Guideline for monitoring noise from road infrastructures

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ABSTRACT

ISPRA has issued a guideline aimed to provide specific criteria for monitoring noise from road infrastructures in the field of EIA – Environmental Impact Assessment. Actually, monitoring procedures are not available in the EIA process for this noise source. For this purpose, the guideline gives general methodologies to be followed for planning, designing and carrying out the noise monitoring of road infrastructures. Nevertheless, monitoring activities should have as their main feature combining all information needed to assess the noise pollution data, as well as to comply with the EIA-prescriptions, validate the results of the Environmental Impact Study, verify the effectiveness of mitigation measures, obtain time series data and managing the people complains.

1. INTRODUCTION

The Italian National Institute for the Protection and Research (ISPRA) has prepared Guidelines on road traffic noise monitoring, aiming to provide specific guidance for the monitoring of noise from road transportation infrastructure, including those subjected to the procedure of Environmental Impact Assessment (EIA).

In the Italian regulatory framework on noise pollution, the art. 10 of D.P.R. n.142/04 provides generally that the noise monitoring systems for road infrastructures have to be made in accordance with the directives issued by the Ministry of the Environment and that the managers of the infrastructures will provide these systems basing on their tasks and using the ordinary budget.

The guidelines provide, therefore, the general criteria and methods to draw-up plans, designs and to carry out acoustic measurements, once the road is built or in the operational phase, in order to comply with the requirements of EIA and follow-up to the above-mentioned D.P.R..

2. OBJECTIVES OF THE ACOUSTIC MONITORING

The acoustic monitoring of road infrastructure can be distinguished in:

1. monitoring on “a wide area”, with the following goals and objectives:
   ● verification of the limit values and/or target values - possibly provided by EIA requirements, more precautionary and able to assure the highest standards of
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- environmental quality - extended on the whole or at least the largely area interested by the effect of the project;
- Environmental Impact Study (EIS) assessment of the project, in order to: execute the post-operam monitoring in compliance to the Environmental Monitoring Plan (MAP); validate both the design conditions and the analysis performed in the noise impact assessment contained in the EIS (verifying the reliability of the forecasts made considering the modeling infrastructure simplifications and approximations and/or where the sound levels are estimated to be near the limit values (border-line points)).
- noise mapping drafting, as legal requirement for the managers of major roads in accordance with Legislative Decree n.194/20056.
- historical data acquisition that can characterize the performance of the noise levels in the long term, and to obtain information on the maintenance of noise protection features of the receivers.

To efficiently pursue these targets, monitoring should be understood as an integrated system that uses noise modeling tools, properly calibrated on real traffic through operating sound level measurements, allowing to extend the analysis of sound levels to the whole interested area and also addressing the choice of the monitoring points. The noise measurements can be carried-out with a sample method such as short-term measurements, and/or long-term measurements in significant points - possibly correlated each other - and they can be carried-out with mobile monitoring instrumentation and/or on fixed points.

2. “located” monitoring, used in the following cases:
- concurrence of more noise sources, to better identify the emitting contribution of the interested source.
- management of warnings/ complaints (in such cases, monitoring should be carried out according to DM 16/03/1998);
- verifying the effectiveness of mitigation designed, including direct interventions to the receivers;
- verification of the compliance of EIA prescriptions.

Another aspect to keep in mind in monitoring, in order to apply an integrated approach, regards the acoustic maintenance of the mitigation measurements whose performance tend to decrease with the time. This item, which is beyond the PMA purpose, is part of the infrastructure maintenance plan.

3. STRUCTURE AND COMPONENTS OF THE MONITORING SYSTEM
The monitoring system, thought as a system of elements, activities and tools all integrated each other, is made, in function of the purpose and complexity of the monitoring, by the following strictly and interconnected factors:
- noise monitoring stations;
- weather monitoring stations;
- traffic detection systems;
- Data Processing Center (EDC);
- Noise prediction models.
A. Noise monitoring stations

The station for acoustic detection is the only element of the system is always present in the monitoring point. We can identify two types: fixed stations and mobile stations.

The fixed stations are generally constituted by a waterproofing box for outdoor uses, containing the sound meter instrumentation and special transmission equipment permanently connected with the Data Processing Center. This type of stations require electricity power connection and, probably, an appropriate structures (eg pole to support the box). The fixed stations are generally used to perform long-term measures.

