Noise mapping of major roads in Milan District

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The paper deals with noise map calculation, according to the first deadline of the END (Environmental Noise Directive, 2002/49/EC), for Milan District major roads. The roads with more than six million vehicles passages per year have been estimated to cover 405 km out of 1090 km total. Noise emission has been calculated from peak hour flow data for each segment of the whole road network and from some local traffic direct measurements. A statistical method to assign mean flow values to each road segment has been used, according to Italian reference periods. These data enable to use an acoustic model on a wide area with several line sources in order to obtain noise propagation maps of L_{den} and L_{night} indicators. A procedure to estimate people exposed to different noise levels, as required by the END, has been also studied. Through a geographic information system it has been possible to intersect population input data (demographic density for different areas, buildings use type and buildings volumetric data) and noise mapping data. Every step of the procedure has been carried out complying with WG-AEN Good Practice Guide recommendations, on the base of the best available data in Milan District.

1 Introduction

Milan District road network has an extension of 1090 km and comprehends several functional infrastructure typologies in diverse territorial contexts.

The present study shows a procedure for the Milan District road network noise mapping according to the first D.Lgs. 194/2005 (which acknowledged in Italian regulations Directive 2002/49/EC) scheduled deadline, considering arterial roads for which a 6 millions vehicles annual flow has been measured or foreseen. WG-AEN *Good Practice Guide* [1] recommendations have been taken into account on the basis of the Milan District data availability.

The main purpose of the study has been the calculation of L_{den} and L_{night} indicators in the areas surrounding road infrastructures as well as the assessment of population exposed to the different noise level ranges. Noise mapping is propaedeutic to the Action Plan elaboration which, according to D.Lgs. 194/2005, identifies and defines the required acoustical mitigation measures.

2 Study dataset

Data required by software simulation have been collected in the initial phase of the project in order to evaluate noise emissions and environmental propagation.

Every data has been catalogued, filed and elaborated in a GIS system. Thus every major road and all related features and information have been represented in an individual territorial information system project.

2.1 Georeferenced territorial data

Main territorial data sources are municipalities aerophotogrammetric files (cad format) and territorial information county database (source: M.I.S.U.R.C., the union of municipalities urban plans); in some cases raster cartographic data (at a regional scale) as well as satellite orthophotos have been used, providing missing data through manual digitization.

The following data types have been collected and added to the GIS project:

- Georeferenced road network graph (Milan District source): the vector graph, 405 km extended, originally available in a large scale representation, has been corrected according to more detailed informations.
- Orographic description of investigated areas based on altimetric data extracted from the abovementioned aerophotogrammetric files.
- Built-up areas description (buildings and other anthropic infrastructures): building volumes have been assessed from spatial informations (available in the aerophotogrammetric files), mainly regarding area and height data. Every building has therefore been classified according to its use type as indicated in the urban plans. Residents have been assessed from a municipality building occupation index (source: ISTAT, Italian statistical national institution) expressed in “dwelling area square meters per resident” where area has been calculated from the volume assuming an average 3 meter floor height.
- Noise-sensitive receivers (schools, hospitals, nursing homes, etc.): their identification and spatial allocation have been provided by municipalities offices, or are included in aerophotogrammetric files and satellite orthophotos. User data, expressed as number of students or beds, have been collected and entered in the database.
- Noise mitigation measures performed or planned: in order to realistically simulate noise propagation and properly assess the number of people affected, mitigation interventions such as the deployment of porous asphalt pavements or noise barriers have been reproduced in the model.

2.2 Traffic data

Traffic flows –distributed in day, evening and night periods- have been assigned to the road network segments according to available starting data:

- hourly traffic data relative to annual measurements carried out in the 2005-2006 period using 54 Milan District owned magnetic sensors (coil type);
- hourly traffic data relative to 8 weekly measurements carried out by the workgroup magnetic sensors (plate type);
- GIS shapefile relative to a 2001 simulation study indicating weekday peak hour (8.00-9.00) equivalent vehicles flow at every segment of the road network.

In order to identify roads with higher than 6 millions passages annual traffic flows, some assumptions have been carried out. Specifically established criteria to extrapolate missing data and obtain average flows are:

a) Sunday traffic flow equals 60% of the weekday one;

b) Saturday traffic flow equals 80% of the weekday one;

c) August average traffic flow equals 60% of the weekday one.

