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Errors evaluation in the estimate of the noise from the road traffic

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Summary. — Specific algorithms together with noise data acquired during a measurement campaign, consisting of approximately 80 one-hour records, were utilized to model the noise levels of a road network. Experimental measurements were used to evaluate the reliability of the model by analyzing the differences between the measured values and the estimated ones. We think that these differences have to be especially ascribed to an imperfect representation of the combined effects of the attenuation due to acoustic wave diffraction and the attenuation produced by the ground effect.

PACS 43.28.Hr – Outdoor sound sources.
PACS 43.28.Js – Numerical models for outdoor propagation.
PACS 43.30.Zk – Experimental modeling.
PACS 43.50.Lj – Transportation noise sources: air, road, rail, and marine vehicles.
PACS 43.50.Rq – Environmental noise, measurement, analysis, statistical characteristics.

1. – Introduction

In order to evaluate the acoustic noise produced by wide sound sources, as suburban road network, it is necessary to make use of suitable simulated models. A problem resulting from this process is the uncertainty in the allocation of the sound noise levels close to the receptors. The aim of the present work is to quantify these uncertainties, in particular in the application of the main algorithms now applied in Europe for the road traffic noise simulation. The first part of this work deals with a study to define a procedure to identify the areas, within the ranges acoustically affected by road networks, where the enforced noise level thresholds are exceeded. Specific algorithms together with noise data acquired during a measurement campaign consisting of approximately 80 one-hour records were utilized to model the noise levels in the vicinity of a road network. The experimental measurements were used to evaluate the reliability of the model by analyzing the differences between the measured values and the estimated ones. The results from three different algorithms normally used to evaluate the noise from the road traffic have been afterwards compared.

2. – Acoustic predictive software

The evaluation of noise generated from vehicular traffic is based on some parameters, separable in two different categories: those useful to source characterization and those useful to characterize the environment where the noise propagates. In the case of roads sound power level calculation depends on the following factors: vehicular flow entity, typology of road surface, traffic flow composition (light vehicles and heavy vehicles), average speed, road slope, and traffic flow condition (fluid, interrupted and accelerating). The sound propagation in the environment is affected by the topography of the site, by the presence of obstacles, by the kind of terrain covering, and by the atmospheric conditions (wind and temperature gradient).

2˙1. *Source characterization.* – Input data necessary to the characterization of a road are distinguished in two categories: those relative to road structural characteristics (number of lanes, lanes width and traffic sense) and those referred to traffic flow entity and typology. Traffic parameters are:

- kind of road surface covering;
- traffic hourly flow (vehicle/h);
- average speed (km/h);
- heavy vehicle percentage;
- typology of traffic flow (fluid, interrupted, accelerating).

The determination of sound power level of vehicular traffic sources in predictive algorithm is based on single vehicle noise emission values defined by the Guide du Bruit des Transports Terrestres (1980) [1]. Vehicle noise emissions were evaluated by measuring noise emitted by several passing cars.

Traffic noise emission level depending on average hourly traffic flow, average speed and heavy trucks percentage is calculated by the following formula:

$$L_W = L_{W,VL} + 10 \cdot \log\left(\frac{\text{flow} + \text{flow} \cdot PL \cdot (EQ-1)/100}{V_{50}}\right) - 30,$$

where

- $L_{W,VL}$ is the acoustic power of a light vehicle;
- flow is the number of vehicles per hour per lane;
- PL is the percentage of heavy vehicles;
- EQ is the equivalence light vehicle-heavy vehicle;
- V_{50} is the speed of vehicle streams.

The acoustic power of a light vehicle is obtained from the following formula:

$$L_{W,VL} = 46 + 30 \cdot \log V_{50},$$

where $V_{50} = 30$ km/h if the speed of the vehicle stream is lower than 30 km/h and C varies in dependence of the vehicular traffic flow typology ($C = 0$ for fluid traffic, $C = 2$ for interrupted traffic, $C = 3$ for accelerating traffic).

After the calculation of the sound power level (L_W), there is need to make use of a specific algorithm to evaluate sound pressure level in some location (L_P). During the study identification, the NMPB-Routes-96 method (SETRA-CERTU-LCPC-CSTB) was used [2-4]. The NMPB method for the simulation of the outdoor sound attenuation takes the following categories into consideration:

– Attenuation by the geometric divergence, A_{div};

– Absorption by the air, A_{atm}.

