Edinburgh, Scotland
EURONOISE 2009
October 26-28

The Milan agglomeration Strategic Noise Map

Giovanni Zambon[a]
Simone Radaelli[b]
Università degli Studi di Milano-Bicocca, Dipartimento di Scienze dell'Ambiente e del Territorio, Milano, Italia

ABSTRACT

This paper deals with the procedure applied in the development of Milan agglomeration Strategic Noise Mapping, as defined by Environmental Noise Directive (2002/49/EC). City of Milan is a complex case study because of the presence of a multitude of sources: roads, railways, tramways and airport (Linate). The assessment method follows the guidelines contained in the "Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure" (WG-AEN). The study of noise generated from several sources was carried out with the integrated use of both numerical models and Geographic Information Systems (GIS). Numerical models allow to estimate noise levels in large areas near to a specific noise source and GIS enable the efficient acquisition, management and elaboration of geo-referenced data representative of territory, sources and buildings. The purposes of this paper are mainly to describe data collected typologies, to show problems connected to their management and to point out technical solution adopted for Strategic Noise Map achievement. In particular we report the methodology for the estimation of road traffic flow data for each reference period (day, evening and night) from rush hour data obtained from a specific road traffic simulator. Furthermore we pay attention to the management of buildings and population data; these data are essential to estimate the number of inhabitants exposed to specific intervals of the noise indicators L_{den} and L_{night}. Finally some results of Strategic Noise map, displayed in different ways, are exposed.

1. INTRODUCTION

In this paper are explained the main aspects about the production of Milan agglomeration Strategic Noise Map, in compliance with the Environmental Noise Directive (END) 2002/49[1]. Lombardy Region defined the agglomeration of Milan as the area within municipality borders with a specific decree[2]. City of Milan covers a surface about 182 km^2 and has about 1˙300˙000 inhabitants; strategic noise map was achieved considering the entire transportation system: roads (linear length about 1˙800 km), tramways (180 km), railways (90 km) and Linate airport that counts about 125˙000 aircraft movements per year. Milan Municipality assigned Laboratory of Environmental Acoustics of Milano-Bicocca University and Environmental and Territorial Agency of Milan (AMAT) to obtain the strategic noise map results for the European Commission. In particular we collected documentation from all infrastructures authorities to create the acoustical model of Milan.
The assessment method follows the guidelines contained in the "Good practice guide for strategic noise mapping and the production of associated data on noise exposure" (WG-AEN)[3].

2. RAW DATA: ACQUISITION, MANAGEMENT AND PROCESSING

The study of noise generated from several sources was carried out with the integrated use of both noise predictive software (CadnaA ver.3.7) and Geographic Information Systems (Arcview

---

[a] Email address. giovanni.zambon@unimib.it
[b] Email address. s.radaelli@unimib.it

GIS 3.2 and ArcGIS 9.1, ESRI). Through a Geographic Information System data have been collected, filed, organised, analysed and made available at different levels of detail and in the most appropriate formats. Data related to: noise sources (location, structural characterization and traffic flows); buildings (type and geometric characteristics, kind of use, number of residents); morphology and type of land cover.
Two different approaches for data related to road, rail and airport infrastructures have been used. For the first two sources, calculations were made by Laboratory of Environmental Acoustics for the totality of infrastructures, independently by the managing authority and the major infrastructures noise mapping results delivered to the competent agglomeration authority. For the airport source, results of noise mapping given by airport operator have been directly used. These data have been used to estimate global noise levels, generated simultaneously from all the sources.
The next paragraphs describe the methodology used to manage data related to different type of GIS layer.

2.1 TERRAIN MORPHOLOGY AND GROUND ABSORPTION

In regard to terrain morphology, afterward the acquisition and analysis of height points theme, it was considered appropriate to maintain the entire surface of agglomerations to a constant altitude; this choice is motivated by several factors:

1. altitude variations inside the agglomeration are negligible compared to the influence of these variations on acoustic wave propagation;
2. increase of calculation time, which does not reflect a significant benefit in terms of accuracy in noise levels estimation.

