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PERCEIVED TRAFFIC NOISE. LS INDEX; INTERNATIONAL RESULTS

R. Barti

Department of Acoustics La Salle, Pg. Bonanova, 8, 08022, Barcelona, Spain

Tel.: 932 902 427 / Fax: 932 902 416 / Email: robert@salleurl.edu

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ABSTRACT
Nuisance can not be measured with traditional methods like Leq in dB A-weighted. Sounds from noise sources are complex, and need multi-dimensional analysis in order to know the real nuisance perceived by citizen. A new LS index was presented in last Internoise '99 in Fort Lauderdale. This index is obtained from analysis of noise emitted by cars passing along a road. Jury people were young, 20 to 30 years old. People of other countries, with different culture and sensibility to car's noise, did some tests. LS index shows a very good correlation with critical cases, when the overall noise is not according with the sensation of the jury, that is, the most noisy is not the highest level.

1 - INTRODUCTION

Car's manufacturers must do a noise control test before selling this products. This measurement is doing under ideal conditions, and for a very particular situation. Full acceleration with third gear between 20 m. is doing. Only peak value of pressure level A-weighted, is take into account. Noise control policies in cities uses very different procedure. Leq is most common procedure used for noise measurements. 6, 8 and even 24 h. of Leq is used, always with A-weighted measurement. One difference is observed between these two standards: Manufacturers passes his products in base of peak values of pressure, instead noise in city that uses Leq values of pressure. Any one of them reflects the real situation. The sensation perceived by people can not be described only by pressure measurements. Is necessary analysing the sound as the human brain analyses it. Not only the spectral distribution of the energy must be considered; also the time evolution of the signal must be considered. New parameters energy-time based was developed for our purposes. A test with sound samples was doing by different community around some different countries. First results are showed in this paper.

2 - MEASUREMENTS

Noise from different cars passing along a road, was recorded on a DAT system. Only one microphone at 2.5 m away from pass-line of the car and 1.5 m height is used. The road shows a 2% of inclination. Only cars passing alone up the hill were recorded. The speed of the car lies between 45 and 60 Km/h. and most of them use third gear. The weather conditions were very good, no rain, and no wind. Manufacturer and model identified each car. 85 cars and 16 mopeds were recorded.

3 - ANALYSIS

Two kind of analysis was doing subjective analysis by a jury test, and qualitative analysis using different methods, unidimensional and multidimensional methods. The target of the study was to classify the nuisance perceived by young people. The sounds were replayed though a headphone set in the laboratory. Of course, the sensation was not the same that in real life, because the recording is not binaural, and the replay was through a headphone (perception of low frequencies by the body is avoided). But the target is to classify, not to quantify the amount of nuisance with a scale. This simplifies the job of the jury, and the test is independent of the level of the replay. Differences between headphone quality of different country test, was not considered, a minimum quality is guaranteed. The samples of the test answers were classified by geographical origin and by sex. Each test consist in classify from the most noisy to

the noiseless, the three cars showed. First laboratory test uses more than tree cars, but this was more difficult for jury accuracy. Sound can not be presented at same time as image. The acoustical memory is not as good as image memory. For this reason, short test (3 cars) was presented each time. People can replay them many times, in order to let to classify. The order of the test appearance was changed. Spectral analysis is the most usual analysis. In many cases the visual aspect of the spectrum averaging is not corresponding with the sensation perceived. Figures 1 and 2 shows two different cars. The graphics shows the 1/3 octave band and overall level.

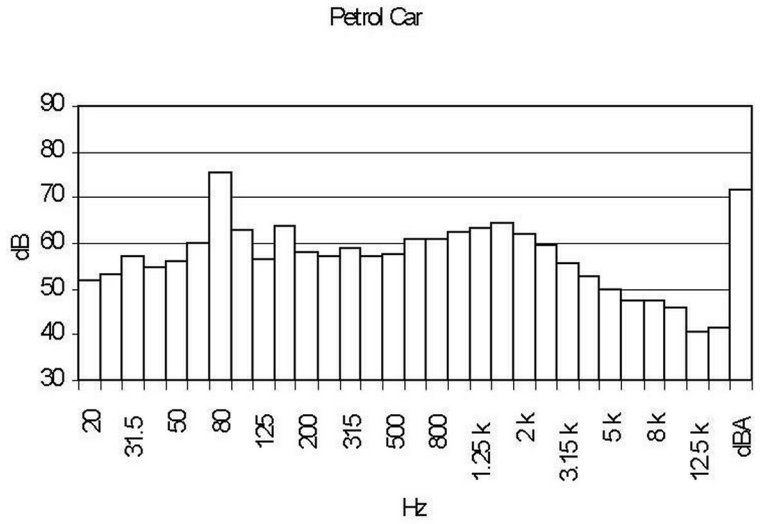

Figure 1.