– Ground effects, A_{ground}.

– Diffraction, A_{dif}.

– Absorption by the vertical surfaces on which the ray has been reflected in the horizontal plane, A_{ref}.

The estimated sound pressure level is expressed by the following formula:

$$L_p = L_W - A_{\mathrm{div}} - A_{\mathrm{atm}} - A_{\mathrm{suolo}} - A_{\mathrm{dif}} - A_{\mathrm{ref}}[\mathrm{dB}(A)].$$

3. – Errors analysis

The analysis of the difference between the experimental noise level and the noise level elaborated by calculation was done considering 60 values; these values correspond to measures taken during the vehicular flow counting.

In particular we have chosen measurements sites with the following characteristics:

– a simple geometric configuration of the road (no presence of viaducts, bridges or tunnels);

– roads with regular vehicles fluxes (far from intersections);

– sites far from other noise sources;

– sites less than 30 meters distant from roads.

For every site of measure experimental $L_{\mathrm{eq,1h}}(A)$, estimated $L_{\mathrm{eq,1h}}(A)$, difference of these values, height of position of phonometers and distance from the center of the road are mentioned.

The parameters used to analyze the difference between the values given by the model and those given by tests are: correlation index R_2, equal to 0.9203, mean difference, equal to +1.155, and standard deviation, equal to 1.392. These parameters were calculated considering a lower number of sample data: sites of measures that, due to particular environmental conditions or building context, did not allow a good reproduction by the software simulation, were not taken into consideration. This last consideration underlines that the algorithm used by the software is not responsible for the contribution of the global error given by these measures, but it is the consequence of the impossibility to simulate such particular conditions.

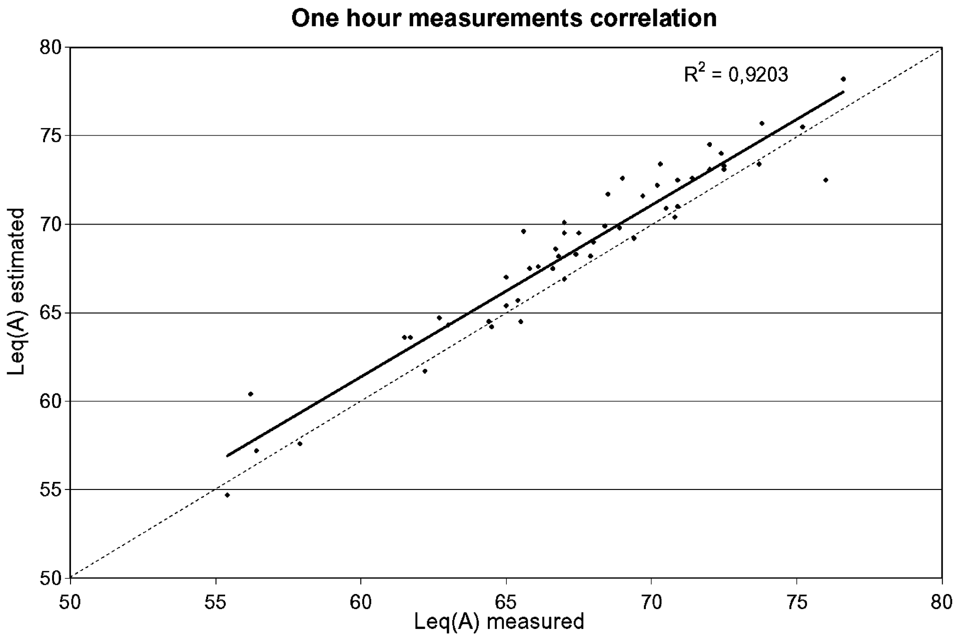

Fig. 1. – One-hour measurements correlation.

Figure 1 shows the correlation between estimated and experimental values: calculated values are higher than the experimental ones; the mean difference value, equal to 1.155, points out this result (a large quantity of points in the graphics are over the bisecting line).

Afterwards the analysis of the difference between experimental and simulated noise levels, a new campaign of measures started in order to find out how the prediction software works and the cause of wrong noise levels. The estimation of noise level has been performed using 3 mathematical algorithms:

- CSTB 92: method developed by the Centre for Science and Technology of Buildings (1992) [3].
- ISO 9613-2: general method of calculation for the attenuation of sound during propagation outdoors (1996) [5].
- NMPB Routes 96: predictive method for railway and road traffic noise developed by SETRA-CERTU-LCPC-CSTB (1996) [2].

