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[N1073] HARMONOISE Project (WP4) – First experimental road traffic noise campaign: comparison among methods to separate road traffic noise from extraneous noise

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ABSTRACT

In the context of the European Commission funded HARMONOISE Project (Harmonised, Accurate and Reliable Methods for the EU Directive on the Assessment and Management Of Environmental Noise) [1], the first experimental campaign was carried out in October 2002 in La Crau (France) [2].

The measurements were performed over one week period and aimed at collecting data from road traffic noise produced by a straight four-lane highway traffic, and meteorological data at six different distances from the line source over a flat, open and homogeneous terrain.
Comparison among different approaches to separate road noise from extraneous noise are discussed and compared together in order to verify the validity of each method. The analysis will focus on the manual separation method, the statistical and the pattern recognition approaches.
The results of the analysis will be discussed and presented in the paper.

KEYWORDS: environmental noise measurements, road traffic noise, extraneous noise, pattern recognition, statistical approach, noise separation

INTRODUCTION

For the description of noise sources the separation of the different sources is essential, especially in this project, which will be the basis of a new harmonised European noise propagation model. To separate the different noise sources from the measurements several methods has been used by JRC, ARPAT and LCPC, e.g. «manual» (JRC, ARPAT & LCPC), «pattern» recognition» (JRC, ARPAT & LCPC) and «statistical» (JRC) methods:

Manual method

The manual method is simply based on the separation of the parasite signals by an operator. This method is the most rigorous but it is also time consuming. Moreover, it needs the knowledge of all the extraneous noises at each microphone positions during the whole experimental campaign.

Pattern recognition

The pattern recognition is based on spectral information of the noise source. To automatically identify noise sources, sound recordings are taken, from which typical patterns for each noise source are derived.

Statistical method

This method uses percentile spectra with a resolution of 10 Hz together with a statistical approach of the level distribution within each frequency band. Using this method also sources with levels close to the background can be separated. This is essential for measurement locations far from the source.

EXPERIMENTAL PROTOCOL

The first experimental campaign for the HARMONOISE project was carried out in the period 18-25 October 2003 in La Crau (France). The measurements were performed over one week period (24 h/day) and aimed at collecting data from road traffic noise (A weighted global L_{eq}, 1/3 octave bands L_{eq}, percentiles levels) produced by a straight four-lane highway traffic (two lanes per direction), and time averaged meteorological data (relative humidity, wind speed, wind direction, temperature, wind and temperature vertical gradients, turbulence parameters, etc.), at six different distances from the line source (15m, 50m, 100m, 150m, 300m, 600m) over a perfectly flat and open terrain (no obstacles, plane topography) the impedance characteristics of which can be considered as spatially homogeneous.

Fig. 1 is a schematic representation of the arrangement of the acoustical sensors; M_x denotes the positions and heights (H) of the acoustical instrumentation, the pattern and the type of the instrumentation used.

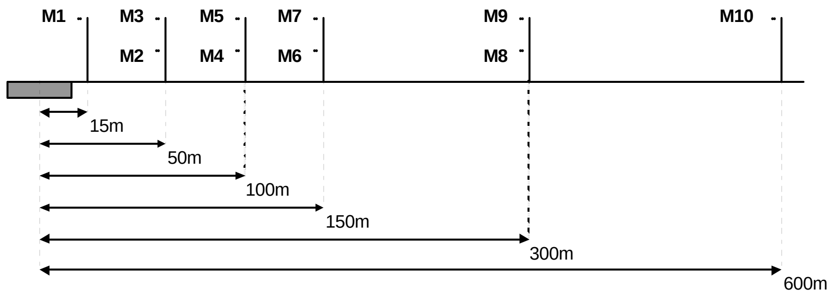

Fig. 1 - Schematic representation of the arrangement of the acoustical sensors. M1 : Symphonie 01dB (ARPAT) H = 4m; M2 to M7 : SIP TR 01dB (LCPC) H = 1.5m/4m; M8 & M9 : B&K and deBAKOM system (JRC) H = 1.5m/4m; M10 : SIP TR 01dB (LCPC) H = 4m

LCPC PATTERN RECOGNITION METHOD

The method used by LCPC to study the respective contribution of «Extraneous» and «Residual» (road traffic) noise to the total noise at one microphone is based on *pattern recognition*. It requires the knowledge of the experimental site (topography, ground impedances, heights, distances, etc.) and the know-how of the operator (typical extraneous sound sources signatures, meteo data, S/N ratio, etc.).

