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REMARKS ON THE HARMONICA INDEX FROM ITS APPLICATION IN SPECIFIC ENVIRONMENTS

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ABSTRACT

This paper describes some remarks and thoughts arising from the application of the Harmonica index (HRM) in specific acoustic contexts with low road traffic, namely mountain quiet natural areas in Aosta Valley, an alpine region in north-west Italy, and the worldwide known city of Venice with the particular feature of busy boat traffic.
The advantages of replacing the L_{A95eq} level with the percentile L_{A95} are outlined and some options are proposed to overcome the drawbacks of HRM observed in quiet areas when the background noise is very low.

Keywords: *Harmonica index, low road traffic environments, information to the public*

1. INTRODUCTION

The European directive 2002/49/EC relating to the assessment and management of environmental noise (END) requires "that information on environmental noise and its effects is made available to the public". To be effective, such information should be easy to understand for non-expert people and closely related to their sound perception. This has been the objective of the HARMONICA project [1], focused on developing the adimensional index Harmonica (HRM), which takes into account two main components of the environmental noise, namely its energy described by the background noise (BGN) and its fluctuation along time due to the noise events (EVT) that stand out from BGN.
This paper describes some remarks and thoughts arising from the application of HRM to specific acoustic environments with low road traffic, namely some mountain quiet natural areas in Aosta Valley, an alpine region in north-west Italy, and the worldwide known city of Venice for its peculiar characteristic of busy boat traffic. In particular, three aspects have been examined, dealing with:

- Time sampling of the sound level L_A;
- Replacing L_{A95eq} with the L_{A95} percentile in the HRM original formulation;
- Management of negative background noise values BGN, often observed in quiet areas.

The above issues are discussed with the support of data collected in the two considered environments, which are rather different from those used to develop HRM (urban areas).

2. MATERIALS AND METHODS

2.1 The Harmonica Index (HRM)

The adimensional Harmonica index HRM, set in its original formulation with values between 0 and 10, is based on the one-hour time series of 1 s short $L_{Aeq,1s}$ and calculated by:

$$HRM = BGN + EVT \quad (1)$$

where the background noise BGN is computed as:

$$BGN = 0.2(L_{A95eq} - 30) \quad (2)$$

being L_{A95eq} the equivalent level of the L_{A95} percentile time series values, where the first value in the series is computed

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referring to the 10-minute interval preceding the one-hour period start, and the subsequent values are updated every second by running along the time the 10-minute time window:

$$L_{A95eq} = 10 \cdot lg\left[\frac{1}{3600}\sum_{i=1}^{3600} 10^{(L_{A95i}/10)}\right] \quad (3)$$

$$\text{for } i = 1 \quad L_{A95(i-600,i]} \quad (4)$$

and the component describing the sound events EVT is calculated by:

$$EVT = 0.25(L_{Aeq,1hour} - L_{A95eq}) \quad (5)$$

Considering Eqns (2) and (5), Eqn (1) can be rewritten as:

$$HRM = 0.25L_{Aeq,1h} - 0.05L_{A95eq} - 6 \quad (6)$$

2.2 Time sampling of the sound levels L_A

A more general formulation of HRM can be devised as long as the time sampling of sound level L_A provides a number of samples sufficient to calculate the L_{A95} level with a preset accuracy [2].

Indeed, the original measurement time TM = 1 hour = 3600 s and 1 s short $L_{Aeq,1s}$ time sampling can be reduced by decreasing the time sampling. For instance, a time sampling of 125 ms provides 8 L_A values per second and, therefore, TM can be decreased to 3600/8 = 450 s = 7’30”. Thus, the width of the running along time window, still set to 1/6 of TM as in the original formulation, would be shortened to 600/8 = 75 s = 1’15”. A further option could be to include the running along time window in the measurement time TM, rather than setting it before the TM start.

The above approach can also be useful for estimating HRM for measurement times less than one hour, which is very frequent when time sampling is applied, instead of long-term continuous monitoring.

2.3 Replacing L_{A95eq} with the percentile L_{A95}

For the determination of L_{A95eq} it is necessary to define the width of the running along time window and computing its value by post-processing, because no current sound level meters provide such calculation. To avoid this drawback, a potential solution would be to use the L_{A95} percentile determined for the measurement time TM, instead of the L_{A95eq} level. This replacement has the advantage that L_{A95} is measurable by the current instrumentation. Thus, the determination of HRM value could be implemented directly into the instrumentation with the consequence of widening its diffusion in the sound measurement practice.

