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NOISE IN HIGHWAYS: DEVELOPMENT OF A STATISTICAL PREDICTION MODEL

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Abstract

Predicting sound levels proceeding from urban streets or highways is a constant necessity in traffic noise investigation. The development of models to explain the noise as a function of, specially, vehicle flow, is a common procedure to handle this issue. In this way, a major research on a highway close to Belo Horizonte - Brazil is being carried out and a noise data base is being generated to include vehicle flow and distance between the source and the receptor. The goal of this work is to validate a statistical model to predict sound levels from the highway which is receiving new lanes. In the near future this highway expansion will attract more traffic which will, by its turn, increase its own noise levels. The predicted noise modelling under consideration has shown good agreement with the measured data already available.

1. INTRODUCTION

The noise emitted from the auto machine vehicles as well as those produced by the contact between the floor and the tires characterize a type of pollution that has been each time more common in medium and large urban area in the current days, the traffic noise.

However this pathology is not exclusive of urban ways. Highways, outside of cities, also, are sources of noise, mainly, for the transit of vehicles. The basic difference between the noise from traffic in the interior of cities and the noise in highways is the frequency spectrum. The noise inside cities is more concentrated in low frequencies, with peak around 70 Hz [6]. This occurs because in low speed the large amount of the noise comes from the combustion system of the engines. When the speed increase, the parcel of the engine becomes insignificantly and gives place for the noise proceeding from the contact tire-floor [7]. The noise emitted from this contact generates sound waves characterized as medium frequencies, around 500 Hz [6].

In this context, predict models used inside urban areas may present low accuracy when applied in highways. The present work has as objective to calibrate a model for forecast of the traffic noise in highways.

2. DATABASE

The database used in this work was collected in the Highway MG-010, next to Belo Horizonte city, capital of the state of Minas Gerais, Brazil. A total of 10 points was selected, where the noise levels and the flow of vehicles in the highway had been measured simultaneously. The reference microphone was always 10 meters distant from the ground (next to the highway).

Besides the L_{eq} (Equivalent sound level), the parameters L_{min}, L_{max}, L_{10}, L_{50} and L_{90} have also been collected. All measurements procedures have been carried out in accordance with the Brazilan Standard NBR 10.151 [3], whose recommendations are closely related to the ones of the ISO 1996/1-3 [8]. For each point, two samples of 15 minutes had been measured. The distance of the microphone was varied between the source (highway) and the receiver in the sample of the 10 selected points.

The equipments used in the field measurements were one frequency analyser 01dB-Stell, model SOLO MVI, series number 10034; one microphone GRAS, model MCE 212, series number 22281; one pre-amplifier 01dB-Stell, model PRE21S, series number 10116 and one calibrator 01dB, model CAL21, series number 0090036. These equipments are type 1 (one), according to IEC 651, IEC 804, IEC 61672-1, IEC 1260, ANSI S1.11 and IEC-60942.

The counting of vehicles also was made in intervals of 15 minutes and was synchronized with the measurements of noise. The vehicles were classified in cars, trucks, buses and motorcycles. The schedule chosen for accomplishment of the measurements and counting of traffic objectified to get a significant sample, of the statistical point of view. For this, moments with low and high volumes of traffic of vehicles had been characterized, mainly around the peaks of the morning and the afternoon.

3. SOUND LEVELS ON THE RIGHWAY

Table 1 shows the sound levels that had been observed during the measurements together with the respective volumes of traffic and the relative microphone position at each instant of measurement. It is possible to verify that the levels had varied between 58 and 72 dB (A), influenced by the vehicles volumes. The vehicle counting results shows a predominance of cars, about 90% in all samples. During the highest volume of traffic registered there were a total of 256 vehicles for the interval of 15min. From this amount 97% where constituted of light vehicles and 2% of heavy vehicles.
The Table 2 presents others noise parameters observed for each one of the 10 points. It is observed that the maximum levels had been next to 87 dB (A), while the minimum level had been around 44 dB (A).