The sites of the new measures were selected taking into consideration their low environmental complexity in order to simplify the modeling of the real world into the software. The ideal sites are close to a rectilinear road, in open field, plane of site and covered with grass. In order to avoid meteorological effects influence, all the measurements were located within 30 meters from road.

4. – New measurements campaign

The phonometrical measures were done close to a 4/6 lanes road; the 3 phonometers were placed on an imaginary perpendicular line and at the height of 4 meters (according

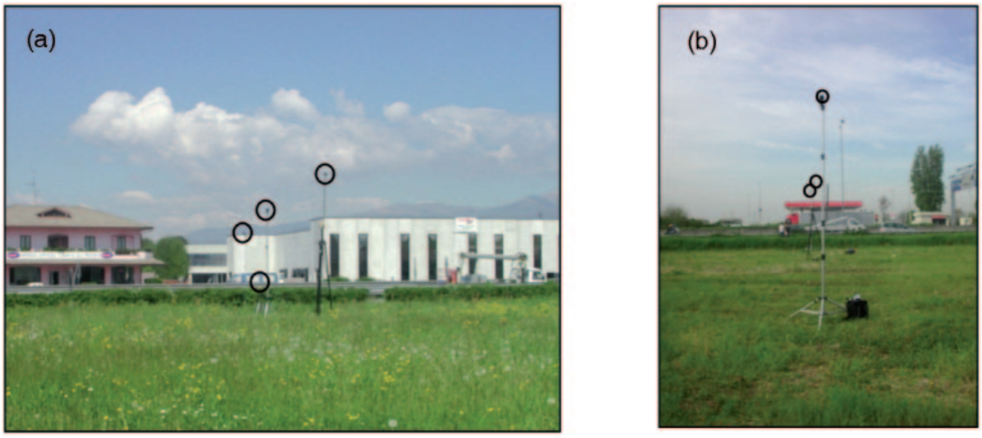

Fig. 2. – Measurements sites of Nibionno (LC, a) and Lissone (MI, b).

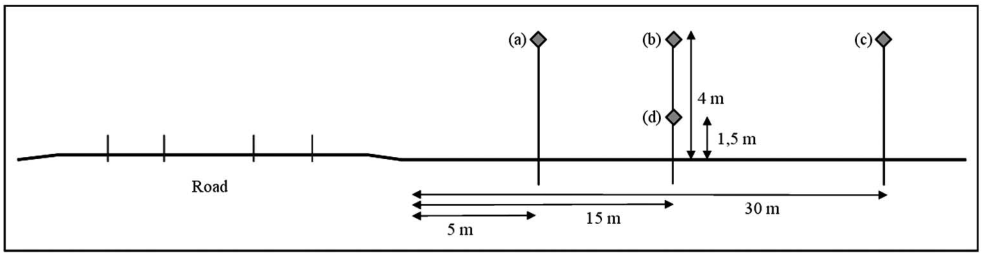

Fig. 3. – Modelling of a measurement site.

TABLE I. – *Hourly vehicle flow, percentage of heavy vehicle and average speed.*

		Carriageway North			Carriageway South		
		1^ lane	2^ lane	3^ lane	1^ lane	2^ lane	3^ lane
Carate1	Hourly flow	478	991	605	1050	1034	511
	% of heavy trucks	54	4	0	32	7	0
	speed (km/h)	80	95	110	80	95	110
Carate 2	Hourly flow	535	989	833	1100	1204	533
	% of heavy trucks	35	6	3	23	9	5
	speed (km/h)	80	95	110	80	95	110
Lissone 1	Hourly flow	873	1152	609	841	946	561
	% of heavy trucks	36	11	0	25	7	0
	speed (km/h)	80	95	110	80	95	110
Lissone 2	Hourly flow	942	1187	613	1123	975	535
	% of heavy trucks	30	8	0	26	5	0
	speed (km/h)	80	95	110	80	95	110
Nibionno1	Hourly flow	864	692	-	662	890	-
	% of heavy trucks	32	7	-	34	5	-
	speed (km/h)	75	95	-	75	95	-
Nibionno 2	Hourly flow	866	616	-	761	672	-
	% of heavy trucks	28	6	-	31	7	-
	speed (km/h)	75	100	-	75	100	-

