# TIME VARIABILITY OF URBAN NOISE AND ESTIMATE OF ITS LONG TERM $L_{Aeq}$ LEVEL

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## ABSTRACT

The proposed European Directive on environmental noise requires that noise descriptors must be determined on annual basis. To reduce the resources for such a long period of monitoring, temporal sampling techniques are usually applied. By this sampling the long term $L_{Aeq,LT}$ level is estimated from the $L_{Aeq}$ data measured on shorter periods. As the accuracy of the $L_{Aeq,LT}$ assessment decreases with the increase of the temporal fluctuation of sound levels and with the reduction of the measurement time, the choice of the most appropriate sampling method is crucial, especially for road traffic noise because this is a typical random phenomenon.

The paper deals with the above issue and describes the results of the statistical analyses carried out on an experimental data base, containing the $L_{Aeq}$ levels for the day- and night-time periods, measured continuously during the course of one year in 9 sites inside urban areas. The analyses provided useful information on the variability of $L_{Aeq}$ levels and the accuracies of the long term $L_{Aeq,LT}$ estimated values achievable by three different temporal sampling methods.

## INTRODUCTION

The proposed European Directive on the assessment and management of environmental noise requires that the descriptors $L_{den}$ and $L_{night}$ must be determined on annual basis [1]. Such a long period is also often taken as reference in the numerical models for the prediction of outdoor noise in order to deal with more stable $L_{Aeq}$ values. However, unattended automatic instrumentation systems for monitoring the noise continuously on long term are expensive and, therefore, their use is limited to special applications, such as the aircraft noise monitoring in the surroundings of large airports. In most of the cases the long term $L_{Aeq,LT}$ is not measured directly, but it is estimated from the $L_{Aeq}$ values collected over shorter periods, usually daily or weekly, the duration and occurrence of which are the parameters of the chosen temporal sampling method. The accuracy of the $L_{Aeq,LT}$ estimated value decreases with the increase of the time variability of the $L_{Aeq}$ levels and with the reduction of the total measurement time TM. Therefore, the greater the time variability of $L_{Aeq}$ and the shorter the TM, the more crucial is the choice of the appropriate temporal sampling method able to provide a $L_{Aeq,LT}$ estimate within a prespecified accuracy. This problem often occurs when dealing with road traffic noise, which is typically a random phenomenon. This source, being the most diffuse in space and time (especially in urban areas), has a large impact on the exposed population. Because of the importance of road traffic noise, in the middle of '90s permanent monitoring systems formed by fixed measurement units were set up in a few Italian towns (i.e. Genoa, Milan, Trento), mainly to survey the most noisy roads. However, because of their high maintenance cost and considering the good repeatibility shown by the noise data on annual term, these systems were later redesigned to replace the fixed measurement units with easily removable or mobile ones to improve their cost/benefit performance.

The present paper deals with the the variability of the day- and night-time $L_{Aeq}$ levels and the accuracy of temporal sampling methods to estimate the $L_{Aeq,LT}$ from $L_{Aeq}$ levels. The main results of the statistical analyses performed on the noise data monitored for a year by the permanent automatic systems implemented by the Provinces of Genoa and Trento in 9 sites located in 3 towns are described. In particular, three different temporal samplings, namely continuous measurement for all the day- or night-time period, for all a week and for two consecutive weeks, were considered and the corresponding accuracies of the $L_{Aeq,LT}$ estimated values have been determined.

## EXPERIMENTAL DATA AND ANALYSIS

The experimental data, provided by the Provinces of Genoa [2] and Trento [3], were collected by permanent automatic systems in 3 towns, namely Genoa (A), Trento (B) and Rovereto (C). In the 9 sites monitored (7 in Genoa and one in each of the other towns) the $L_{Aeq}$ levels for the day- and night-time periods were measured continuously for a long period to cover roughly an entire year. A summary of the data set is given in Table I, where for each site and measurement period the number *N* of the $L_{Aeq}$ values available and the standard deviation *s* of these values are reported for the three temporal sampling methods considered. The long term $L_{Aeq,LT}$ level, computed from the set of the day- or night-time $L_{Aeq}$ levels, is also given.