This issue has been investigated by using the experimental data collected in the environments considered in this study, as shown in the result section.

2.4 Determination of HRM in quiet areas

The original formulation of BGN (Eqn. 2) implies that positive values occur only for $L_{A95eq} > 30$ dB(A). This setting is most likely due to the typical sound environment in urban areas for which HRM was developed. In quiet natural zones, like those monitored in the mountains in Aosta Valley reported in this study, L_{A95eq} is often less than the 30 dB(A) threshold, leading to BGN negative values. Furthermore, low L_{A95eq} values increase the contribution of the EVT component (Eqn. 5) to the HRM value (Eqn. 1). The counterbalance of the BGN and EVT components when BGN is negative was investigated in this study.

2.5 Data processing

The data considered in the present analysis were selected from those collected by continuous sound monitoring in previous studies [3-4]. In particular, six sites have been considered:

- three in the Chamois town (in Aosta Valley, car-free and accessible only on foot, by bike, or by cableway) during some days in three seasons (summer, autumn and winter) in 2017-2018 (455 hourly intervals);
- three in Venice monitored in the same entire week in May 2022 (499 hourly intervals).

For all the above sites, the 1 s short $L_{Aeq,1s}$ time history was available and imported in the “R” software environment [5] by a specifically developed script used to determine the values of L_{Aeq}, L_{A95eq}, L_{A95}, BGN, EVT, and HRM on an hourly basis. Descriptive statistics of the results obtained was also carried out. The HRM hourly values were computed in all the sites, setting the 10-minute running along time window at the beginning of the 1-hour interval.

3. RESULTS AND DISCUSSION

Figure 1 shows the values obtained for the two components BGN and EVT. For the former negative values are observed for several hourly intervals in the Aosta Valley sites as they were monitored in very quiet areas, whereas in Venice sites only positive values were obtained. As expected, the EVT value, describing the sound events, increases with decreasing of BGN.

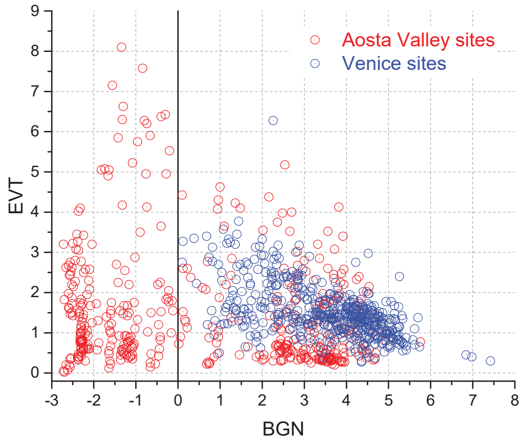

Figure 1. BGN versus EVT values obtained for the data set.

Figure 2 shows the hourly $L_{Aeq,1h}$ levels plotted versus the L_{A95eq} and HRM values determined by Eqn. (1), where the red and blue dots correspond to the Aosta Valley and Venice sites, respectively. The top plot reports also the linear regression between $L_{Aeq,1h}$ and HRM, which shows a very good Pearson's correlation coefficient ($r = 0.99$). HRM negative values are obtained in very quiet sites where $L_{Aeq,1h}$ is less than 30 dB(A).

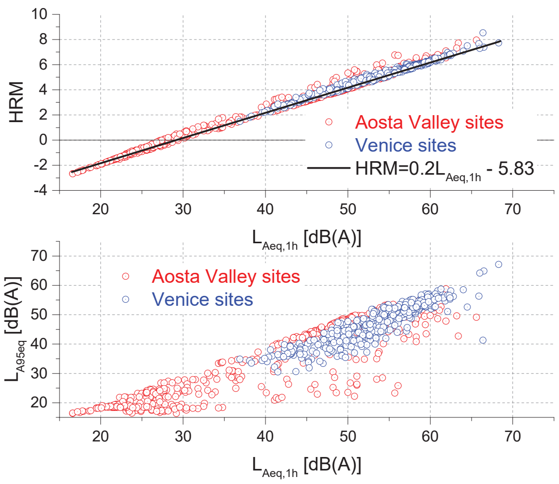

Figure 2. $L_{Aeq,1h}$ levels versus L_{A95eq} and HRM.