Particular situations in terrain morphology that have a significant influence on noise levels estimation (e.g. special infrastructure cross sections or hills) have been however considered through the manual insertion of contour lines, whose heights have been extracted from height points theme.
An absorption coefficient (G) of 0.0 (reflective soil) has been attributed to Milan agglomeration's ground, because it is principally covered by asphalt and cement. Areas interested by parks and cultivated fields have been defined with a G value of 1.0, as suggested in *Good Practice Guide – WG-AEN*, *Toolkit 13*.

2.2 BUILDINGS AND POPULATION

Buildings layer has a primary importance for creating acoustic model propagation space and producing results related to exposed population that must be transmitted to European Commission. To obtain a georefenced database of buildings, including information on height, perimeter and resident population, the following data have been collected and processed (in *ESRI Shapefile* format): polygon theme of all buildings indicating geometrical characteristics and use (year 2005): point theme of civic numbers indicating resident population (2008); polygon theme of census zones (defined by national statistics institute ISTAT, 2001). After appropriate additions and corrections of acquired database, the following procedure for the assignment of resident population to residential polygons was applied:

- phase 1: calculation of global resident population in each census zone "*n*" ($Res\text{-}TOT_n$).
- phase 2: calculation of global residential building volume for each census zone "*n*" ($Vol\text{-}TOT_n$).
- phase 3: calculation of coefficient $C_n = Res\text{-}TOT_n/Vol\text{-}TOT_n$, related to each census zone "*n*" (population density).
- phase 4: assignment of residents number to each building through a multiplication between coefficient C_n and building volume.

During the importation of building theme in the noise predictive software an absorption coefficient of 0.2 for all buildings has been defined, following indications suggested in *Good Practice Guide – WG-AEN, Toolkit 16*.

2.3 ROADS

The acoustic characterization of road infrastructures is based on data provided by a traffic flow model developed by *Agenzia Milanese Mobilità e Ambiente*, and relating to all road infrastructures inside Milan agglomerate boundaries. In Figure 1 are showed the different managing authorities (*Comune di Milano*, *ANAS S.p.A.*, *Autostrade per l'Italia S.p.A.*, *Milano Serravalle – Milano Tangenziali S.p.A.*, *SATAP S.p.A.*).