The mobile stations are constituted by equipment with a sufficient amount of memory to store the monitoring noise data for several days, with the possibility to operate periodically data unloading. A autonomous power supply (batteries) is needed to feed these stations so they can operate even if power supply is missing. The measuring instrumentation are normally placed within mobile means specifically adapted, for example, with telescopic poles for the positioning of the microphone, or suitable suitcases/boxes to be placed on a pole used as a support. The mobile stations are generally used for medium and/or short-term measurements (spot).

The monitoring system requires several precautions. In particular, the measuring instrumentation system must have the following requirements:

- an auxiliary power supply through the use of back-up batteries;
- the possibility to operate in off-grid (automatic transmission of alarms to the EDC)
- always need to have sufficient free memory for storing data (thus avoiding overwriting the recorded data).
- comply with article 2 of DM 16/03/1998 (class 1 of IEC 61672).
- filters and microphones used in compliance, respectively, with CEI EN 61260 and CEI EN 61094.
- calibrators must be in accordance with CEI EN 60942 for Class 1 (the measurements are valid if the calibrations differ by at most 0.5 dB.
- certificate of calibration for instruments and measurement systems (they must be renewed every 2 years by an accredited laboratory).

B. Weather monitoring stations

Weather information are essential not only to validate the acoustic data monitored, but also to assess the effects of atmospheric conditions on the noise propagation (e.g. favorable noise propagation conditions).

The noise level measurements must be carried out in accordance with the provisions of paragraph 7 of Annex B by DM 16/03/1998, or under the following conditions:

- lack of precipitation;
- absence of fog and/or snow;
- wind speed <5 m / s;
- microphone equipped with a windshield (for use outdoors);
- compatibility between the weather conditions during the measurements and specifications of the measuring system in Class 1 of IEC 61672-1.

In relation to the above points, it is necessary to obtain the following weather data during the measurement period, useful for the validation of the same measurements:

- atmospheric precipitation (mm);
- prevailing direction (degrees relative to North) and maximum wind speed (m / s);
- relative humidity (%) and temperature (° C).
The minimum characteristics of measuring instruments are as follows:

- for the wind speed resolution $\leq \pm 0.5$ m/s;
- for the wind direction resolution $\leq \pm 5^\circ$;
- sampling frequency of the direction and wind speed such as to ensure the production of an hourly average value and return the value of the gust of wind, generally time-base 10 minutes for the short-term measurements and 1 hour for long-term measurements;
- for the temperature, the instrumental uncertainty $\leq \pm 0.5$ °C;
- the relative humidity, the instrumental uncertainty $\leq \pm 10\%$ of nominal value.

Weather data can be acquired from a remote sensing fixed installed at the location of acoustic monitoring station, or information retrieved from databases (such as Aeronautical Military Service, SCIA9, etc.).

C. Traffic detection systems
There are several possible solutions for the detection, classification, and monitoring of the traffic:

- the simplest keyboard-equipment for manual counting of vehicles (sample-monitoring assisted by operator and carried out in significant days and periods);
- systems with centralized management for vehicle census with electromagnetic sensors (coils), possibly associated with piezoelectric sensors for dynamic weighing;
- the most advanced portable video systems or radar detectors suitable for both temporary and permanent detections, installed on structures standing above the road.

The architecture of a system for traffic detection, with the exception of manual counting, generally involves:

- detection Systems data (sensors of various types);
- device data acquisition from the sensors;
- wiring for the connection between sensors and devices;
- for monitoring of long duration, wiring for power supply connection or devices capable to ensuring sufficient power autonomy (eg photovoltaic panel);
- center of general supervision and its communication system.

Since the detection system have to allow traffic to correlate the data traffic flow with the measurements of noise, the minimum data set to acquire is the following:

- Traffic flow with detail schedule, in order to identify the total number of vehicles of different periods of the day (day, evening, night), usually distinguishing by category (cars, vans up to 35q, means of three 35-q);
- Average speed of transits by category.

The place of installation of the system will be evaluated, taking care to identify a representative section of road (traffic flow being measured). For radar systems must also be verified that there are no elements (trees, buildings, etc.) that clog-up the radar “vision” on the road.