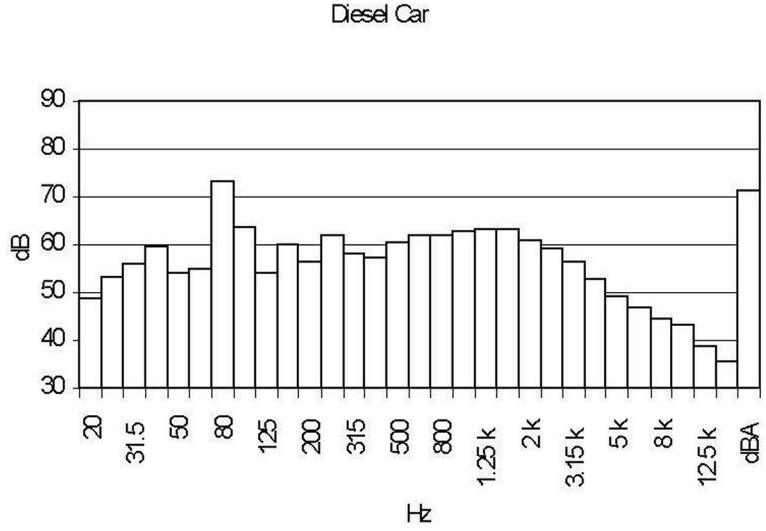

Figure 2.

Diesel car has a particular sound, very different from the petrol car. The manufacturer of them is the same. The 1/3 octave band spectrum is very near one to each other. The overall level was the same. But the sound perceived from this two cars are very different, and the classification by jury is clear. Third octave band analysis is not enough to describe the sensation produced by these two sounds.

4 - TRIAL TEST

The samples of sound from different cars were showed to a test jury. Most of them are 20 to 30 years old. In each test, tree cars are heard. The order of appearance varies for each test. The target is to classify the cars by nuisance. This procedure ensures more repetitively than scale-based procedures. The level of the sound samples can be replayed with no calibrated levels. The same car is compared several times

with different cars. The result of the test is an ordering by level of nuisance by small groups. In order to have a classification by the degree of nuisance is necessary to do a change in the scale. After each test group, a matrix with the subjective results was made. This matrix let us to change the ordering scale, to a classification scale. This scale lies between 0 to 40. Maximum values correspond to maximum level of nuisance.

5 - RESULTS

After the firsts results showed in last Internoise '99, more cars were recorded and selected for the new test. Some part of the jury test was from Spain, the most of them, and results from Japan and France were available at the moment. The total amount of people was 65. Only 10 people from Japan and 10 people from France were available, the rest of people were from Spain. The results of the statistical analysis of the subjective answers can not to be considered definitive at all. Is necessary to collect more subjective analysis from more people.

Men and women show different degrees of sensitivity to car's noise. Women than considers cars with high frequencies components, noisier by men. Diesel cars were also noisy by woman than by men. Low frequency components are also important. Woman considers cars with high level in low frequencies, noisy. Men generally, associate the low frequency sound with sportive sound of the car, and are considered less noisy. Table 1 shows the resume of some results for men and women answers. Women criteria are closer to loudness evolution than men criteria. For men, balance of the sound, and other factors must be considered.

Order	MEN	Balance	L	Car	WOMEN	Balance	L	Car
1	28.201	27.951	68.63	G	30.666	27.951	68.63	G
2	26.274	23.195	49.1	C	23.35	6.0729	46.32	T
3	23.684	12.673	40.81	U	23.224	12.673	40.81	U
4	20.2	8.8592	38.04	K	22.751	23.195	49.1	C
5	16.258	22.151	47.43	R	20.335	4.435	39.04	I
6	16.257	4.435	39.04	I	15.346	3.1181	42.65	O
7	15.465	6.0729	46.32	T	14.962	8.8592	38.04	K
8	12.235	4.0169	40.38	P	13.136	6.8374	40.53	Q
9	12.123	10.301	38.38	B	12.386	4.0169	40.38	P
10	11.798	6.8374	40.53	Q	11.755	0.4486	40.02	M
11	8.0232	5.7995	37.71	E	10.822	10.301	38.38	B
12	7.6531	4.9647	36.92	A	10.492	22.151	47.43	R
13	7.4401	4.1485	33.57	L	10.118	5.7995	37.71	E
14	7.2057	6.3153	36.52	J	9.6667	3.2726	32.36	F
15	6.9264	3.2726	32.36	F	9.1684	4.2403	39.35	D
16	6.4755	8.2299	32.56	H	8.3482	6.3153	36.52	J
17	6.2951	3.1181	42.65	O	7.45	4.9647	36.92	A
18	5.9184	3.4865	29.59	N	7.4301	1.5149	36.26	S
19	5.6757	4.2403	39.35	D	6.8162	8.2299	32.56	H
20	5.3548	1.5149	36.26	S	6.2284	3.4865	29.59	N
21	4.661	0.4486	40.02	M	5.8716	4.1485	33.57	L

