percentages are known, the number of passing vehicles during night and day can be obtained. Consequently the hourly fluxes, for day time and night time, can be easily obtained by dividing the total number of vehicles by the number of hours.

As the availability of direct data was limited to just some census sections, we have drawn a standard distribution graph (fig.3) that has been obtained as an average on a weekly basis of the results of the road stretches under consideration. This graph is used as a reference in order to allocate the flows to the roads that have not been directly monitored.

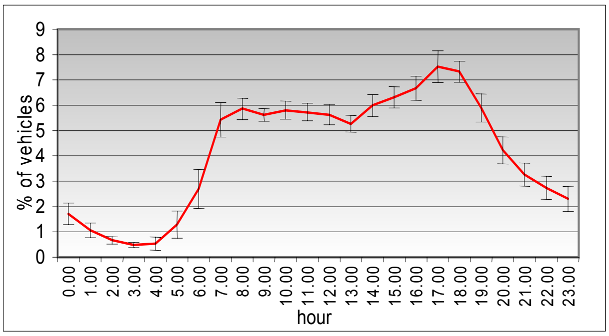

Figure 3: standard distribution of weekly vehicular flow

6 Results

The noise level mapping in Leq(A) has been performed in two different scenarios according to the time periods considered by the regulations: day time (06:00 am – 10:00 pm) and night time (10:00 pm – 06:00 am).

The output gives two kind of information collected on two meshes of points: *horizontal maps*, which provide the noise level at a height 4 meters above the ground and *front maps* which provide the estimated noise levels at receptors homogeneously distributed on the front of the buildings.

By superimposing the acoustic horizontal maps and the acoustical road boundaries we have been able to produce a new layer of information, subdivided into three ranges, relevant to the critical areas only, that is the areas where the noise is expected to exceed the threshold levels. In Figure 4 a section of the road under consideration is reported with emphasis both on critical areas and on the level of surpassing the allowed limits.

The front maps transferred on GIS have been processed in order to identify for each building the highest noise level points: such levels have been then subdivided in three ranges according to the amount of surpassing as well as utilized for comparison with the limits imposed by regulations. By means of the information on the noise exceeding for each building it is possible to evaluate the actual level of acoustic pollution for each area and consequently to plan a suitable reclamation work. Figure 5 shows the section of a road where for each building the point of highest surpassing is emphasized.
The extent of the area where the surpassing of the prescribed limits has been evaluated depends mostly on the kind of road under consideration and from the related number of overexposed receptors when the road is crossing some built-up area. The total length of the sections where a noise reduction action is planned has been estimated.