TABLE II. – *Experimental levels, estimated values and relative deviation.*

Meas. sites	Phonometer distance	Leq(a) exp	NMPB 96		CSTB		ISO 9613	
			Leq(A)	Dev.	Leq(A)	Dev.	Leq(A)	Dev.
Caratel	R1-5m	76.9	77.2	0.3	77.3	0.4	76.5	–0.4
	R2-15m	73.3	74.9	1.6	74.8	1.5	74.0	0.7
	R3-30m	69.6	72.5	2.9	71.3	1.7	70.6	1.0
Carate 2	R1-10m	75.3	76.0	0.7	76.0	0.7	75.0	–0.3
	R2-20m	71.3	74.0	2.7	73.5	2.2	72.9	1.6
	R3-30m	68.7	72.6	3.9	71.4	2.7	70.5	1.8
Lissone 1	R1-5m	74.7	76.0	1.3	75.6	0.9	75.2	0.5
	R2-15m	70.6	73.8	3.2	73.5	2.9	72.7	2.1
	R3-30m	67.3	71.5	4.2	70.8	3.5	70.1	2.8
Lissone 2	R1-5m	74.5	76.0	1.5	75.6	1.1	75.2	0.7
	R2-15m	70.3	73.8	3.5	73.5	3.2	72.7	2.4
	R3-30m	67.2	71.5	4.3	70.8	3.6	70.1	2.9
Nibionnol	R1-5m	74.0	74.7	0.7	75.3	1.3	74.5	0.5
	R2a*-15m	70.9	72.8	1.9	73.3	2.4	72.3	1.4
	R2b**-15m	68.1	71.3	3.2	70.0	1.9	68.8	0.7
	R3-30m	67.6	70.5	2.9	70.4	2.8	68.9	1.3
Nibionno 2	R1-5m	70.4	72.8	2.4	73.0	2.6	71.7	1.3
	R2a*-15m	67.9	69.7	1.8	69.8	1.9	68.3	0.4
	R2b**-15m	64.9	67.4	2.5	66.0	1.1	65.0	0.1
	R3-30m	65.5	67.2	1.7	66.9	1.4	65.6	0.1
Mean deviation				2.26		1.98		1.08
Standard deviation				2.53		2.16		1.38
Correlation index R2				0.928		0.957		0.955

a* and b phonometers are in the same position respectively at the height of 4 meters and 1.5 meters**

to the Italian law and European directive), and in a particular case another phonometer was used at the height of 1.5 meters. The distances between road and phonometers were 5, 15, 30 meters. The low-lying phonometers were always placed at the distance of 15 meters, at the central position. Figures 2(a) and (b) show 2 different sites of measure.

The simulation of road was done reproducing separated lanes: each lane has its own parameters (noted during the hourly measure) regarding the hourly mean vehicular flow, the percentage of heavy vehicle and mean speed (km/h). Figure 3 shows an example of simulation of a phonometric measure. Table I includes noted data helpful to reproduce the characteritics of vehicle flow in the software of simulation.

5. – Results from new measurements campaign

Table II shows experimental levels and estimated values elaborated by three different algorithms. Noise values refer to three different distances of measure and the deviation between experimental and estimated level (Dev.) is also explained.

The plot in fig. 4 shows experimental and estimated values given by each algorithm. The graphic shows that all the models of simulation overestimate experimental values, as confirmed by the values of the mean deviations given in table II.

The analysis of values of table II as well as the results given in figs. 4 and 5 points into evidence good correlation between wrong noise level and distance; in particular error rises with distance and this trend is more evident for NMPB.