D. Noise prediction models
The predictive models can also be used to extend, on a wide area, the results of an acoustic monitoring. In fact, the use of mathematical models associated with the acoustic monitoring is absolutely indicated to obtain a homogeneous evaluation of the sound levels in case of the
investigated area has an extension or a complexity that makes potentially ineffective or extremely costly a noise levels assessment with only monitoring instrumentation. Moreover, an integrated models-measures approach for noise assessment is useful when we are in presence of more infrastructures of transport and/or territorial complex morphology.

The combined technique, consisting synergistic use of experimental measurements and numerical modeling makes it possible to produce an accurate description of spatial-temporal distribution of sound levels for the entire extension of the object of study. Mathematical models have to determine the noise indicators required by the regulations, or the equivalent level LAeq referring to day (06 ÷ 22) and night (22 to 06) and, with aims to drafting acoustic mapping, the level Lden (day/evening/night level) and Lnight as defined by Legislative Decree n.194/2005 (transposition of European directive 2002/49/EC). In reference to the implementation of Legislative Decree n. 194/2005, it is suggested the use, as a model for the source road, the French standard "NMPB Rou-tes 96".

The application of predictive models typically requires a series of operations:

1. Identification and characterization of noise sources (interested source and any other sound sources in the area under investigation; individuation of homogeneous sections of the road in terms of structural characteristics and traffic);
2. Mapping and planimetry of the investigated area.
3. Location of the monitoring points in significant and homogeneous sections (source-oriented reference point and receiver-oriented control point) and in situ monitoring;
4. Sources modeling;
5. Environment modeling (3D modeling and acoustical properties of the ground surface in the interested area);
6. Calibration of the calculation model and validation of the results by comparison with the measurements referred to in previous point 3;
7. Calculation of noise levels at the points of interest and / or noise map in plan, section and / or in front (with any estimate of overall uncertainty of the model calculation or expression of the uncertainty of the results obtained).

Regarding the uncertainty of the prediction model, it should be noted that the accuracy of the results is influenced by several factors; following are reported the main factors that contribute to the uncertainty final (as set out in the UNI 11143-1):

- presence of multiple acoustic sources in the study area.
- input data for the calculation model (sound power, noise sources directivity, source modeling).
- assumptions on which is based the calculation model (representation of geomorphological and weather conditions, reflection and diffraction).
- wideness of the investigated area by the model, ie the maximum distance of the evaluated points from the sources.

It is important to underline that the noise data used for calibration and verification of the model are affected by uncertainty due to the uncertainty of the instrumentation, the duration of the measurements, the characteristics of the source (variability of noise levels) and the environment (weather conditions, soil conditions, etc..). For the uncertainty assessment of the measurements are available the technical rules UNI ISO 1996² or UNI / TR 11326³.

Relating to the measuring process, the positioning of the microphone shall be made in accordance with the conditions reported in DM 16/03/1998:
- In the case of measures to *receiver-oriented* (control point), the height of the microphone is 4 meter from the ground and at 1 meter distance from the façade of the building; in the absence of buildings, or in case of buildings high less than 4 meters, the microphone must be positioned at 1.5 meter from the ground (height taken as a reference standard for the human ear).
- In the case of *source-oriented* (point of reference), the choice depends by the relative position of the microphone between measuring point and monitoring source. Empirically, it has been noted that it is better measuring positions at 3 meters from the ground.
- in order to comply with the Legislative Decree n.194/2005, the measures must necessarily be related to a height of 4 meter from the ground and the measured value must be relative to the single incident energy (microphone positioned at least at 2 meters from the façade of the building, or 1 meter considering the reflection that increases the sound levels measured by 3 dBA and, consequently, the levels used for the determination of the values of noise mapping will be decreased by 3 dBA).

The weather probe position, in cases of weather station integrated with noise monitoring system, have to be chosen as close as possible to the microphone, at least 5 meters from interfering elements that can produce turbulence, in a good position to receive wind from all directions and with a height of at least 3 meters from the ground.

### 4. DATA ACQUISITION, PROCESSING AND TRANSMISSION

The main data measured by the instrumentation is the $L_{A_{eq,1s}}$ (acquired with time constant Fast or “short $L_{A_{eq}}$”), from which we get the $L_{A_{eq}}$ on hourly basis.