Table I – Summary of the experimental data

| City | Site | Period | $L_{Aeq}$ values | Duration of the temporal sampling | | | $L_{Aeq,LT}$ dB(A) |
|---|---|---|---|---|---|---|---|
| | | | | 1 day | 1 week | 2 weeks | |
| A | 1 | Day (D) | N. (s dB) | 359 (1.26) | 50 (0.59) | 24 (0.55) | 75.4 |
| | | Night (N) | N. (s dB) | 359 (0.70) | 49 (0.43) | 24 (0.40) | 70.6 |
| | 2 | D | N. (s dB) | 362 (1.64) | 50 (1.14) | 25 (1.06) | 75.4 |
| | | N | N. (s dB) | 364 (0.66) | 52 (0.43) | 26 (0.39) | 69.7 |
| | 3 | D | N. (s dB) | 312 (1.43) | 40 (1.13) | 19 (1.05) | 71.5 |
| | | N | N. (s dB) | 313 (0.87) | 42 (0.70) | 20 (0.63) | 67.6 |
| | 4 | D | N. (s dB) | 346 (1.67) | 46 (1.29) | 22 (1.21) | 56.7 |
| | | N | N. (s dB) | 344 (1.81) | 45 (1.56) | 21 (1.45) | 52.8 |
| | 5 | D | N. (s dB) | 355 (1.42) | 47 (0.74) | 22 (0.60) | 66.1 |
| | | N | N. (s dB) | 356 (1.01) | 48 (0.60) | 23 (0.55) | 59.6 |
| | 6 | D | N. (s dB) | 335 (1.50) | 47 (0.74) | 22 (0.60) | 59.7 |
| | | N | N. (s dB) | 339 (2.18) | 46 (1.50) | 22 (1.33) | 56.1 |
| | 7 | D | N. (s dB) | 346 (0.95) | 45 (0.47) | 22 (0.44) | 75.5 |
| | | N | N. (s dB) | 348 (0.72) | 47 (0.47) | 23 (0.43) | 70.8 |
| B | 8 | D | N. (s dB) | 336 (1.51) | 39 (0.83) | 17 (0.78) | 68.2 |
| | | N | N. (s dB) | 335 (1.53) | 38 (1.23) | 17 (1.11) | 61.8 |
| C | 9 | D | N. (s dB) | 331 (1.14) | 36 (0.58) | 15 (0.55) | 68.3 |
| | | N | N. (s dB) | 332 (1.45) | 37 (0.99) | 16 (0.93) | 62.3 |

In most of the sites (7 out of 9) the road traffic noise was the predominant source, excepting site 4, located in a public green area inside the town, and site 6 where the noise from a steel plant was the main source.

The following three temporal sampling methods were considered for the analysis:

1) the day- or night-time $L_{Aeq}$ level, taken as the estimate of the $L_{Aeq,LT}$ level, which roughly corresponds to a TM/LT ratio of 0.3% for the analysed 18 data sets;

2) the weekly day- or night-time $L_{Aeq,W}$ level determined for a complete week, starting with Monday, corresponding to a TM/LT ratio of about 2.3% (averaged across the 18 data sets);
3) the fortnightly day- or night-time $L_{Aeq,2W}$ level determined for two consecutive complete weeks, corresponding to a TM/LT ratio of about 4.9% (averaged as above).

An example of the time series $L_{Aeq}$ values available for the analysis is given in Fig. 1, where the time series showing the smallest and largest standard deviation *s* of the $L_{Aeq}$ values are plotted. The gaps in the time series collected at the A6 site were due to malfunctions of the automatic monitoring system.

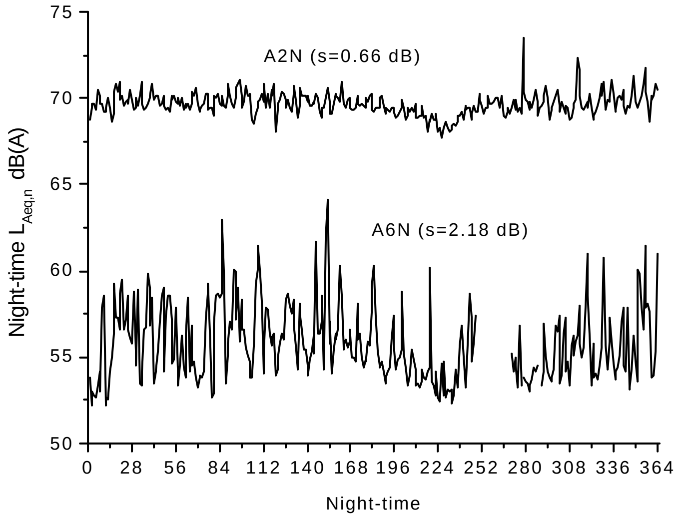


Fig. 1 – Examples of the time series of $L_{Aeq}$ values available for the analysis

## RESULTS AND DISCUSSION

The analyses made on the data were diversified to investigate the variability of $L_{Aeq}$ levels for different time periods (months, days) and the accuracy of the three examined temporal sampling methods to estimate the $L_{Aeq,LT}$ from $L_{Aeq}$ levels.