Table 1.

Table 2 resumes the subjective sensation tests made by Spanish and French people. Three cars are lighted in three different colours for clarity. Japanese classification is very different from Mediterranean classification. Cars with very similar level of nuisance for Japanese people, shows higher or lower levels of nuisance for Mediterranean people.

Spain	Bal	L	Car	Japan	Bal	L	Car	France	Bal	L	Car
28.201	27.951	68.63	G	31.2	27.951	68.63	G	31.6	27.951	68.63	G
26.274	23.195	49.1	C	28.8	23.195	49.1	C	29.333	23.195	49.1	C
23.684	12.673	40.81	U	23.6	6.0729	46.32	T	27.934	12.673	40.81	U
20.2	8.8592	38.04	K	19.2	4.435	39.04	I	20.379	8.8592	38.04	K
16.258	22.151	47.43	R	18	12.673	40.81	U	18.666	22.151	47.43	R
16.257	4.435	39.04	I	15.6	8.8592	38.04	K	15.634	6.0729	46.32	T
15.465	6.0729	46.32	T	15.2	4.0169	40.38	P	15.395	4.2403	39.35	D
12.235	4.0169	40.38	P	12.4	10.301	38.38	B	15.078	6.8374	40.53	Q
12.123	10.301	38.38	B	11.8	6.8374	40.53	Q	14.92	4.0169	40.38	P
11.798	6.8374	40.53	Q	11	0.4486	40.02	M	12.189	5.7995	37.71	E
8.0232	5.7995	37.71	E	10.8	4.2403	39.35	D	11.232	4.435	39.04	I
7.6531	4.9647	36.92	A	9.4	6.3153	36.52	J	11.079	10.301	38.38	B
7.4401	4.1485	33.57	L	9.4	22.151	47.43	R	10.951	6.3153	36.52	J
7.2057	6.3153	36.52	J	9.2	5.7995	37.71	E	9.1578	4.9647	36.92	A
6.9264	3.2726	32.36	F	8	3.2726	32.36	F	8.2534	0.4486	40.02	M
6.4755	8.2299	32.56	H	6.4	1.5149	36.26	S	7.8724	3.2726	32.36	F
6.2951	3.1181	42.65	O	5.6	4.9647	36.92	A	7.3803	3.1181	42.65	O
5.9184	3.4865	29.59	N	5.6	3.1181	42.65	O	7.1106	1.5149	36.26	S
5.6757	4.2403	39.35	D	5.5	3.4865	29.59	N	6.7612	8.2299	32.56	H
5.3548	1.5149	36.26	S	5	8.2299	32.56	H	6.0092	4.1485	33.57	L
4.661	0.4486	40.02	M	4.8	4.1485	33.57	L	5.5235	3.4865	29.59	N

Table 2.

6 - PSYCHOACOUSTICS CRITERIA

Psychoacoustics criteria can add more information than spectrum averaging. After this first analysis, this metrics seems not correlate well with the car's noise. Figures 3 and 4 show the correlation between Sharpness and Loudness and the degree of nuisance.