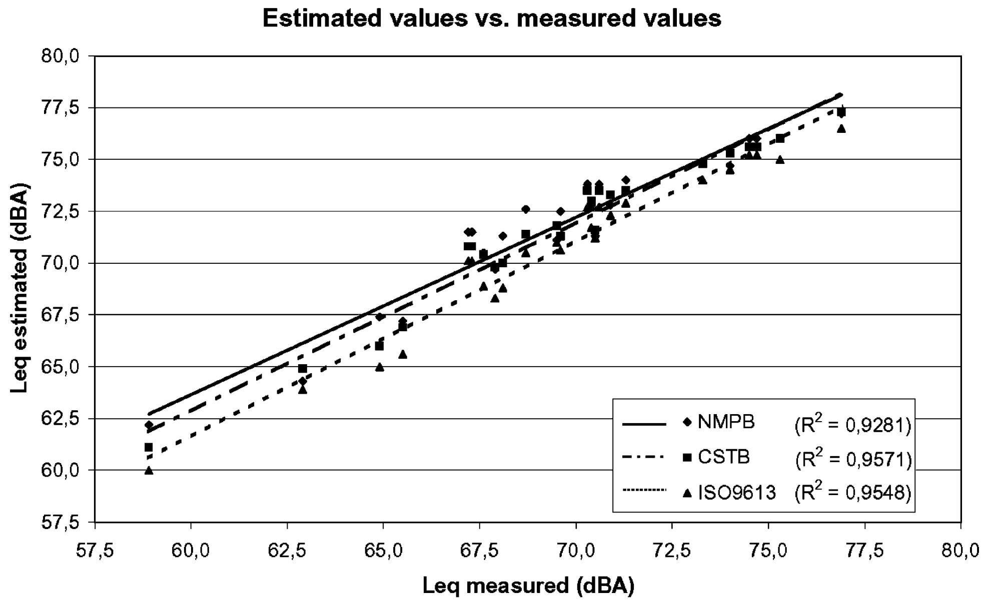

Fig. 4. – Comparison between experimental and estimated values.

The values relative to position 1.5 meter high show that deviation of experimental measurements due to NMPB increases but the opposite is done by CSTB and ISO 9613.

Measure “Nibionno 2” of table II is relative to a site distinguished by the presence of a bridge crossing the road under analysis. In this case the algorithm takes into con-

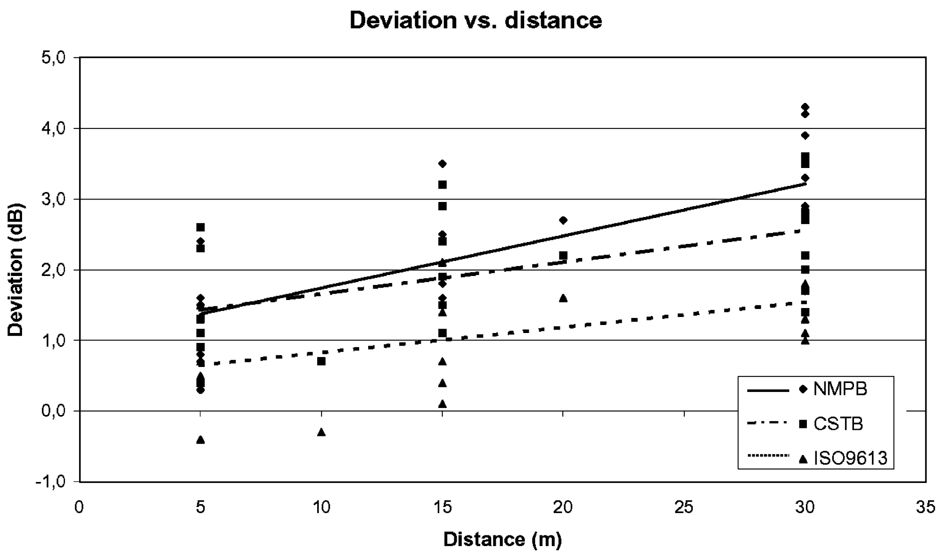

Fig. 5. – Deviation *vs.* distance.

sideration the contribute due to diffraction which increases with distance. The different deviation shows that diffraction attenuation corrects the error due to ground effect and so it is possible to notice as attenuation due to diffraction is overestimated.

6. – Conclusions

These results show that there is a need for some additional studies about how the algorithms work. It is also clear that the most important factors are diffraction and ground effect. These parameters should be the objects of future investigations.

The main parameters characterizing the sound attenuation are geometric divergence, atmospherical absorption, diffraction, ground effect and absorption by the vertical surfaces. Ground absorption is the only parameter that significatively changes with the distance, because of the experimental configuration and atmospherical conditions of measurements sites. We can then conclude that this factor is the main responsible for the overestimate.

We have accepted the tendency of the simulation model to overestimate noise levels taking into account that it is better to adopt a careful approach in the evaluation of noise exposure levels at receivers.

Furthermore, studies so far conducted will give us important indications to determine more sophisticated propagation corrections to improve the actual algorithm.

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