Regarding the variability of $L_{Aeq}$ levels, Fig. 2 shows the monthly averaged night-time $L_{Aeq}$ levels, and the corresponding standard deviation *s*, for the sites A2N and A6N above described. It can be seen that for most months the values are close one another and only in August there is a reduction of noise levels (on average 1 dB less than the $L_{Aeq,LT}$) , most likely due to the summer holidays. Same trends were observed for the other sites and for the day-time values.

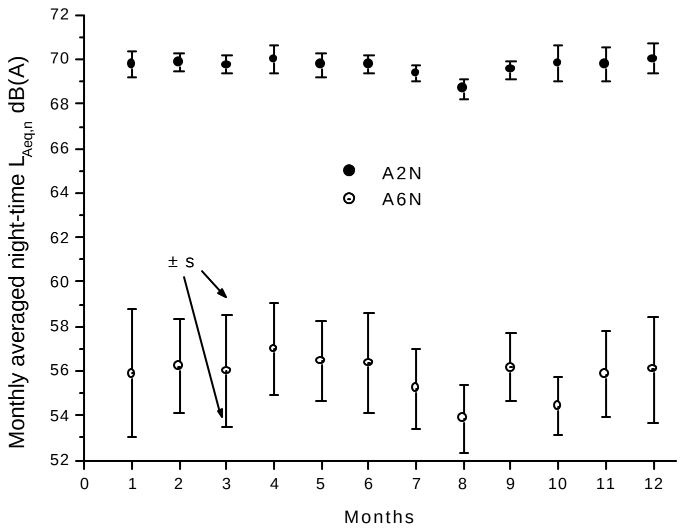


Fig. 2 - Monthly averaged night-time $L_{Aeq}$ levels observed for the sites A2N and A6N

Regarding the temporal sampling method 1), the differences between the day- or night-time $L_{Aeq}$ values and the corresponding long term $L_{Aeq,LT}$ were calculated; a summary statistics of these differences is shown in the box plot given in Fig. 3. The mean values (square dots in Fig. 3) lay within ±1 dB for all sites and differ from the median values (indicated by the line inside each box in Fig. 3) in most of the cases.

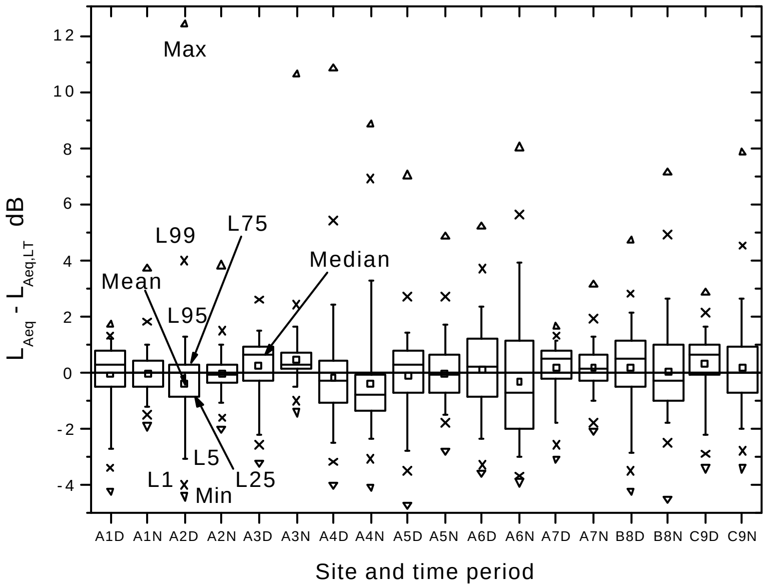


Fig. 3 – Box plot of the differences $L_{Aeq}$ – $L_{Aeq,LT}$

From a practical point of view it is also important to know the probability for the estimated $L_{Aeq,LT}$ value to lay within some specified range of accuracy. Fig. 4 shows the probability for the long term $L_{Aeq,LT}$ value, estimated from the day- or night-time $L_{Aeq}$ levels, to have an accuracy within a range of ±1 and ±0.5 dB. It is evident that this probability increases with the decrease of the standard deviation *s* of the $L_{Aeq}$ levels; in particular it increases by about 18% (or 13%) with every decrease of 0.5 dB in *s* for ±1 dB (or ±0.5 dB) accuracy range (see the regression lines in Fig. 4).