Numerical sound files from 1/3-octave bands sonometers (temporal evolutions) are used. Each file, corresponding to one week noise recording at one microphone, is first meticulously studied, in order to determine the amplitude of its 1s L_{eq} variations on the whole week period in « normal » acquisition conditions. This preliminary study is very important and is carried out for several 1/3 octave bands the central frequencies (from 25Hz to 20kHz) of which are directly connected to typical parasite («Extraneous») sound sources, such as, *high wind* (very low and very high frequencies); far (very low frequencies) or near (low frequencies) *mechanical sound sources* such as *aircrafts* or *helicopters*; *human voices* (medium frequencies); *animal presence* (medium frequencies); *birds* (high frequencies), etc.
Thus the operator is able to settle a threshold for each of those typical 1/3 octave bands above which the acoustic signal can't be only caused by road traffic. All those 1/3 octave thresholds are of course determined for each microphone, depending on the medium characteristics (topography, heights, distances and ground impedances involved) and on the propagation conditions (micrometeorological data).
Then, the software allows to code automatically the acoustic signal on the whole period (e.g. 7 days for this HARMONOISE experimental campaign) for each microphone, whether the considered 1/3 octave 1s L_{eq} is above («Extraneous») or below («Residual» i.e. Road Traffic Noise) the associated threshold. We can also fix the width of the automatic coding window, which is linked to the considered parasite sound source. A particular 1/3 octave 1s L_{eq} coding generates the same codified 1s L_{eq} for all the 1/3 octave bands from 25Hz to 20KHz and, as a result, for the A weighted global level. The software can also give the associated percentiles, e.g. L_1, L_{50} and L_{95} for the HARMONOISE experimental campaigns.

Finally, we calculate, for each 15min[1] L_{eq} samples the respective contributions of «Extraneous» and «Residual» (road traffic) noise to the total noise recorded at one microphone position. For example, Table 1 below shows typical results for the 1/3 octave band centered on 1kHz frequency:

	1kHz (example) 1/3 octave band at one microphone (example)									
Start of the period	Total noise				Extraneous (parasite noise sources)			Residual (road traffic noise)		
	Leq	**L95**	**L50**	**L1**	**Leq**	**Partial**	**%**	**Leq**	**Partial**	**%**
18/10/02 20:15	64,4	59	63,7	69,1	65,8	63	71,1	62,3	59,1	28,9
18/10/02 20:30	62,6	56,7	62,1	67	65	58,2	35,9	61,7	60,7	64,1
18/10/02 20:45	59,2	51,1	58,2	64,4	64,7	42,9	2,4	59,1	59,1	97,6
18/10/02 21:00	56,9	49,3	56	61,9	-	-	-	56,9	56,9	100

Table 1 - 1kHz (example) 1/3 octave band data at one microphone (example)

where the «Partial» 15min L_{eq} represents the same equivalent acoustic energy level but calculated on the whole period (15min) instead of calculated only on the signal apparition period (≤ 15min). This powerful method gives very satisfactory agreement with the manual method. It leads to the validation (or rejection) of each 15min L_{eq} samples, whether the percentage («%») P=100*10^((L_{eq} Residual Partial)/10)/ 10^((L_{eq} Total noise)/10) is ≥ 90 (or respectively < 90) for example.