All acoustic parameters useful to describe the noise level (daily and weekly $L_{A_{eq,TR}}$, $L_{day}$, $L_{night}$, etc ...) and/or to verify compliance with the limit values are obtained processing the hourly $L_{A_{eq}}$.

For levels $L_{A_{eq,TR}}$, measured in order to assess compliance with the legal limits values, the measurement must be performed as specified in section 2 of Appendix C of the DM 16/03/1998; in this case the uncertainty of measurement is given by the only contribution of the instrumentation. In all other cases in the guidelines are indicated “long-term” or “short-term” measurement techniques. It also recommended to use other indicators such as “time history” of the $L_{A_{eq}}$ possibly associated with the statistical percentile levels $L_n$, the maximum and minimum levels, the spectra in octave for frequencies from 0.02 to 20 kHz.

The data acquired by the instrumentation can be inserted into the database of the monitoring system through one of the following methods:

- Manual entry of the data file, prior to processing.
- Manual entry of the data, downstream processing.
- Automatic insertion of data through a radio transmission (analogic/digital) or phone line (landline/mobile).

### 5. REPORTING AND INFORMATION

Once activated the monitoring system, in order to disseminate and publicize the acquired data, it is expected that the managing body draws up periodic detailed technical reports addressed to the institutions involved in various capacities on the subject, such as the National Institute for the Protection and the Environmental Research (ISPRA), the Italian Regional Agencies for Environment Protection, the technical departments of the Italian Regions, the Provinces and the interested municipalities.
Similarly, the controlling and verifying authority, will provide to stakeholders a periodic report about the verification activities performed. The guidelines\(^1\) provide in attaching a format of report that the manager must be release, containing the main monitoring information such as: measures by fixed stations, measurement campaigns with mobile instrumentation and studies obtained using computational models and results with technical conclusions. The guidelines\(^1\) also shows the data included in the reports drawing up by verification authorities.

### A. Public information

The environmental data obtained through the monitoring system have to be accessible to the public. The task of disseminating the data competes to public authority, or the state governments, regional, local, and special autonomous companies, public authorities and concessionaires of public services. The following figure shows the pattern that the information flow. These data can be verified by the subject in charge of checking the efficiency of the system.

![Diagram](image.png)

**Figure 1:** Public information flow among several subjects involved.

### B. Management of people complaints

An adequate system for the management of people complains is provided, in accordance with two different channels: they can be forwarded to the municipal administration with territorial jurisdiction, or presented directly to the infrastructure manager. To facilitate communication among stakeholders, a format should contain at least the following information:
- Indication of the complainant (name, committee / association);
- complainant address and/or indication of the noisy area;
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- Date of the complaint;
- Where applicable, the date of the noisy event;
- Time/periodo of the disturbing noisy event;
- Possible cause of the disturbing event (e.g., damage to the mitigation measures, low maintenance of the road surface, etc.).
- Characteristics of the disturbing event (e.g., high noise level, episodic noise, frequency of episodes, etc.).
- Type of the receivers (home, office, school, etc.).

The manager, upon receipt the complaint, will act to take the necessary measures to provide an adequate response to the complainant.

6. CHECKING MONITORING EFFICIENCY

In order to determine the overall quality of the noise pollution monitoring, procedures can be defined for system verification, based on two important aspects:

- Verification of requirements: the activities are directed to ensure that all components of the monitoring system are properly installed and able to carry out the provided functions;
- Checking the efficiency: the activities are addressed to ensure that the monitoring system provides to maintain reliable data with the time and it is able to determine the noise levels.

The description and the results of the verification activities, carried out by an auditor, have to be contained in a specific report that is summarized in an Appendix on the guidelines¹.

7. CONCLUSIONS

ISPRA and the Regional environmental agencies system have been involved in the assessment and monitoring of noise level for linear transport infrastructures such as road. The proposed procedures, intended as a standard for the agencies and for the same management companies, have been developed to homogenize the monitoring approach and filling a gap in the regulation regarding acoustic monitoring of roads, including projects under EIA procedure.

Such procedures, actually, have been developed to match the legislative rules in the field of noise pollution with the operational practice, by means of simplifying the methodologies in terms of time, resources employed and costs, as well as ensuring the same reliability in the measured results.

REFERENCES

1. ISPRA, “Guidelines on road traffic noise monitoring”.