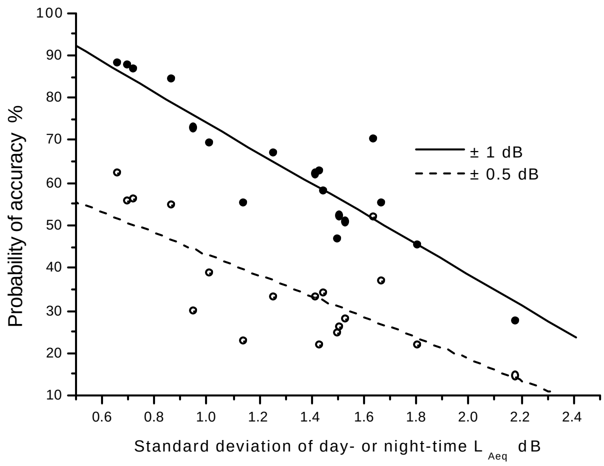


Fig. 4 – Probability of the accuracy of the long term $L_{Aeq,LT}$ value, estimated from the day- or night-time $L_{Aeq}$ levels, to lay within ± 1 and ± 0.5 dB

Among the days of the week, the best accuracy was observed for Tuesdays and Fridays (mean values of $L_{Aeq}$ -$L_{Aeq,LT}$ within ± 0.5 dB in 10 out of 18 data sets), whilst, as expected, the worst ones were obtained for Sundays (underestimates of $L_{Aeq}$ -$L_{Aeq,LT}$ in 14 out of 18 data sets).
The above analysis was repeated for the weekly $L_{Aeq,W}$ and fortnightly day- or night-time $L_{Aeq,2W}$ levels, determined according to the temporal sampling methods described in 2) and 3) respectively. As an example, Fig. 5 reports the box plot of the differences between the $L_{Aeq,W}$ levels and the corresponding long term $L_{Aeq,LT}$.

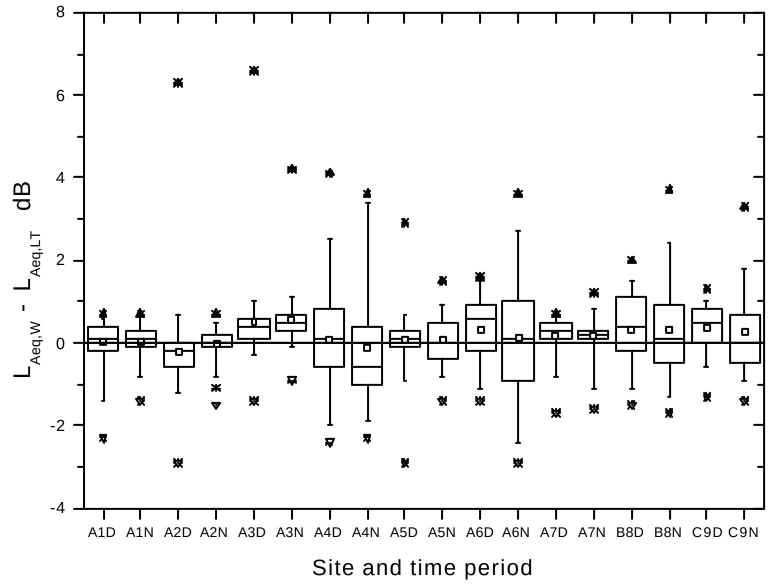


Fig. 5 - Box plot of the differences $L_{Aeq,W} – L_{Aeq,LT}$

As would be expected, the variability of these differences is reduced and, therefore, the accuracy of the $L_{Aeq,LT}$ estimate is increased. Fig. 6 shows the probability for the long term $L_{Aeq,LT}$ value, estimated from the weekly $L_{Aeq,W}$ and fortnightly $L_{Aeq,2W}$ levels, to have an accuracy within a range of ± 1 and ± 0.5 dB.