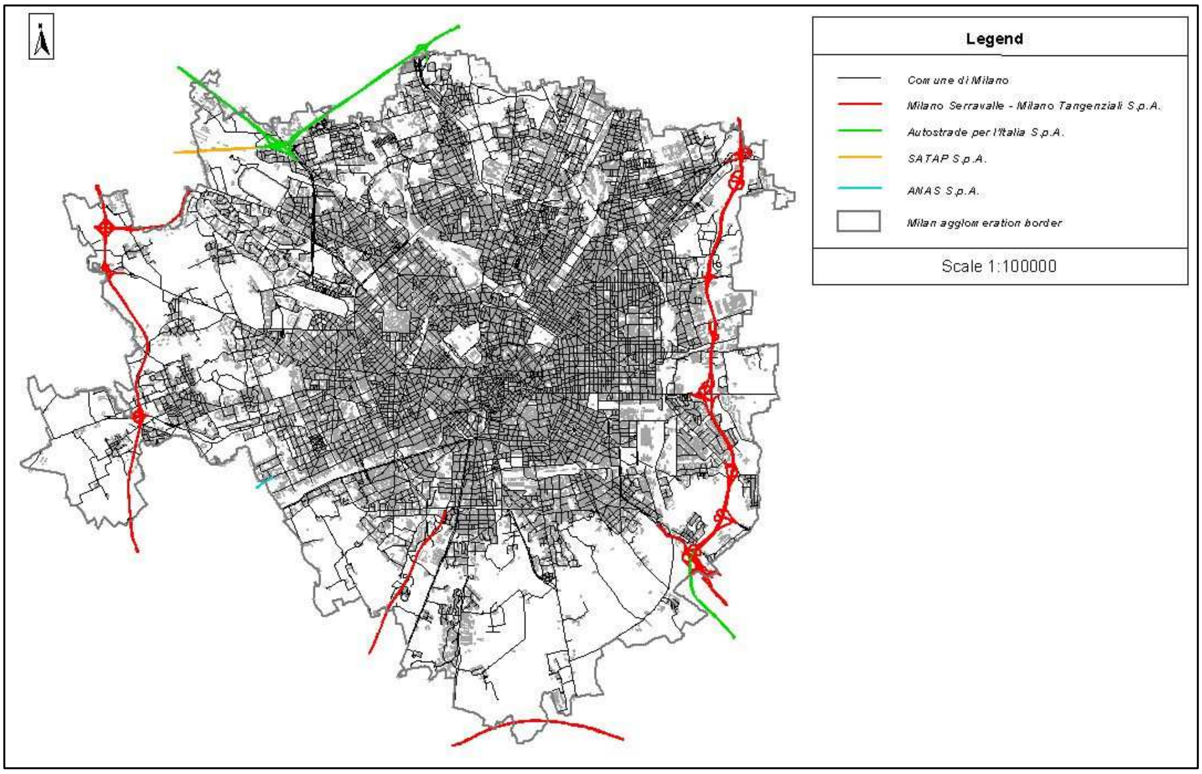

Figure 1: Milan agglomeration road network.

The traffic flow model allows to associate the data to two types of road graphs: the 1st level graph, more detailed, and the 2nd level graph (Figure 2). The road graph used for strategic noise mapping is the 2nd one. One of the most important difference between the two graphs is related to the representation of separated carriageway roads and rotaries. In the 2nd level graph the first ones are digitized with a single line in the middle of the road and the seconds are simply represented as an extension of all the road segments till they cross each other in the rotary centre.
To reproduce the acoustic scenery as accurate as possible, some manual corrections of roads layout have been introduced, as the localization of pedestrian areas and pedestrian or cycling routes.

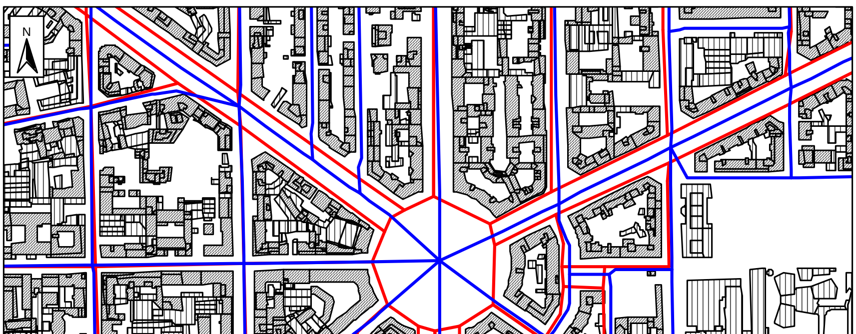

Figure 2: Two different representations of road graph.

Data associated to segments that compose the road network concern: geometric, structural and physical characteristics (including road surface type): road typology; flow, velocity and composition of traffic (light vehicle, motorcycle and heavy vehicle) referred to rush hour (08:00 – 09:00). The combination of these data, available in different georeferenced database (*ESRI shapefile*) and included in a Geographic Information System, allowed to define the following parameters (associated to each road segments, for the three time periods): average traffic flow per hour (vehicles/hour); average velocity (km/h); traffic composition (heavy vehicles percentage); road surface type; traffic flow conditions.

The tramway sources have been integrated into road infrastructure because often tram-lines and ordinary vehicular traffic shared the same roads (solution also indicated in *Good Practice Guide – WG-AEN*, *Toolkit 8*). The sound pressure level L_w attributed to each tram-line in the three period time derives from SEL value for convoy type and from the numbers of transits along the different lines.

2.4 RAILWAYS

The rail infrastructures that cross Milan are controlled by three managing authorities : *Ferrovie dello Stato S.p.A.*, *Ferrovie Nord Milano S.p.A.* and *Azienda Trasporti Milanesi S.p.A.*. The different managing authorities gave useful information for the acoustic characterization of rail source, as number of annual transits along competent trades and convoy type.

First of all, to represent railway source, a linear theme of the principal tracks has been digitalized. From traffic data the daily number of convoys, divided into categories, that pass during the three period time along each trade, has been calculated.

