TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS

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In the context of the European project DYNAMAP, a campaign of acoustic monitoring of road traffic noise was realized in the entire area of the city of Milan.
The operations involve the collection of temporal trends of noise levels in order to create a statistically significant sample for post-processing analysis.
The monitoring activities encompass the following steps:
- collection and selection of previous noise data concerning the road sources;
- identification and selection of monitoring sites based on specific criteria such as road geometric characteristics, the functional road classification (A, D, E, F), the type of traffic, the absence of other noise sources, etc.;
- acquisition of the acoustic data by weekday using various types of units for the long-term noise monitoring;
- correlation of acoustic data with weather data and deletion of data when levels of rainfall and wind speed exceeding threshold values;
- identification and removal of abnormal events through sonogram analysis;
- acquisition of series of equivalent sound levels, measured on different time intervals: 5, 10, 15, 20, 30 and 60 minutes;
- acquisition of traffic flow data related to road stretches, via statistical modeling or on-site measurements.

All acquired data are stored in a geodatabase useful for further processing, such as cluster analysis and the development of an acoustic model for the city of Milan. The acquisition of noise data will also provide useful indications to size a monitoring network of low-cost sensors, one of the main target of the DYNAMAP project.

1. Introduction

The DYNAMAP project aims at developing a prototype system in an effort to achieve the real-time noise mapping of road infrastructures in two pilot areas: a part of the agglomeration of Milan and a section of the Motorway A 90 in Rome. One of the main goals of the project is to create a low-cost sensor network able to make the five-year update of the strategic noise maps required by the European Directive 2002/49/EC more efficient and less expensive. In further stages of the project a statistical method will be introduced to automate the process of noise mapping.

This paper describes the methodology used to create the initial collection of noise trend required for the statistical analysis of the project.

The original assumption of the project is that an experimental approach, based on real-time noise measurements, could be used to map road's sources in urban areas.

The use of low-cost sensors allows to roll-out a large monitoring network and steadily obtain continuous noise data for long periods of time. This feature introduces a different role for the experimental measurements in the noise mapping process.

Nowadays noise measurements are used mainly to validate results obtained from computational models and they are usually not directly involved into the noise mapping process.

Recent studies, concerning the road noise sources in Milan, revealed that the city's streets show an "acoustic behavior" not strictly related to the road functional categories (A, D, E, F), to the road geometric-structural characteristics (number and width of lanes, the road surface types, etc.) or to their traffic volumes. Therefore it's actually possible identify a limited number of road's clusters characterized by similar noise trends.

The construction of a database, containing the noise emission of road infrastructure obtained in previous measurements and in new measurements in the city of Milan, is necessary to characterize the "acoustic behavior" of homogeneous groups of roads.

Therefore one of the first actions of the project is the realization of a large-scale noise monitoring survey specifically made to improve the previous noise data acquired with new ones.

To this end, a wide traffic noise monitoring campaign was planned on the entire area of the city of Milan, considering the space-time variability of the noise emissions generated by traffic sources. For each measurement point, different series of equivalent noise levels with different time resolutions were obtained for the period of 24 hours.

This study summarizes the first results of this activity which is still ongoing.

2. Collection of previous acoustic data

The first activity involved the archiving of previous noise measurements. From all the historical data available, only those specifically related to road sources and with a duration of 24 hours were selected.

The Department of Environment and Territory and Earth Sciences has carried out since 2007 several measures of acoustic monitoring in the city of Milan.

The collected data have different origins. Some sound level measurements were performed for research purposes, others for collaborative activities carried out for institutions such as the Lombardy Region, the Municipality of Milan and the Milan Territory Environment Agency Mobility AMAT.

The dataset of previous continuous noise monitoring consists in 49 sites, related to 8 different road categories.

The increase of the historical database with noise trends coming from other institutions or research organizations is one of the next targets of the research team group.

3. Execution of acoustic monitoring campaign

The second phase of the study involved the planning and execution of a new campaign of acoustic monitoring, closely related to the purposes of the project DYNAMAP.