EVALUATION OF STATISTICAL AND PATTERN RECOGNITION APPROACHES USED BY THE JOINT RESEARCH CENTER (JRC)

The following evaluation deals with the measurements performed by the Joint Research Center at the distance of 300 m from the source, and microphone height of 4m (M9).

For the evaluation of the data measured by JRC, the deBAKOM evaluation software used which gives the possibility to separate among different noise sources, using one of the following procedures:

1. It's possible to listen to all the audio files recorded, and manually select all the part that do not come from road traffic like local noises, noise coming from aircraft, birds, air-conditioning systems, industrial activities, church bells, etc. This is one way to separate road traffic noise from extraneous noise.
2. It is also possible to use a pattern recognition procedure, by which the noise nature of the source can be recognised, and the noise levels produced by different sources can be automatically separated. In order to minimise the possible errors of pattern recognition software was developed to adopt the pattern for different measurement situations.
3. Making the hypothesis that the noise levels from road are normally distributed in each frequency band, a statistical approach can be used, in order to separate the levels between road noise and extraneous noises.

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[1] 15min acoustic sample duration is chosen to be homogeneous with 15min micrometeo sample duration, which is approximately the shortest micrometeo sample duration usable to consider the propagation conditions as stationary.

During this evaluation the first and the second procedures were used and applied to the same data in order to minimise at almost zero the errors occurring: a pattern recognition procedure was used but, then, all the audio data were listened in order to detecte all the noises that the procedure erroneously recognised: as road traffic when the noise was produced by an extraneous source, and vice versa.

"STATISTICAL" ROAD NOISE APPROACH *vs* THE PATTERN RECOGNITION METHOD

All the extraneous noises were calculated as a "difference" between L_{eq_tot} and $L_{eq\_road}*S_{time}$:

$$L_{extraneous} = 10 \cdot \mathrm{Log}\left(10^{\frac{Leq\_tot}{10}} - S_{time}\, 10^{\frac{Leq\_road}{10}} \right) \quad (1)$$

where S_{time} represents the percentage (%) of time, during the ½ hour of measurement time when road noise was detected.

It is possible to make a comparison between the L_{eq_road} measured (pattern recognition *plus* manual procedure) and the L_{eq_road} calculated with the statistical approach. The results, concerning the period from October 18th and 20th (after midnight) are shown below (Fig. 2).