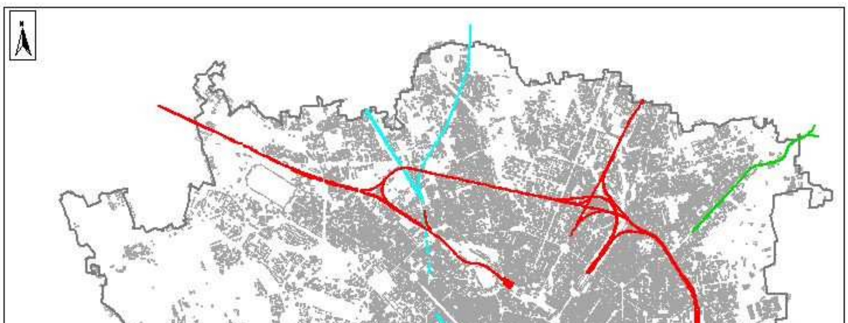

Figure 3: Milan agglomeration rail infrastructures.

2.3 AIRPORT

On the basis of data provided by Linate airport managing autority (SEA – Aeroporti di Milano), a procedure to estimate global noise levels, generated by all the sources inside the influence area of Linate airport, has been developed. Influence area has been defined considering for L_{den} indicator a minimum threshold of 45 dB(A) and for L_{night} indicator of 40 dB(A) (Figure 4).

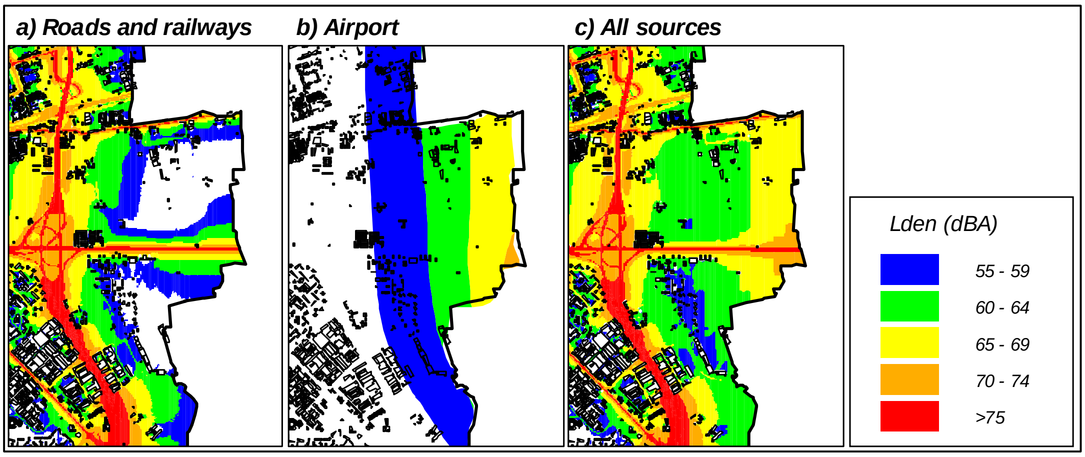

Figure 4: Addition of Airport noise to road and railway noise.

3. CALCULATION AND RESULTS RESTITUTION

The noise predictive model allows to estimate noise levels in different modalities. To obtain the result typologies requested by END, the following calculation options, that have differences relative to the position of receivers were used:

- *Calculation grid.* Receivers are located at the intersection points of a square grid whose spacing and ground elevation can be defined by the user. For the noise map of the agglomerate of Milan these parameters are respectively 10 meters and 4 meters.
- *Building evaluation.* Receivers are located along building's façade. Parameters to define their position are: ground elevation (set as 4 meters), distance from facade (2 m) and minimum distance between each receptor in the horizontal plane (10 m). Reflection contribute of the back facade is not contemplated.

Calculation results made through *calculation grid* have been exported into the following layers (ESRI shapefile):

- Point theme relative to calculation grid including estimated values of L_{den} and L_{night} indicator;
- Polygon themes representative of L_{den} and L_{night} intervals, as indicated by legislation. The polygons are obtained interpolating the values associated to calculation grid points; this interpolation is carried out by the noise predictive model (Figure 5).