Table 1 – Data field collected (each 15 minutes)

Point	Leq dB(A)	Cars	Buses	Trucks	Motorcycle	Distance (m)
1	72	157	8	3	1	6,2
1	72	140	6	7	6	6,2
2	71	171	4	3	4	6,1
2	71	145	10	7	5	6,1
3	70	125	2	7	9	11,8
3	69	130	4	9	10	11,8
4	65	148	2	6	7	13,8
4	68	177	9	13	7	13,8
5	63	249	2	3	2	37,6
5	64	167	7	6	11	37,6
6	63	198	4	3	4	59,4
6	63	235	5	4	2	59,4
7	70	171	6	4	5	12
7	70	180	5	5	9	12
8	62	165	11	11	8	58,6
8	62	230	10	10	5	58,6
9	62	240	6	4	5	64,5
9	59	212	4	2	3	64,5
10	59	142	13	3	6	54
10	60	156	8	7	5	54

Table 2 – Noise parameters (each 15 minutes)

Point	Measurement Data (dd/mm/yyyy)	Initial time (hs)	Duration (min)	Temp (^oC)	Humidity (%)	Wind speed (m/s)	Lmin	Lmax	L90	L50	L10
1	31/05/2006	06:20	15	12	90	< 5	56	81	60	69	76
1	31/05/2006	06:38	15	12	90	< 5	53	86	58	69	76
2	01/06/2006	06:10	15	12	90	< 5	56	82	58	67	76
2	01/06/2006	06:26	15	13	90	< 5	56	83	59	68	75
3	01/06/2006	07:07	15	14	90	< 5	53	87	56	66	73
3	01/06/2006	07:24	15	15	88	< 5	54	78	57	66	73
4	01/06/2006	18:19	15	20	60	< 5	50	76	54	61	69
4	01/06/2006	18:36	15	20	63	< 5	51	79	56	64	71
5	01/06/2006	19:15	15	20	70	< 5	51	71	57	61	66
5	01/06/2006	19:32	15	20	71	< 5	44	74	52	61	68
6	05/06/2006	5:47	15	08	90	< 5	55	70	57	62	66
6	05/06/2006	6:04	15	08	90	< 5	54	69	56	62	67
7	05/06/2006	7:01	15	09	88	< 5	54	81	59	68	74
7	05/06/2006	7:17	15	10	86	< 5	54	80	59	68	74
8	09/06/2006	17:54	15	17	72	< 5	44	73	52	59	66
8	09/06/2006	18:11	15	17	72	< 5	44	70	55	60	65
9	09/06/2006	18:44	15	16	80	< 5	48	78	53	59	64
9	09/06/2006	19:01	15	16	81	< 5	45	66	52	58	61
10	09/06/2006	19:38	15	17	80	< 5	46	67	51	58	63
10	09/06/2006	19:55	15	17	80	< 5	47	74	51	58	63

5. EXISTENT TRAFFIC NOISE PREDICT MODELS

An area that is frequently revisited by researchers all around the world is the development of models to predict traffic noise since it is a very useful tool that helps knowing the noise in hypothetical situations thru noise simulations techniques. The models should be as simple as possible to become an easy tool for practical applications. The great majority of the existing predicting models are addressed to forecasting noise in urban ways. In this way, the distance between the source and the receiver is not considered as an independent variable because, almost always, the sound level meter is located in the edge of the street. Some used statistical models for noise forecast are shown:

- [1]

$$L_{eq}= 62 + 1,78 \log(VL) + 8,28 \log(VP) \tag{1}$$

- L_{eq} is the Equivalent sound level;
- VL is the number of light vehicles to each 10 minutes;
- VP is the number of vehicles heavy to each 10 minutes.

- [5]

$$L_{eq}=67,3+2,6logQp+0.043sqrtQl+2,73KQp-0,52Lp+1,98sqrtDD+2,2sqrtDA-0,58DA \tag{2}$$

- Qp is the volume of vehicles heavy;
- Ql is the volume of light vehicles;
- Lp is the width of the sidewalk;
- DD is the descending slope of the way;
- DA is the ascending slope of the way;
- K is a variable dummy for Qp>500 vehicles/h.

- [2]

$$L_{10}=10\log Q+33\log(v+40+500/v)+10\log(1+5p/v-27,6) \tag{3}$$

- L_{10} is the level percentile 10 for equal fixed distancia 13,5m;
- Q is the volume of traffic;
- v is the average speed;
- p is the percentage of heavy vehicles.