Therefore a solar year matches 324 equivalent weekdays.

The assignment procedure of relevant data to every segment of the investigated road network has been summed up as follows:

1) The following informations have been elaborated from 62 measurements dataset:

- Average hourly distribution of the daily traffic flow;
- Average hourly distribution of the daily traffic flow normalized according to total daily traffic flow in order to extrapolate percent peak hour (8.00-9.00) traffic flow as well as percent day (6.00-20.00), evening (20.00-22.00) and night (22.00-06.00) traffic flows;
- Automatic vehicles grouping (8 classes), according to length values, has been rearranged parting light vehicles (less than 7.5 meters length) from heavy vehicles (more than 7.5 meters length);
- Automatic vehicles speed grouping (6 classes) has been elaborated determining light and heavy average speed values at each time period.

2) Surveyed road network segments have been classified in order to automatically calculate the traffic flows at each scenario according to specific distribution schemes developed from measured data. Classification is the outcome of a statistical analysis of the initial dataset where relevant parameters have been selected and grouped by according to their significance in noise emission. *K-means* clustering method has been assumed with the purpose to define some group significatively distant each other [2]. Conversion indexes have been established for each group to correlate peak hour flows to day/evening/night average hour flows.

3) Furthermore since available peak hour traffic flows refer to a weekday situation (i.e. Saturdays, Sundays and August days are not accounted), a correction factor has been applied to reproduce the average day annual scenarios. As abovementioned, equivalent weekdays have been formulated. The following expression shows the adopted correction:

$$\textit{annual peak hour flow} = \textit{annual weekday peak hour flow}*(324/365)$$

Since annual peak hour data refer to *equivalent light vehicles*, a further elaboration has been carried out to separate light and heavy traffic flows. Taking into account the heavy vehicles percentage and the equivalence light/heavy factor adopted in the previous simulation, a correction to the original flow has been applied to obtain the real one.

4) Last step consists in classifying each road network segments which, lacking the directly surveyed data, have a traffic flow assigned from the peak hour simulation.

These segments functional classification (performed just in the case of the direct surveys) has been accomplished through proximity analysis and functional affinity. Consequently, applying the abovementioned correction factors to the peak hour traffic flows, at every classified road segment, all estimated data required for the noise simulation have been collected. Vehicles average speed values have been defined according to the road segment classes, e.g. urban, extra urban and main roads. Specific corrections have been applied in case of roundabouts and access roads.

3 Noise simulation

IMMI 5.3 is the software used for the noise simulation. The noise propagation algorithm adopted in the study, NMPB – Routes 96 (SETRA – CERTU – LCPC – CSTB), complies with the requirements of European Commission Recommendations (2003/613/CE), approved in the Italian Law in D.lgs 194/2005.

The software adopts day, evening and night periods time scheduling enabling to calculate of L_{day}, $L_{evening}$ and L_{night} (and consequently derive L_{den}) noise maps and façade levels.

The calculation area width has been defined from the source line taking into account a 1200 meters maximum half-extension. This assumption enables to encompass the 55 dB(A) L_{den} contour line, in compliance with the norm, even in the case of free-field favoured noise propagation and maximum traffic flows [3]. All data required in the simulation, with the exception of orography, have thus been reproduced merely in the abovementioned area.

Software set up consists of the following steps:

- Orographic description of the investigated areas through the input of a dataset of elevation points; therefore a DGM, *digital ground model*, has been elaborated, its resolution depending on the density of elevation points.
- Road network segments input: calculated vehicle traffic flows (ref. 2.2) have been assigned to each homogeneous segment. Besides every major road has been divided into different sections whenever a 50% difference between a segment and initial one traffic flow occurs. According to this segmentation, dwellings and population exposure data have been afterwards aggregated. Width, carriageway and lanes numbers as well as surface type characterize every arterial road reproduced in the model. For some of them a 3D aerophotogrammetric data (100 meters on each side from the centre of the road) are available enabling the analyst to reproduce altimetric features such as trenches, spans, access roads.
- Building geometric data (base and height dimensions) are associated to their use and residents number in case of dwellings. Acoustical façade properties have been homogeneously established (reflection index =1).
- Ground absorption index has been likewise assumed *G factor* = 0.5 for all the residential areas; in the case of extra urban areas, such as parks, fields and woods, higher values have been supposed.