In order to create a representative statistical sample of the entire road network of the city, the following general criteria were adopted to identify the measuring sites:

- homogeneous distribution on the entire metropolitan area and between the nine city's districts of Milan;
- uniform distribution between the different road categories (A, D, E, F) and road subclasses (E1, E2, F0, F1; F2, F3);
- various urban scenarios (urban canyons with different conformation, open sound field, etc.);
- different road surface type;
- different traffic flow types (fluid continuous flow, pulsed continuous flow, pulsed accelerated flow or pulsed decelerated flow);
- no influence of other roads on the monitored road stretch;
- absence of other noise sources (tram lines, railways, airports, etc).

In the monitoring campaign, three different types of monitoring units have been used. These units are:

- fixed monitoring stations (Fig. 1 A);
- semi-permanent monitoring stations (Fig. 1 B-C);
- monitoring stations placed on cart or on mobile laboratory (Fig. 1 D-E).

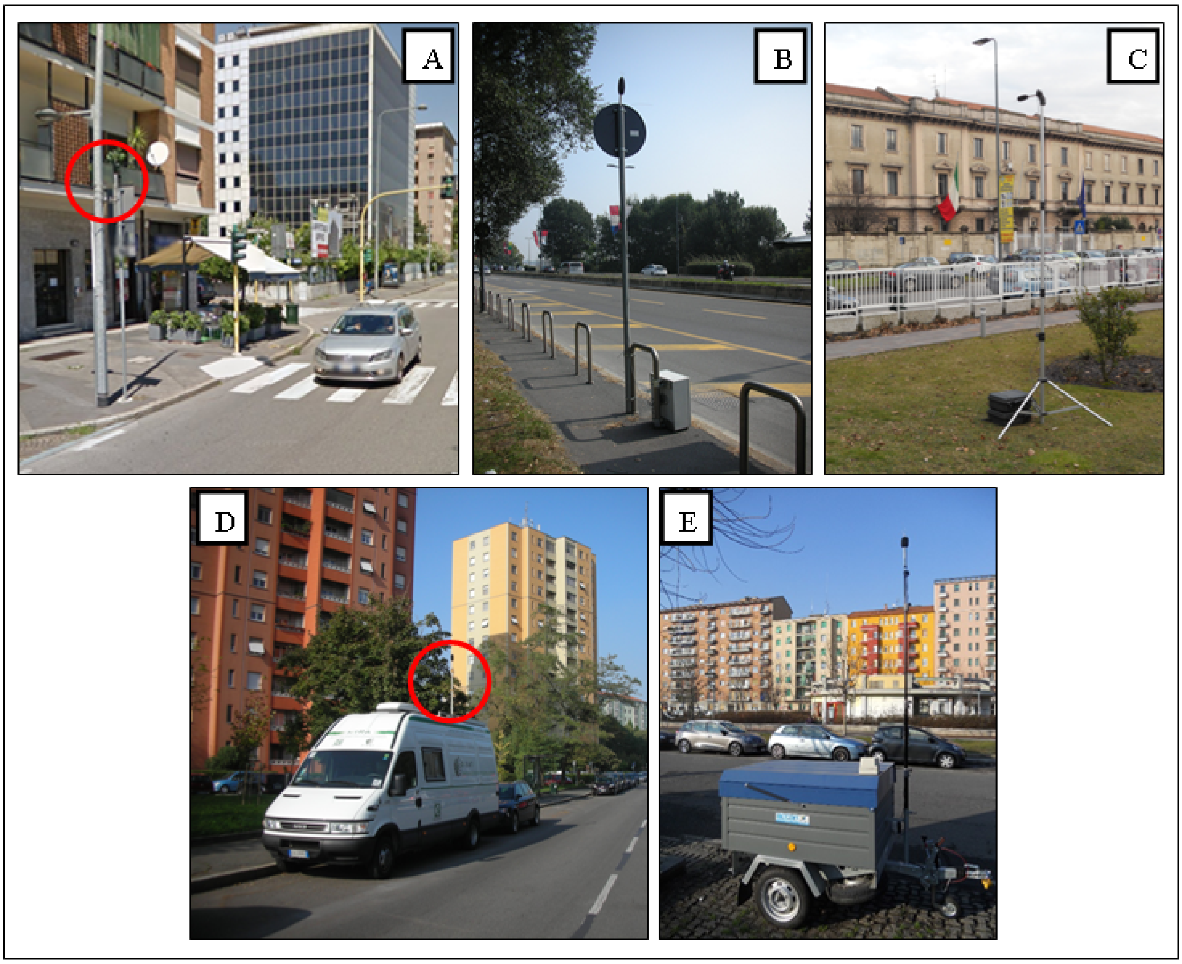

Figure 1. The monitoring stations used during the DYNAMAP noise monitoring campaign.

All monitoring stations are equipped with a class 1 sound level meter able to obtain the main noise indexes and the spectral trends in third-octave bands with a temporal resolution of 1 second.

The monitoring activity was sized on a minimum measurement time of 24 hours, starting at 6 a.m. and eventually protracted for different days.

4. Processing of the measurements

Subsequently to the execution of the noise measurements, all acquired data was elaborated in a three steps.

The first operation involved the exclusion of noise records of public holidays and anomalous days (such as days of school closures) in order to extrapolate only the acoustic data relative to a typical weekday.

The second operation involved the correction of the acoustic data with weather data. The units of acoustic monitoring in fact are not equipped with weather stations, therefore, it was necessary to associate every single noise level with weather data of rainfall and wind speed measured in the different weather stations of ARPA (Regional Agency for Environmental Protection) located on Municipality of Milan (Fig. 2).

To get weather data related to the real weather conditions detectable near each measurement site, each site was selected and compared to the reference weather station closest to the point of measurement itself.

The effect on the acoustic data of rainfall events was evaluated considering a method proposed by ARPA. In detail, the criteria used are:

- precipitation < 2 mm: irrelevant;
- precipitation > 2 mm: influential on individual hourly data;
- precipitation > 4 mm: influential for the time immediately following the event weather.

To evaluate the influence of atmospheric turbulence on the acoustic data, the criterion used is indicated by Italian normative. The acoustic data were discarded when:

