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Determining environmental noise measurement uncertainty in the context of the Italian legislative framework

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ABSTRACT

This paper aims to demonstrate the importance of uncertainties in the measurement of environmental noise in the context of Italian legislation on noise pollution focusing the attention on the variability of the measurand as a source of uncertainty and offering a proposal for the evaluation of uncertainty for traffic noise measurement. In particular, drawing on a real traffic noise dataset, firstly outliers are eliminated from the actual noise measurements using an outlier detection algorithm based on *K*-neighbors distance and then uncertainty range is estimated with the bootstrap-*t* method. Since the original sequence was Gaussian, this range was compared with the confidence interval of the mean ± standard deviation interval and two intervals were almost coincident.

1. Introduction

Currently there is considerable interest in the problem of noise pollution. This is because of the high numbers of people who could be potentially be negatively affected by this phenomenon. A number of studies demonstrate that high levels of sound pressure can damage people's health in a variety of ways, making initiatives to control noise a study of key importance to society [1,2].

In Italy, the law establishes maximum limits of acceptable environmental noise levels based on the following equation:

$$L_{eq} = 10\text{Log}\frac{1}{T}\int_{T}\left[\frac{p(t)}{p_{rif}}\right]^{2}\mathrm{d}t$$

2. Italian legislative framework on noise pollution

Italian legislation on noise pollution was developed from the beginning of 1990s through the establishment of a general law with supporting decrees. There follows a brief description of the main pieces of legislation.

The Decree of the President of the Council of Ministers of 01/03/1991 "Maximum limits of exposure to noise in residential areas and outdoors" is the first piece of legislation act adopted by Italy to regulate and control noise pollution. The Decree of Council of Ministers President of 1 March 1991 was subsequently integrated into the General Law Act No. 447/1995. The decree determined immediate steps required to safeguard the quality of the environment and human exposure to noise across six categories of urban area provides and sets out the basic principles for management of the external and indoor environment. The General Law on noise, in addition to concepts contained in the Decree of the President of the Council of Ministers of 01/03/1991, has 17 articles and establishes the basic principles regarding the protection from noise pollution of external environment and indoor environment; it defines the responsibilities of public administrations, and of public and/or private entities that may be the direct or indirect cause of noise pollution.

A number of other decrees have been promulgated to regulate limits for sound sources, techniques for detecting and measuring noise pollution and management of noise levels from transport infrastructure (Appendix A).

In summary, the main decrees and regulations to which we must pay particular attention are:

- Law 26 October 1995, no. 447 "Law on Noise Pollution framework".
- Decree of 11 December 1996 "Application of the differential criteria for continuous production cycle plants".
- Decree of Council of Ministers President of November 14, 1997 "Determination of limit values of sound sources".

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- Decree of 16 March 1998 “Techniques for detecting and measuring noise pollution”.
- Legislative Decree 81/2008 Title VIII – Chapter II “Protection of workers against the risks from exposure to noise at work”.

3. Measurements and limit values

It is important to emphasize that any comparison between a measured value and the maximum levels permitted in law is a complex matter. This is because this is not a comparison between two fixed numerical values since a measurement is only an approximation or estimation of the value of the measurand. It is essential to take into account the uncertainties associated with the measurement, as reported for international technical standards [3], because uncertainties are a quantitative indication of the reliability of the result.

The values below the limit are defined as being in a specification zone, that is range in which different levels below the maximum are tolerated. The uncertainty, associated with a measured value, is known as the confidence zone (see Fig. 1).

In order to evaluate compliance of near limit values it is necessary to establish some rules, which essentially add or subtract the uncertainty from the limit in order to create an acceptance zone, also known as guardband [4,5].

Simple acceptance and simple rejection rules are the most basic.

The first establishes that the result of a measurement is compliant if it falls within the specification zone (Fig. 2: cases 1 and 2) while the second establishes non-compliance if a result of a measurement falls outside the specification zone (Fig. 2: cases 3 and 4).

The probability that a decision based on these basic rules may be erroneous can be very high, up to 50% if the estimated value coincides with a lower or upper limit value (Decree of Council of Ministers President of 14/11/1997).

Stringent acceptance and stringent rejection rules do not take account of ambiguous results, those for which the lower or higher limit value of specification zone is within the range of confidence zone (Fig. 3: cases 2 and 3).