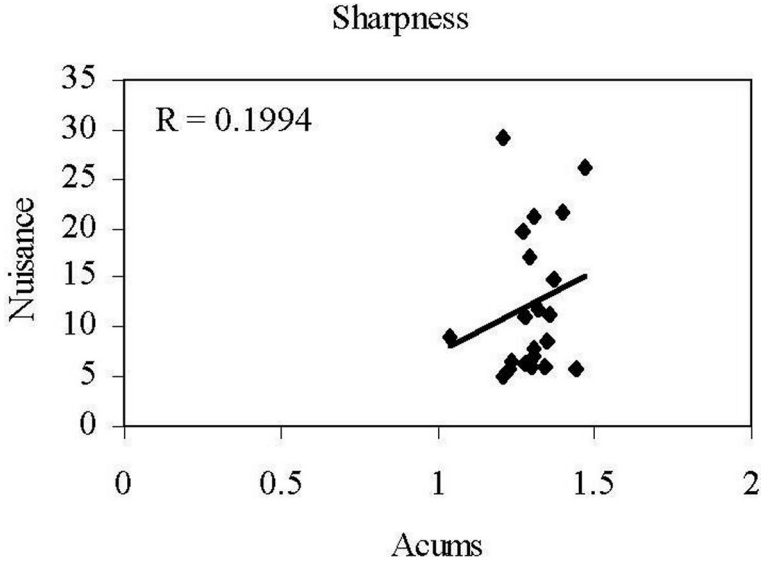

Figure 3.

As is shown, the correlation factor is poor, especially for sharpness index. Other psychoacoustics criteria like Unbiased Annoyance shows similar correlation coefficient. Loudness seems to have a good correlation coefficient, but locking at special or complex cases, is observed a very low correlation. Figure 5 shows the correlation between subjective answers (nuisance) and LS index. Correlation coefficient is the highest of all.

7 - CONCLUSIONS

1. Psychoacoustics criteria are not enough for describe the subjective sensation of that people.

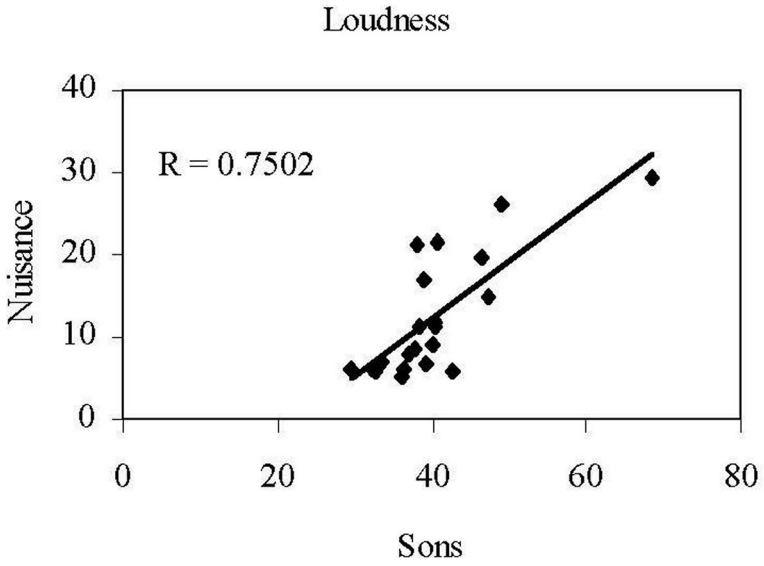

Figure 4.

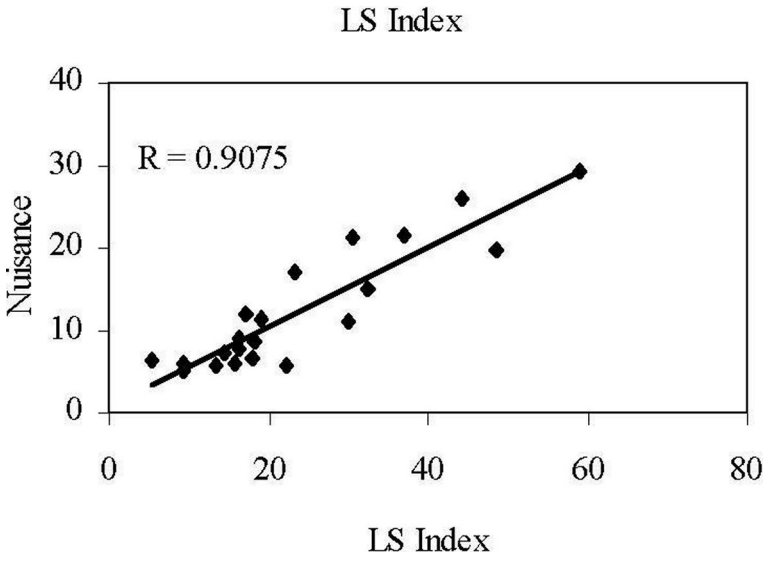

Figure 5.

2. Time analysis, must be used for well correlate the measured nuisance with subjective answers. Leq measurements, particularly with A-weighted network, must be avoided.

3. Ls index is showed, with good preliminary results. This index shows the best correlation coefficient with the answers of the jury.

4. A world's unique nuisance index seems not possible, due to different cultural criteria of people from different countries.