- wind speed > 5 m / sec

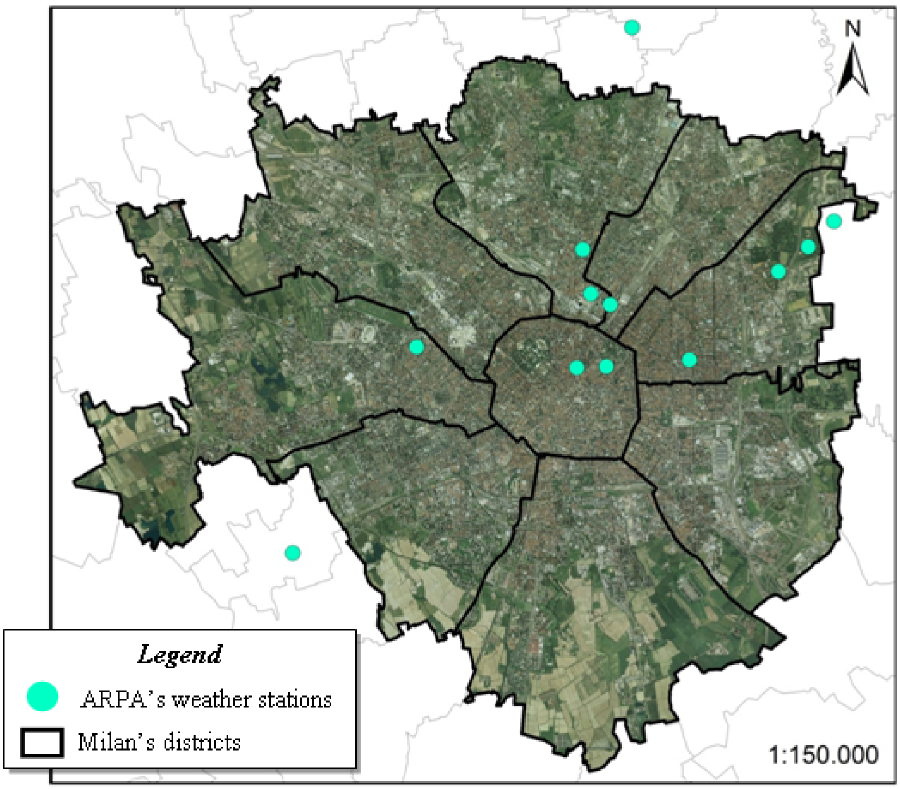

Figure 2. The dislocation of ARPA's weather stations in the territory of Milan.

The third corrective operation of the original acoustic data involved the elimination of extraordinary or abnormal events (such as sirens, horns, airplane transits, noisy human activities, technical facilities, etc.), since their presence can affect and alter the equivalent noise level.

This operation is important because it allows to achieve an acoustic data closely related to the single traffic source.

The identification of the extraordinary events was based on the comparison and analysis of the sonograms. Sonograms are graphic representations of a sequence of spectra in time, where the sound pressure level, in a chromatic scale, is expressed in function of time and frequency (Fig. 3).

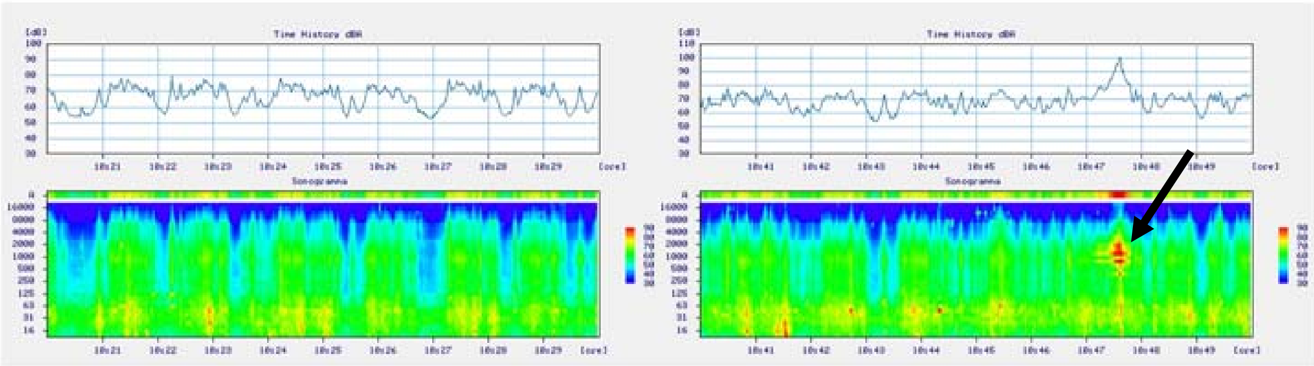

Figure 3. Sonograms related to road traffic in normal conditions and in the presence of an anomalous event (ambulance siren).

After the corrections of the acquired data, the sound pressure levels were calculating by integrating the acoustic data on different time intervals, respectively 5, 10, 15, 20, 30 and 60 minutes.

The succession of equivalent noise levels on 24 hours represents the trend noise, which constitutes the basis for subsequent statistical analysis. Each noise dataset consists of 6 distinct temporal profiles obtained with different sampling of data per second.

At the present state of art, a total amount of 182 noise trends was obtained: 152 coming from previous noise monitoring activities and 50 coming from the DYNAMAP noise monitoring campaign (Fig. 4). These 182 trends well describes the noise emissions of 76 roads of Milan (Table 1). Road categories A and D have been almost entirely described, while the E and F road classes, that show an high internal variability, will be the object of future noise surveys (Fig. 5).

Table 1. The results of the noise monitoring campaigns.