The stringent acceptance rules state that the result is compliant if the entire measurement including the confidence zone lies within the specification zone (Fig. 3: case 1), minimizing the risk of a erroneous acceptance. On the other hand, stringent rejection rules only consider non-compliance for those measurement that fall entirely outside the specification zone including allowance for the confidence zone (Fig. 3: case 4), minimizing the risk of a false rejection.

The relaxed acceptance and relaxed rejection rules are less precise because they allow for greater flexibility around whether a measurement is compliant or non-compliant, when the lower or higher limit value of specification zone is within confidence zone (Fig. 4: cases 2 and 3).

The relaxed acceptance rules state that the result of a measurement is compliant if it is not outside the specification zone including the confidence zone (Fig. 4: cases 1, 2, 3), minimizing the risk of a false rejection, The relaxed rejection rules state that the result of a measurement is not compliant if it is outside the specification zone with all the confidence zone (Fig. 4: cases 2, 3, 4), minimizing the risk of a false acceptance.

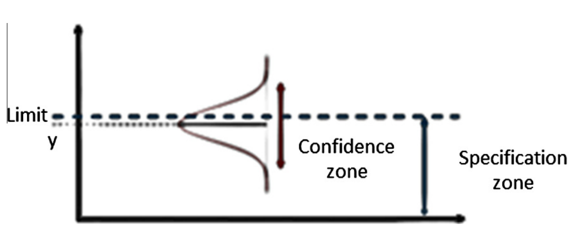

Fig. 1. Specification zone and confidence zone.

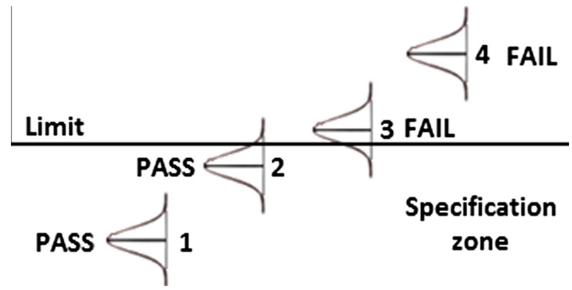

Fig. 2. Simple acceptance and simple rejection rules.

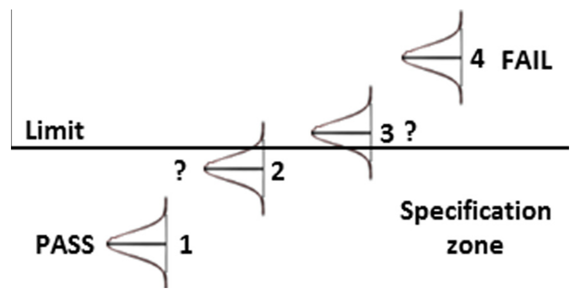

Fig. 3. Stringent acceptance and stringent rejection rules.

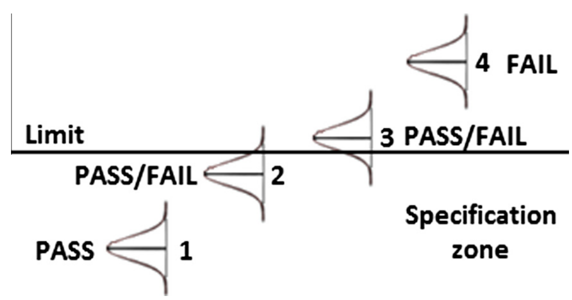

Fig. 4. Relaxed acceptance and relaxed rejection rules.

In the field of environmental acoustics the choice of decision rules depends on the purpose of the evaluation. In particular, to protect the receiver, stringent acceptance + relaxed rejection rule (Fig. 5) is chosen, and, to protect the source, relaxed acceptance + stringent rejection rule (Fig. 6) is chosen.

In any case, the determination of measurement uncertainties is necessary to quantify the probability of the success of a choice.

4. Sources of uncertainties in environmental noise measurement

In recent years there has been considerable interest amongst the scientific community and experts in the field of acoustics about the quantification of environmental noise measurement uncertainties [6–9]. In particular, there has been close examination of possible sources of uncertainties associated in this area i.e. characteristics of measurement instrumentation [10,11], variability of the measurement conditions [12,13], and instrumentation calibration [14].

An example of application of the Guide to the Expression of Uncertainly in Measurement (GUM), which involves statistical