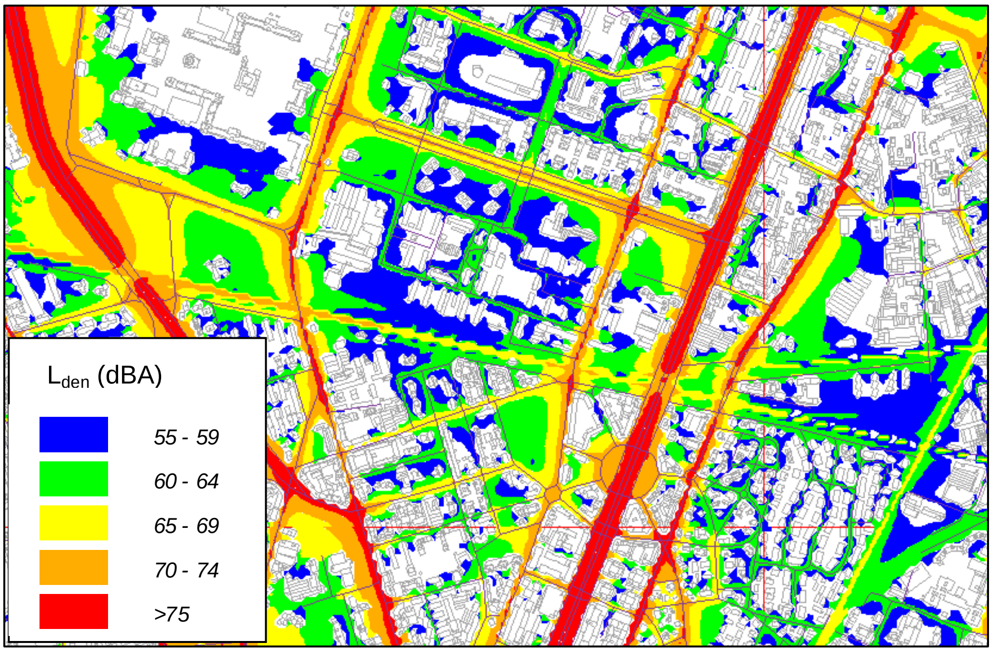

Figure 5: Example of polygon theme representing noise map.

Building evaluation has been performed to estimate population exposed to specific L_{den} and L_{night} values: for this reason receivers are located exclusively in correspondence of residential buildings. Following calculation these informative layers have been exported:

- Point theme relative to receivers localization around buildings containing estimated values of L_{den} and L_{night} indicator (Figure 6);
- Point theme including a point for each residential building; each point reports the maximum value of L_{den} and L_{night} estimated in correspondence of the buiding.

The determination of the population exposed to different L_{den} and L_{night} values is based on maximum estimated value in correspondence of buildings, using a specific function implemented into calculation software.

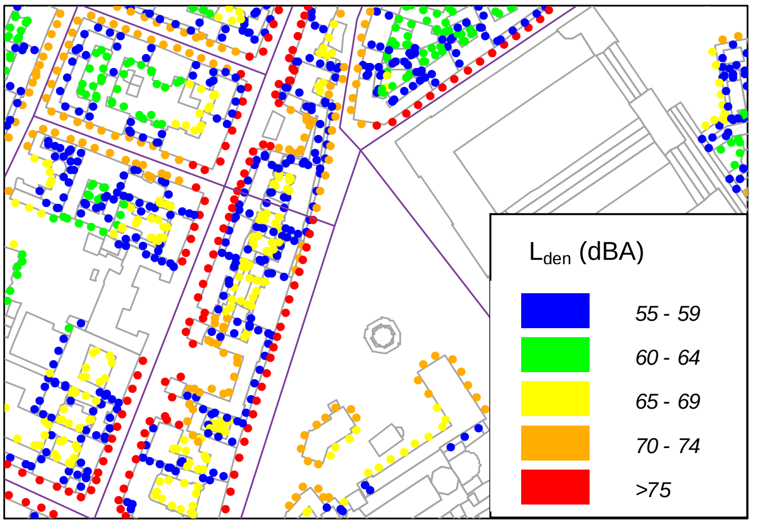

Figure 6: Point theme from building evaluation calculation.