3.1 Difference L_{A95eq} - L_{A95}

The difference $L_{A95eq} - L_{A95}$ is negative only in 0.9% of all the 954 hourly intervals and never less than -0.2 dB(A). Thus, L_{A95eq} is very often greater than L_{A95} (Fig. 3), and in 87.7% of cases $L_{A95eq} - L_{A95}$ is within 0 ÷ 2 dB(A)). The differences are more spread in the Aosta Valley sites than those in Venice. However, for the former 80.6% of the differences are within 0 ÷ 1 dB(A), whereas 63.3% are in this interval for the latter. For the Venice sites 89.7% of the differences are within the range 0 ÷ 2 dB(A).

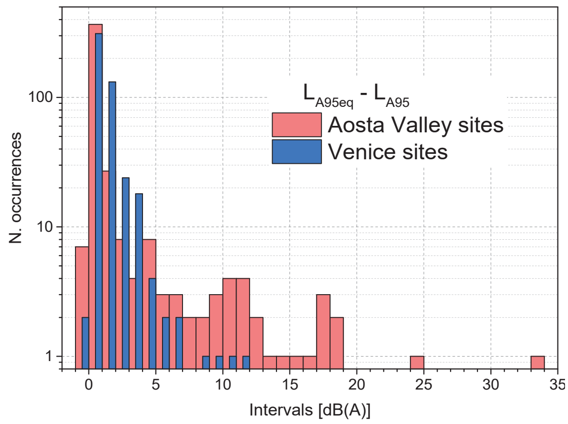

Figure 3. Histogram of the $L_{A95eq} - L_{A95}$ differences.

High values of the above difference are observed when a steady sound is present for a large fraction of the 1-hour interval, as shown in Fig. 4 for the case where $s_{LA} = 15.7$ dB(A) and the maximum value of the difference $L_{A95eq} - L_{A95}$ is 33.9 dB(A).

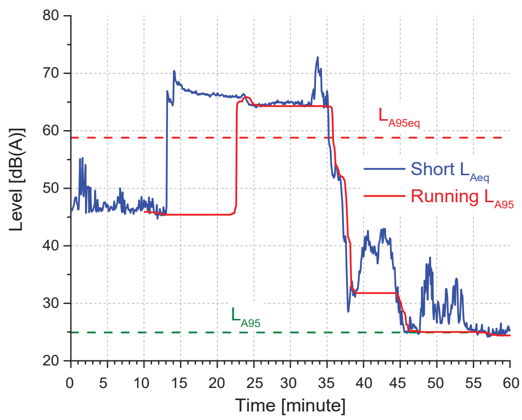

Figure 4. Example of the difference $L_{A95eq} - L_{A95}$.

Furthermore, the difference $L_{A95eq} - L_{A95}$ increases with the increasing of the standard deviation s_{LA} of the 1 s short L_{Aeq}. However, this trend has a small influence on the difference between the HRM value from Eqn. 1 and the one HRM_{95} computed by replacing L_{A95eq} with L_{A95}. Fig. 5 shows the differences between HRM – HRM_{95} plotted versus the standard deviation s_{LA}. It has to point out that this difference is almost always (99.1%) negative. Replacing L_{A95eq} with L_{A95} leads to higher values of HRM; therefore, HRM_{95} could be an acceptable precautionary approach. Even when HRM – HRM_{95} is positive, the difference is less than 0.2. For 84.1% of cases with $s_{LA} < 5$ dB(A), the largest difference HRM – HRM_{95} is -0.31.

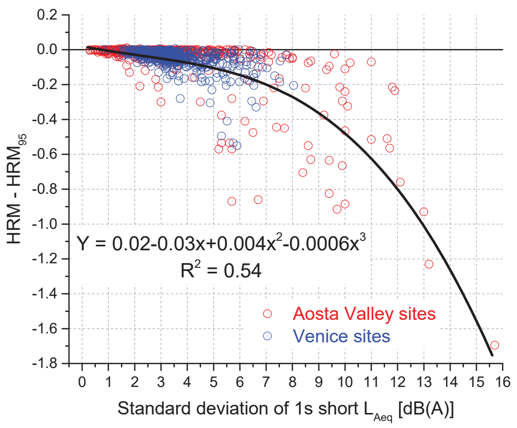

Figure 5. Difference HRM – HRM_{95} versus the standard deviation s_{LA} of the 1 s short L_{Aeq}.

The above outcomes support the option of replacing L_{A95eq} with L_{A95} in the HRM calculation, at least when the standard deviation of sound level s_{LA} is not too large and considering the advantage of a feasible implementation of HRM computation in the instrumentation.