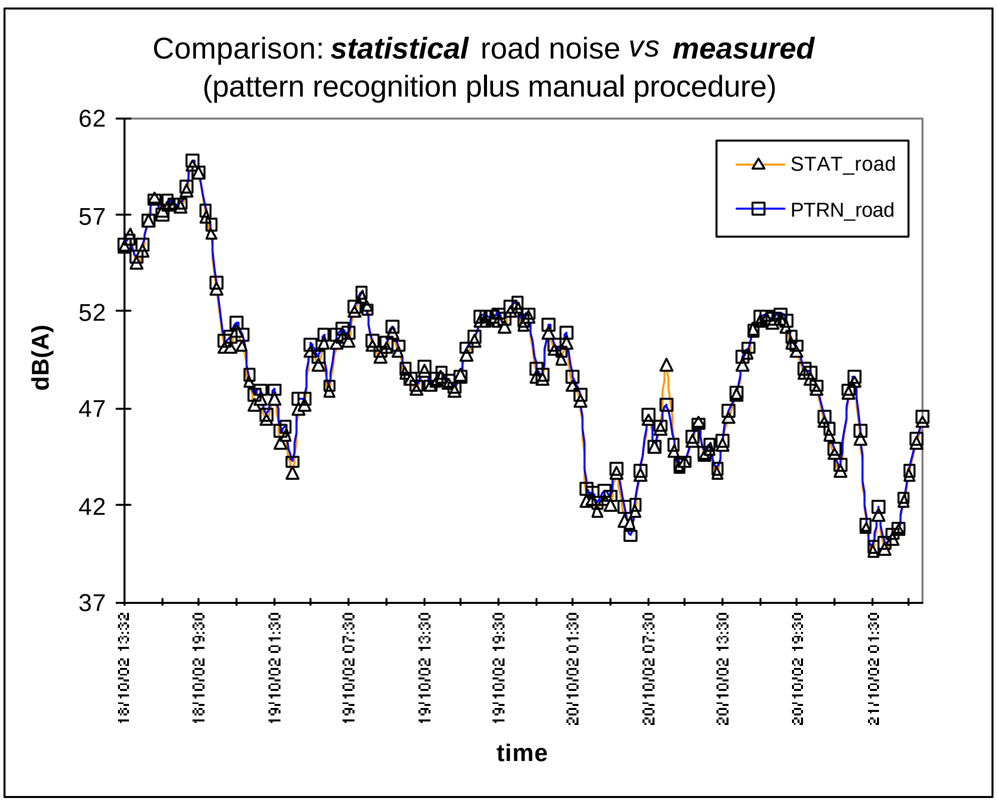

Fig. 2 – Comparison of the approaches used

["STAT" stands for Statistical approach, whereas "PTRN" for pattern recognition + manual approach]

When considering the statistical approach the software can select three levels of quality (*few*, *some*, *too much extraneous noise*) depending on the level of the extraneous noise if compared with the noise from road traffic. In the next representative chart (Fig. 3) (linear frequency, $\Delta f=10$ Hz) the two lines at the top represent the spectra of TOTAL noise [Seq (+10)] and the ROAD TRAFFIC noise [NG (+10)] [2] respectively.

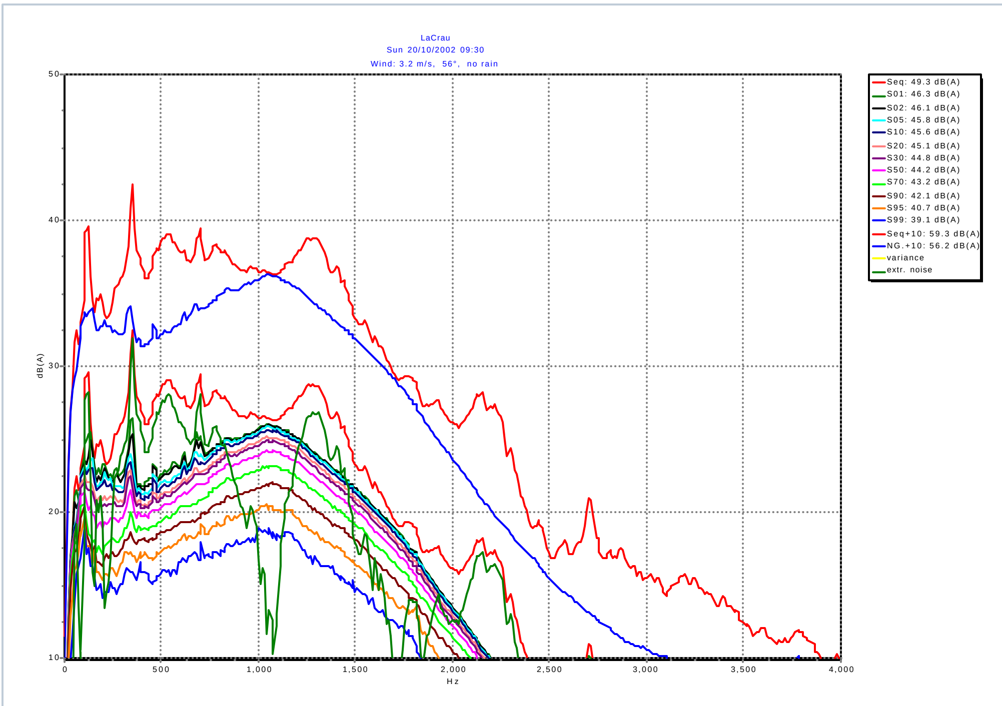

Fig. 3 - Statistical approach. – *Some extraneous noise*

It's also possible to make an evaluation between the two methods from a spectral point of view (1/3 octave band). When the extraneous noise is not high (*few* and/or *some extraneous noise*) the statistical approach performs very well (nearly identical levels for both approaches at each frequency), whereas when there is *too much extraneous noise*, the statistical approach and the pattern recognition show larger differences at certain frequencies. Fig. 4 represents a case in which there is *too much extraneous noise*.