Functional class of road	Number of roads monitored	Number of daily noise trends collected
A	3	5
D	9	20
E1	17	52
E2	10	25
F0	11	19
F1	6	10
F2	9	21
F3	11	30

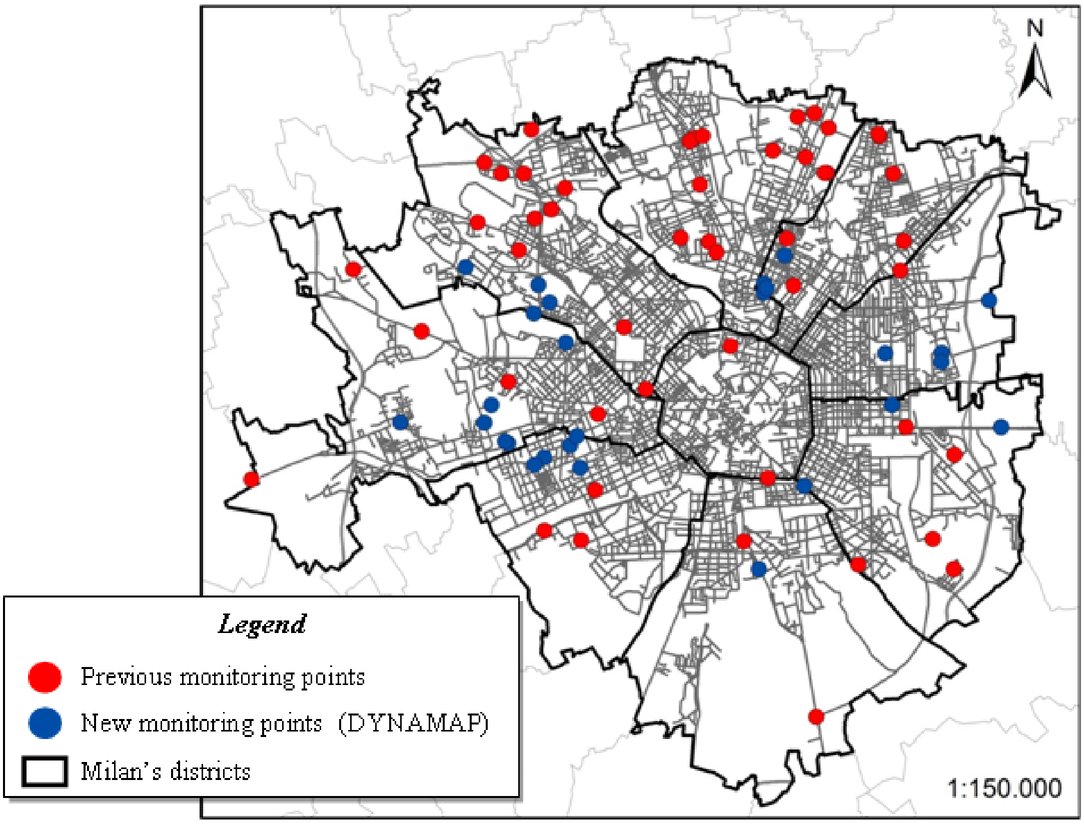

Figure 4. The location of noise measurements positions.