3.2 Determination of HRM in quiet areas

In 21.4% of all considered cases (two sites monitored in Aosta Valley), the sound environment was very quiet, as shown in Fig. 6. Since the L_{A95eq} and L_{A95} are below 30 dB(A), according to Eqn. (2) BGN is negative.

In these situations, the sound events, represented by EVT, clearly stand out from the low background BGN ($\Delta = EVT - BGN$), potentially evoking an annoyance reaction. Unfortunately, the HRM value computed according to Eqn. (1) underestimates such a phenomenon and can itself become negative if BGN > EVT.

To overcome this drawback, a possible option would be to set BGN = 0 when it is negative and, therefore, HRM, denoted HRM_0 in Fig. 7 (the subscript inform the public that the area is quiet), is determined only by EVT. Thus, Eqn. (2) is modified as follows:

$$BGN = 0 \text{ if } BGN = 0.2\left(L_{A95eq} - 30\right) < 0 \qquad (7)$$

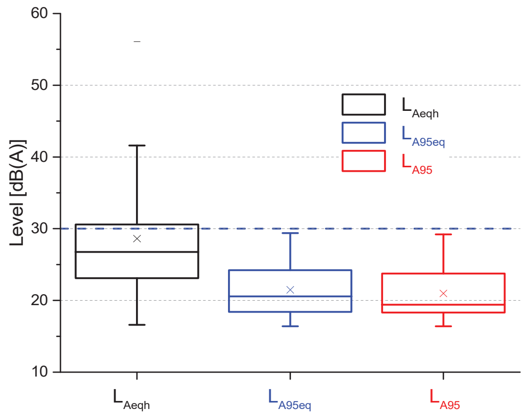

Figure 6. Box plots of sound descriptors for the quiet sites in Aosta Valley (21.4% of all cases).

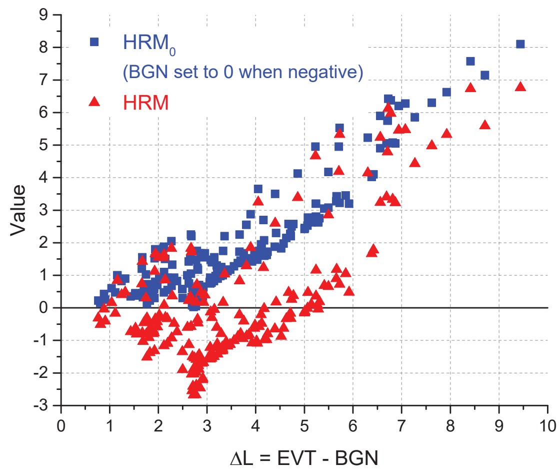

Figure 7. HRM values for the sites with BGN < 0 according to Eqn. (2) and Eqn. (7).

A further option would be to reduce the 30 dB(A) threshold in Eqn. (2), as it refers to urban areas where the HRM index was developed. For instance, this value could be reduced to 20 dB(A), as it is still above the noise floor of class 1 current sound level meters.

However, both the two above options provide BGN values no comparable with those computed by Eqn. (2) and, therefore, the same applies for the obtained HRM values.

4. CONCLUSIONS

Some remarks have arisen in applying the Harmonica index in environments rather different from those (urban areas) where it was developed.

The results obtained from the large dataset (954 hourly intervals) show that using the L_{A95} level instead of L_{A95eq} has two advantages:

- It is measured directly by the current instrumentation, which can easily be set to perform the HRM calculation;
- It leads to higher values of HRM and, therefore, HRM_{95} could be an acceptable precautionary approach.

More questionable is the HRM application in quiet areas, where the original HRM formulation underestimates the potential influence of sound events on annoyance when BGN < 0. To overcome this drawback, two options are proposed, but the corresponding HRM values are not comparable with those from the original formulation.

It has to remind that the constants in the Eqns (2) and (5) come from fitting the acoustic data with the subjective sound perception [1]. This is a crucial issue which need to be better investigated, especially in low road traffic environments, such those considered in this analysis. Due to the lack of perceptual data, the current analysis has been limited to the acoustic data only and, therefore, the values of the constants were not modified from the original formulation.

Further studies are underway to evaluate the use of descriptors based on the Harmonica index principle also for sources other than vehicular traffic and for particular receiver conditions (e.g., indoor sound propagation).

5. ACKNOWLEDGMENTS

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