Excessive extraneous noise is a problem that becomes greater as we move away from the source, since the ratio S/N becomes lower. During this experimental campaign the extraneous noise was mainly caused by high wind speed (at a distance = 300 m and wind speed > 4 m/s the data was affected too much by the noise caused by the wind), by aircrafts and helicopters and by birds.

[2] 10 dB were added to the original values just to distinguish them from the rest

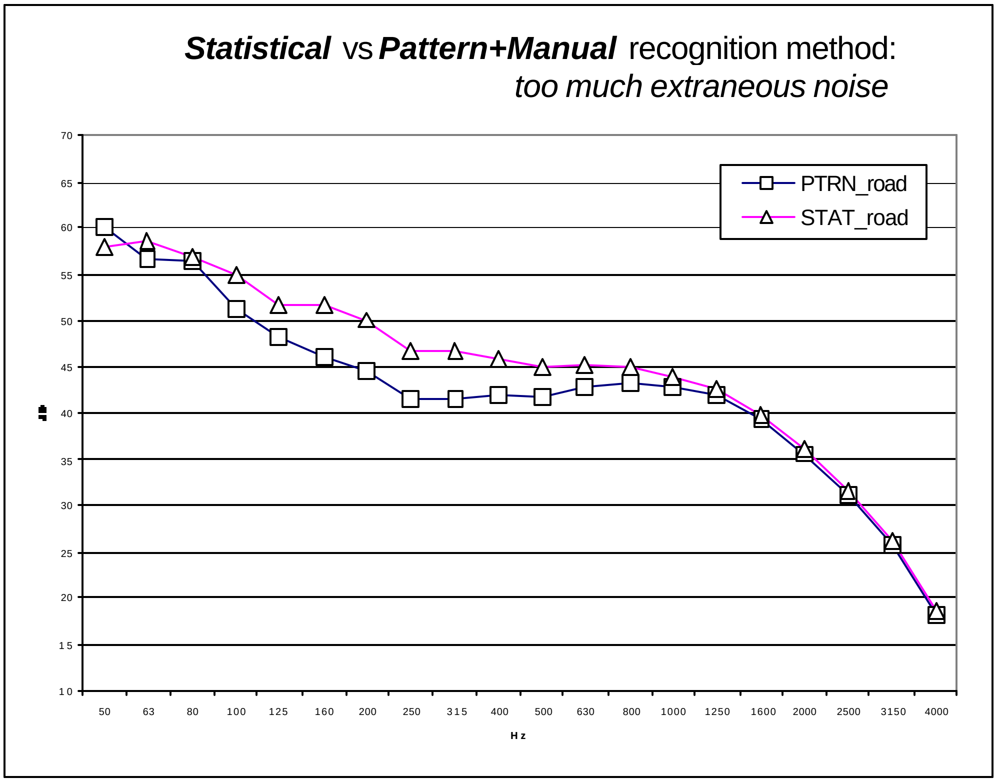

Fig. 4 - Comparison between the statistical approach and the pattern recognition (*plus* manual) method. *Too much extraneous noise*

Data from the experimental campaigns which are being performed in the context of the HARMONOISE project will be provided by the partners of WP4 in the form of a database, considering *manual*, *statistical* and *pattern recognition* approaches.

CONCLUSIONS

Using different approaches of noise separation it could be shown that large amount of acoustic data can be separated with respect to extraneous noise and the noise under consideration (road, rail noise). The automatic separation method, which is based either on pattern recognition or statistical assumptions about the energy distribution within each frequency band, showed in most cases nearly identical results.

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