Noise level computation has been carried out according to two different methods: to generate surface noise mapping, obtained by interpolation of a 4 meter above the ground grid calculated levels; to generate reports indicating location points (dwellings and sensitive receivers) 2 meters from façade maximum L_{day}, $L_{evening}$, L_{night} and L_{den} levels; relative façade reflection index has been set to zero. Therefore a direct attribution of the noise levels to affected residents has been accomplished.

4 Results format and reporting

The following noise exposure data have been elaborated taking into account 2001 ISTAT dwelling area square meter per resident factors, their volumes and noise simulation outputs.

- the estimated number of people, living in dwellings outside agglomerations, that are exposed to each of the following bands of values of L_{den} 4 meters above the ground on the most exposed façade: 55-59, 60-64, 65-69, 70-74, >75;
- the estimated number of people, living in dwellings outside agglomerations, that are exposed to each of the following bands of values of L_{night} 4 meters above the ground on the most exposed façade 50-54, 55-59, 60-64, 65-69, >70;
- assessed (square km) area, dwellings number and population exposed to L_{den} levels higher than 55, 65, 75 dB(A). Area has been calculated as a sum of simulation grid primary cells where noise levels are higher than selected ones.

All data have been calculated in GIS environment and grouped by major road section (defined, as aforementioned, according to annual traffic flow distribution).

Outcomes have been presented either in paper form, to help citizens understanding, or in a digital form, as required by the commissioner and to comply with Italian and Communitarian standards.

Single road representation paper outputs are composed by:

- non-technical synthesis to describe procedure main steps;
- tables to show traffic data, population and façade noise exposure;
- full scale representation of the district area indicating commissioner handled road network and other infrastructures;
- detailed scale representation of road surroundings with noise maps indicating maximum façade noise levels at dwellings and at sensitive receivers. For the purpose a building hem chromatic scale representation has been adopted. Besides previous mitigation measures have been pointed out.

All graphic charts present aerophotogrammetric features as background.

Following digital data (relative to above 6 million vehicles flow roads) have been produced; every informative layer has been georeferenced either in Gauss-Boaga system or in WGS84.

- road center lines with relative length and traffic flow characteristics (linear shapefile);
- 55, 65, 75 dB(A) L_{den} noise contours with relative extension, exposed dwellings and population (linear shapefile);
- 55-59, 60-64, 65-69, 70-74, >75 L_{den} level ranges with relative exposed population (polygonal shapefile);
- 50-54, 55-59, 60-64, 65-69, >70 L_{night} level ranges with relative exposed population (polygonal shapefile);

Polygonal shapefiles are defined by pixels centred at the calculation grid nodes with associated noise level information. Digital data structure complies with Italian Environment Ministry specifications.

5 Conclusions

Aforementioned noise mapping process led to new indicators noise level prediction (L_{den} and L_{night}) for Milan District road network. 58 major roads, divided in 90 sections according to the traffic distribution, have been studied. Total investigated area extends to 800 square km, adding up to 40% of the total District dimension.

Adopted procedure would simplify prospective updates due to changes of urban or infrastructural conditions as well as traffic flows. Furthermore digital outcomes enable integration or overlapping with similar maps, for instance with the purpose to identify several infrastructures concomitance in exceeding noise limits, or to define strategic noise maps.

Concerning the Action Plan, missing, at the present time, L_{den} and L_{night} indicators limits in Italian regulation, identification and quantification of acoustical criticalities couldn't be accomplished. Thus noise mitigation measures at above 6 million vehicles flow roads will be carried out according to Noise Confinement and Abatement Plan, which Milan District Authority is finalizing in compliance with Italian Law D.M.A. 29/11/2000 for the entire road network.

References

[1] European Commission WG-AEN "*Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure*", Version 2, January 2006.

[2] A. Bisceglie, G. Zambon, S. Radaelli "*Procedura di assegnazione di flussi veicolari a una rete stradale per la stima dell'emissione acustica*". Atti del 34° Convegno Nazionale AIA, Firenze, June 2007.

[3] G. Zambon, S. Radaelli, A. Bisceglie "*Criteria for determination of the area to be mapped around roads (Directive 2002/49/EC)*", 19th International Congress on Acoustics, Madrid, September 2007.