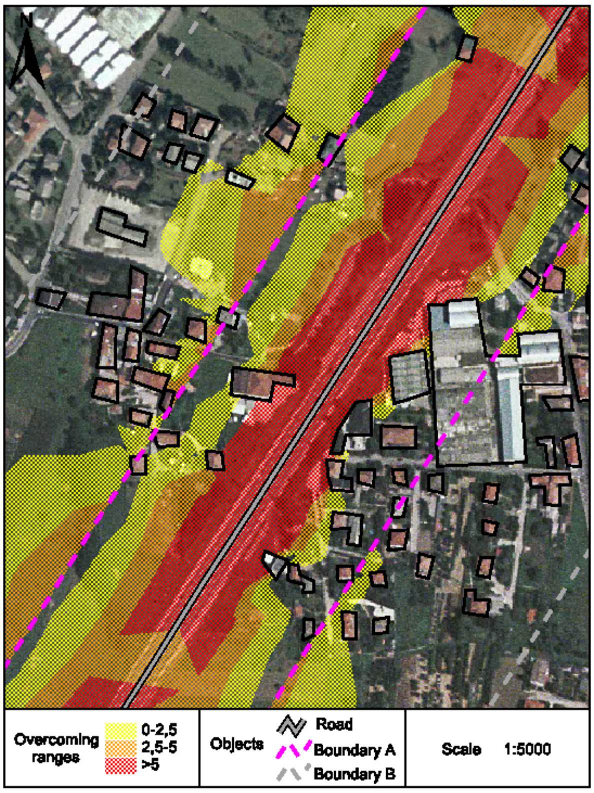

Figure 4: critical areas

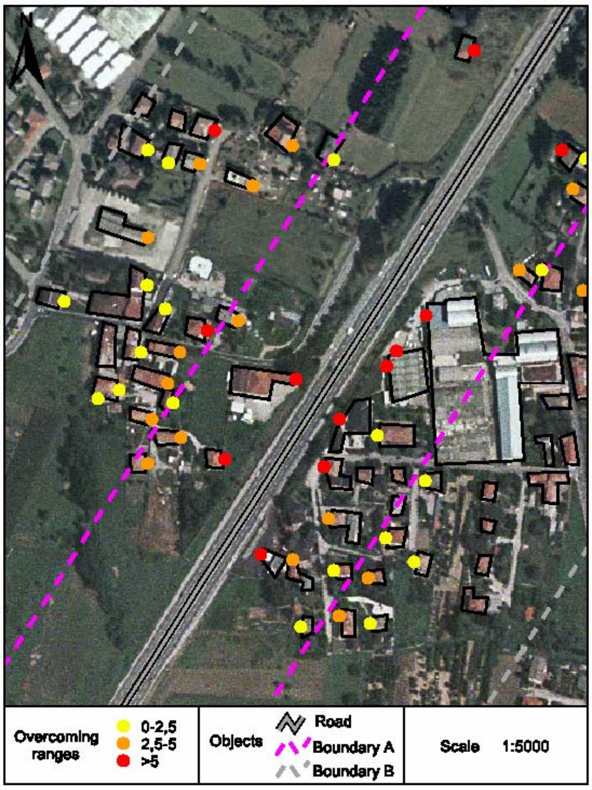

Figure 5: points of higher overcoming

The kilometers where a noise reduction action is planned is reported for each road section in the following table (Table 1). The sections we have recognized are those where there are receivers with a noise level exceeding at least 5 dB the limits imposed by the Italian regulations. As it can be noticed it is necessary to plan an action for the redevelopment for almost the 29% of the whole road system.

Table 1: noise reduction plans

ROAD	Total length (Km)	Required plan of action	
		Km	%
SS9	57,50	8,57	14,9
SS12	20,70	9,90	47,8
SS33	32,40	22,03	68,0
SS36	137,40	34,57	25,2
SS37	10,00	2,81	28,1
SS38	125,70	38,60	30,7
SS39	29,50	2,10	7,1
SS42	129,60	29,52	22,8
SS45B	60,80	10,15	16,7
SS233	17,90	2,24	12,5
SS237	4,60	0,00	0,0
SS301	35,70	4,09	11,5
SS336	20,50	5,81	28,3
SS340	53,00	24,19	45,6
SS340D	28,30	5,71	20,2
SS341	13,30	5,63	42,3
SS342	21,20	13,40	63,2
SS344	11,80	5,05	42,8
SS394	47,00	20,03	42,6
SS494	17,10	9,34	54,6
SS526	30,10	6,31	21,0
SS629	19,50	8,43	43,2
Tg. Lodi	6,20	0,00	0,0
RAA7	10,40	0,09	0,9
RA Como	3,20	1,95	60,9
RA VA	4,60	2,34	50,9
Tg. VA	3,70	0,10	2,7
TOTAL	951,70	272,96	28,7

References

[1] ESRI – *ArcView GIS User's Manual* – 1996

[2] 01 dB, CSTB – *Mithra 5.1.12 Technical Manual* – November 2003

[3] *Decreto del Presidente del Consiglio dei Ministri* – 16 Marzo 2004

[4] *Decreto del Ministero dell'Ambiente* – 29 Novembre 2000

[5] *Decreto del Presidente della Repubblica* – 30 Marzo 2004