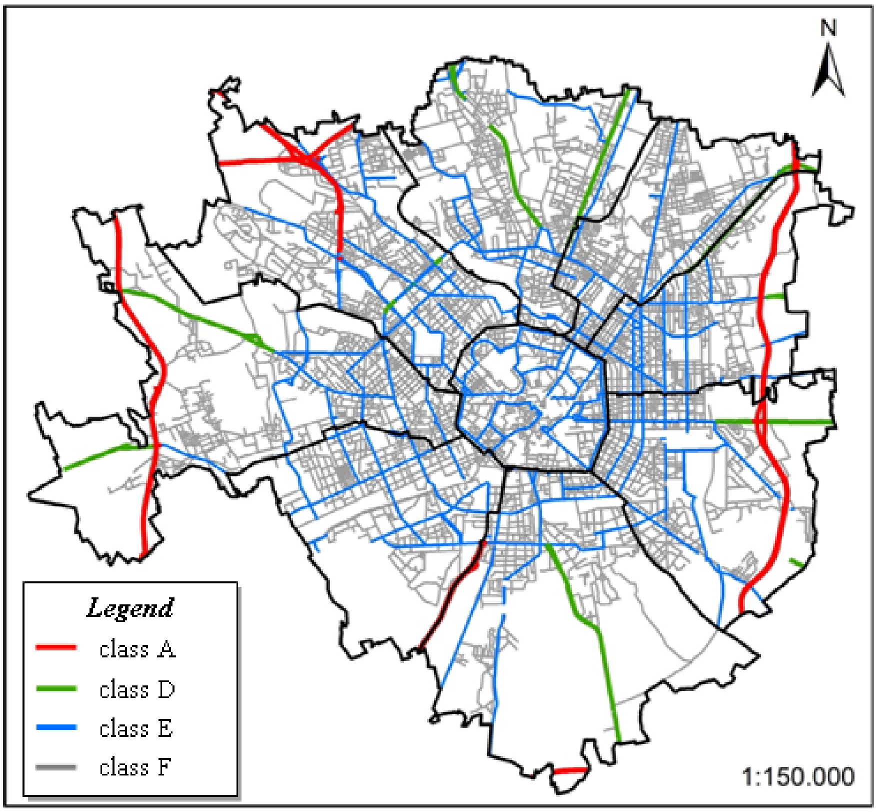

Figure 5. The road's categories of Milan.

5. Traffic flows

The opportunity of applying a statistical method (as provided by the project DYNAMAP) for the description of the entire urban road network requires that, in addition to the acoustic information relating to a road stretches, a "non acoustic" parameter is found to complete the description of all edges of the road network.

The parameter most easily obtainable and directly comparable with the acoustic data is the daily vehicular traffic, expressed in number of vehicles/h and referred to each stretch of the road network.

The data traffic flows can be obtained using two approaches:

- modeling approach, based on origin-destination matrices;
- experimental approach consisting in on-site measurements.

The modeling approach estimates the rate of traffic flow using a statistical model of calculation made for specific mobility's studies by AMAT (Agency of mobility, environment and territory of Milan). The data provided by this model has the advantage of being extended to all road stretches, but on the other hand the data extrapolated are affected by the confidence limits connected to the modeling approach.

The experimental approach is instead performed simultaneously with the campaign of acoustic monitoring and proceeds with the count of vehicular traffic flow through radar instruments, portable traffic analyzers or magnetic loops.

When possible, in addition to the numerical data of traffic flow (vehicles/h), more information were acquired about the traffic composition (number of light and heavy vehicles) and the average speed achieved.

A future phase will analyze the correlations between:

- acoustic data and traffic flow data;
- traffic flow data estimated by the simulation model and those obtained experimentally in situ for test the reliability of the model.

6. Production of a Geodatabase

All data presented were collected on a GIS platform and inserted into a relational geodatabase (DBMS) purposely created. This tool, containing the acoustic data, the data of traffic flows and the georeferenced position of the measuring points, also collects and integrates a large series of information that may be useful for further consideration and elaboration. In detail, these informations are specifically:

- the identification code of the measurement;
- the type of monitoring units used;
- the date and the duration of the measure;
- characteristics of the measurement stations (microphone height, reflective surfaces and obstacles, the distance between the noise source and the roadway edge);
- information about the road monitored such as identification code, name and functional class of the road;
- photographic documentation;
- presence of structures (schools, hospitals, rest homes, etc.) in the neighborhood.

7. Conclusions

This paper briefly explains the various activities that have allowed the creation of the noise data collection, that will be used in the next stages of the DYNAMAP project.

The geodatabase obtained is currently the largest collection of acoustic trend referred to the road network of the city of Milan and it's an important basis for any future processing.

Specifically, in the context of the DYNAMAP project, the collection of data will be the basis for the statistical analysis of the road network in Milan and will represent a useful tool for the future sizing of the low-cost sensors monitoring network.

In the future, the amount of data collected will be increased and the database could be used for other processing and purposes. The collection of traffic noise trends could be also shared and compared with data obtained in others urban areas.

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