- [4]

$$L_{eq} = 7,7 \log[Q(1+0,095VP)] + 43 \tag{4}$$

- Q is the flow of vehicles;
- VP is the percentage of vehicles heavy;

- [3]

$$L_{eq}=68,87+3x10^{-3}Q \tag{5}$$

- Q is the flow of vehicles;

6. DEVELOPMENT OF THE PREDICTING MODEL

To calibrate the traffic noise prediction model the data of the 10 points of measurement had been used. Initially it was carried out tests to identify and validated those variables which where more significant from the statistical point of view. The validation of the model precision was made through the determination coefficient statistics (R^2) and analysing the absolute average error, that if it relates to measured of the error of each point, calculated according to Equation 6.

$$E_{ma} = \sum_{i=1}^{n} \frac{\sqrt{\left(X_r - X_p\right)^2}}{n} \tag{6}$$

- E_{ma} is absolute average error;
- X_r is the real noise level;
- X_p is the predicted noise level.

A correlation between all those possible independent variable was founded. It was checked:

- Flow of light vehicles;
- Flow of vehicles heavy;
- Flow of motorcycles;
- Distance of the source.

The best correlations had been observed for the logarithms of the total vehicles flow and for the logarithms of the inverse of the distance. Therefore, the calibrated model took this in consideration and is presented in equation 7 as follows:

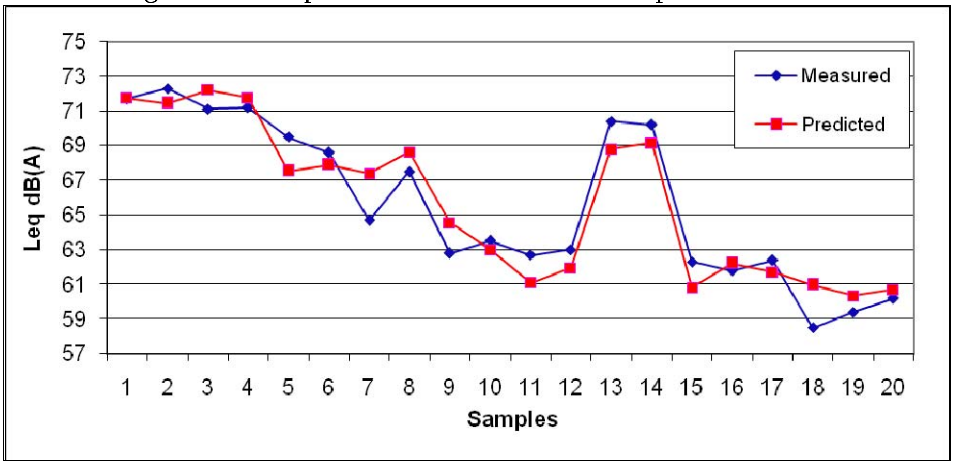
$$L_{eq} = 54{,}56 + 5{,}2.\ln\left(\frac{Q}{d}\right) \tag{7}$$

- Leq is the equivalent sound level;
- Q is the total flow of vehicles;
- d is in the distance between the source and the receiver.

The model presented a coefficient of determination (R2) equal to 0,91 and the absolute average error was 1,15 dB (A). In order to verify the consistency of the statistics and the accuracy achieved for the presented parameters, the results are plotted in Figure 1.

In this graph the real values measured in the field are compared with those predicted by the model and a good agreement between them can be observed. The largest difference between the predicted and the measured noise level is of 2.5 dB(A). As a matter of fact it is possible to verify that the curve of the predicted model is similar to the curve of the real data registered in the field with a significant precision as it was initially expected.

Figure 1 – Comparision between the real and predicted noise



6. CONCLUSIONS

This paper presented a traffic noise prediction model that showed a good correlation with the measured data registered in a highway located near to Belo Horizonte city in Brazil. The predicted model has been calibrated closely to straight lanes in the highway with 3% slope and with no influence of reflections from local topography. For these conditions the model has shown to be very effective, simple to use and very useful for practical purposes.

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