The main configurations used to run calculations are: reflection number equal to 1, maximum search radius included between 400 and 800 meters (it depends on building density), conditions propitious to propagation equal to 0% in all three time periods.

4. MODEL ACCURACY EVALUATION

In order to evaluate model accuracy, calculated noise levels have been compared with results of georeferenced historical noise measurements, collected by AMAT from 1995 to 2008. In particular only those measures that were carried out at 4 m of height above ground and those lasted at least 24 hours have been used for comparison. From 331 historical measurements, 116 measurements have been considered. The differences between experimental noise levels and calculated noise levels have been calculated using a proximity criterion: each “historical” noise level is compared with average level from the levels of the 4 calculation grid nearest points.

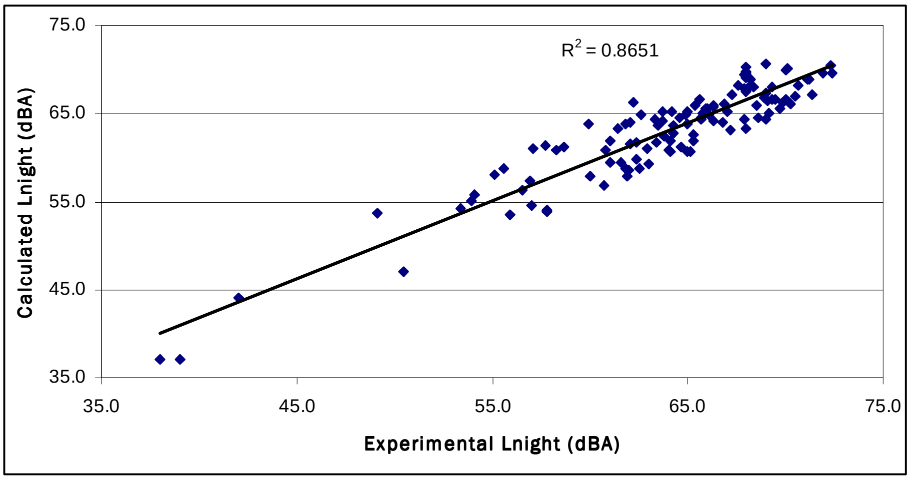

Figure 7: Calculated vs. Experimental noise levels.

The parameters used to analyze the difference between values given by the model and those given by measurements are: correlation index, equal to 0.8651, mean difference, equal to +1.0, and standard deviation, equal to 2.3. Considering the extent of the study area, from these results emerge that noise sources and propagation environment inside the model are recreated in an accurate way.

5.CONCLUSIONS

The achievement of Milan agglomeration strategic noise map has highlighted several problems in data management and data processing. In order to obtain the results as required by European legislation it was necessary to integrate information available in different formats, with various degrees of detail and different updating time, as generally used for purposes unrelated to those required by strategic noise mapping. In addition, analysis of a large city as Milan, characterized by a continuous evolution of its urban setting, needed frequent updating, which involved the use of monitoring and verification instruments as aerial images available onto the Internet and on-site surveys.

Finally this work confirms that the coupled use of GIS and noise predictive software actually is the best way for the analysis of noise generated by a wide inhomogeneous infrastructures network. The main benefits regarded the manage of a large amount of data, the quickly elaboration of results as well as their easy representation, maintaining a suitable accuracy.

REFERENCES

1. Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise, 25 June 2005.

2. Decreto della Giunta Regionale della Lombardia 27 ottobre 2005 n. 8/942 “Individuazione dell’agglomerato di Milano e dell’autorità competente ai fini degli adempimenti previsti dal Decreto Legislativo 19 Agosto 2005, n. 194, in materia di determinazione e gestione del rumore ambientale”.

3. European Commission Working Group – Assessment of Exposure to Noise (WG-AEN), Good practice guide for strategic noise mapping and the production of associated data on noise exposure, Ver. 2, 13 August 2007.