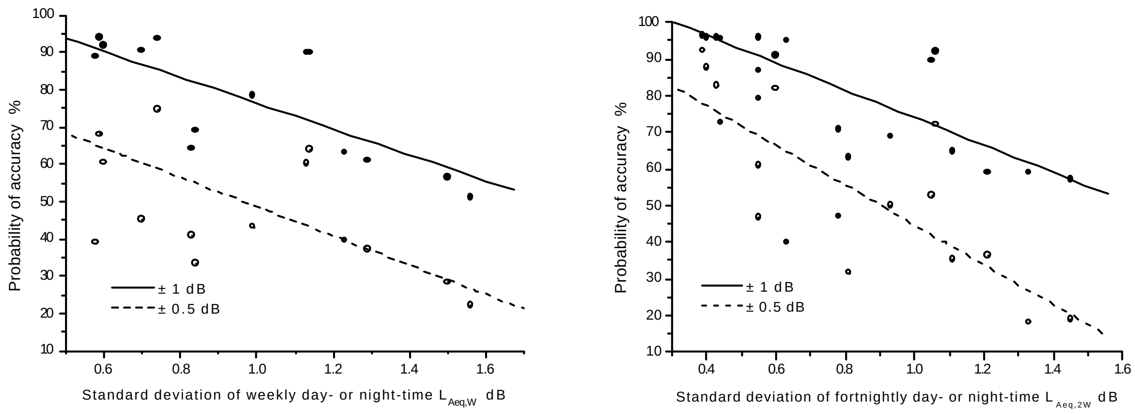


Fig. 6 - Probability of the accuracy of the long term $L_{Aeq,LT}$ value, estimated from the weekly and fortnightly $L_{Aeq}$ levels, to lay within ± 1 and ± 0.5 dB

This increase in the accuracy is also evident in Fig. 7, showing the reduction of the interquartile range (L75-L25) of the differences $L_{Aeq,TM}$ - $L_{Aeq,LT}$ against the standard deviations *s* of the $L_{Aeq,TM}$ values observed for the sites A2N and A6N. This reduction is due to the increase of the TM/LT ratio of the sampling method, from the minimum value of 0.3% (daily method 1) up to 4.9% (fortnightly method 3). The weekly method 2 is required at present by the Italian legislation for road traffic noise monitoring.

In order to design a valid and efficient temporal sampling the most common approach is to reveal the probabilistic nature of the time series $L_{Aeq}$ levels. This can be achievable by the time series modeling via the class of autoregressive moving average (ARMA) models, as shown in [4]. In general, when the $L_{Aeq}$ levels are statistically independent one another the number of measurement data required to get a prespecified accuracy for the $L_{Aeq,LT}$ estimate is less than that necessary when the independence criterion is not met. The autocorrelation of the Z-scores from the time series data can be used to test their statistical independence, as indicated in [5].

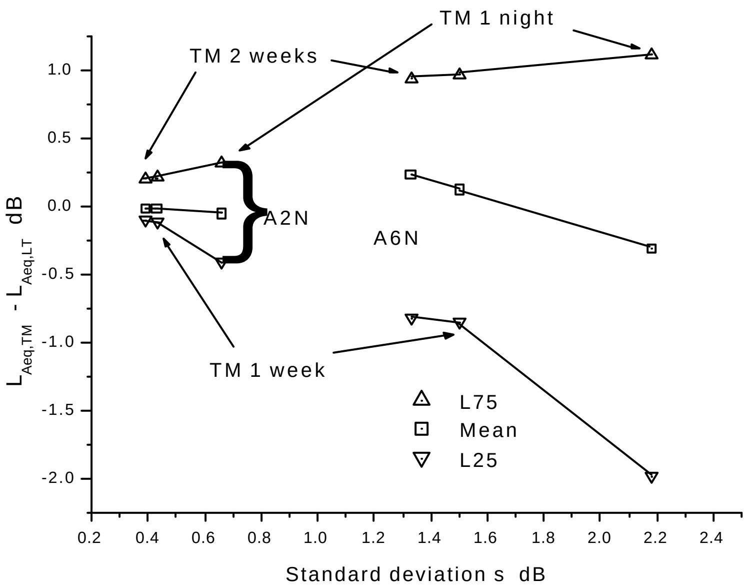


Fig. 7 - Interquartile range (L75-L25) of the differences $L_{Aeq,TM}$ - $L_{Aeq,LT}$ against the standard deviations *s* of the $L_{Aeq,TM}$ values

## CONCLUSIONS

The results of the descriptive analyses carried out on the 18 sets of urban noise data monitored all through an entire year provided useful information on the time variability of $L_{Aeq}$ levels and on the accuracies of the annual $L_{Aeq,LT}$ estimate. At this stage the weekly monitoring method appears to be a reasonable compromise between the resources involved in the monitoring and the accuracy of the annual $L_{Aeq,LT}$ estimate.

Further statistical analyses, aimed at revealing the underlying probabilistic nature of the time series noise data, are planned as they can provide more insights to improve the efficiency of the temporal sampling strategies.

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