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DEVELOPMENT OF A PREDICTION TRAFFIC NOISE MODEL TO ROADS IN DUPLICATION PROCESS

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Abstract

With the constant growth of the number of vehicles in the world is common to increase the capacity of urban and rural routes through duplication. In this context, this significant intervention has direct impacts on the traffic noise. This paper aims to present the procedures used to calibrate a statistical model to predict traffic noise from a database collected in a process of duplication of a highway in the state of Goiás, Brazil. It will be tested from a matrix of correlation, parameters such as vehicle flow, percentage of heavy vehicles, average speed, slope floor, and others. Intend with the model to help the planners to predict what will be the changes in the noise levels of a highway in duplication process still in the stage of project.

1. INTRODUCTION

With the constant growth of the numbers of vehicle around all over the world, the vehicles flow on the roads, whether urban or rural, also increases. To support this demand increase is common to expand the highway capacity by adding more lanes in a duplication process. In addition to increasing capacity, it also provides a significant increase in security with this procedure.

However, this increase in the vehicles flow due the roads duplication generates a series of environmental impacts, including the increase in the noise levels. Several studies have shown that traffic noise is proportional to the vehicles flow, such as was shown in the work done by Rodrigues [5].

In the case of roads duplication, in addition to the traffic increase, the noise will be impacted by the average speed increasing. This parameter also impact directly on the noise levels. This is because, for speeds greater than 55 km/h the largest portion of noise emmited by a vehicle in motion is due to the contact tire-pavement [4, 6]

The noise on roads, having a vehicle as a sound source, can be segregated, basically into two main categories: (I) the engine noise and exhaust noise and (II) the friction between tire and pavement. However, a number of other factors influence the resulting noise levels, such as speed, volume and density of the flow, vehicles classification (motorcycles, light or heavy vehicles, etc), technology and conservation state of vehicles, geometrical characteristics of the track, weather conditions, among others [3].

Being connecting ways between urban areas, the roads generate, in large part of their extensions, impacts for a small number of people, since they are in rural areas. Nevertheless, when they cross urban centers this situation reverses considerably. Due to have significant volumes of traffic at higher speeds than those observed in urban centers, the level of noise emitted by vehicles in traffic at the roads comes to be higher than the urban traffic noise itself.

In this context, it is very important to traffic engineers and public agencies know what will be the impacts from the roads duplication. Thus, the present study aims to present a model to predict noise generated from traffic to roads in process of duplication. The database was collected on a highway in the state of Goias, Brazil, which fits in that context. A fact that deserves to be commented, about this particular road, BR 153, is that there is a very significant plot of heavy vehicles. This peculiarity will have direct influence on the model, as will be shown in the following.

2. METHODOLOGY

Initially were measured levels of noise, together with the measurement of the vehicles flow in 11 points in the road, through a total of 350 km. Beyond these parameters, were observed, for each point, the presence of ramp (slope), the vehicles average speed and the distance between the source and receiver, always considering as a source the highway flow division line.

All procedures were performed in accordance with the NBR 10151 [1] and the International Standard ISO 1996/1-3 [2]. The sampling time was 15 minutes, and each point was measured twice adding 30 minutes. Data was collected every 1 second, totaling 1800 samples.

This time was chosen due to the characteristics of the traffic on the highway, higher than the minimum recommended by the Technical Standards, in accordance with the methodology set out in a paper recently published by Rodrigues et al. [5], in which it held a diagnosis of noise on a highway that is going to pass through duplication process. Were also measured the maximum and minimum levels, and the levels percentiles.

The equipment used was a type II sound level meter, Extech brand, model 407780. It was calibrated before and after each measurement in the frequency of 1000 Hz with the sound pressure level of 94 dB.

To make LAeq prediction, initially a statistical correlation matrix was set up to identify the parameters that are most relevant to appear in the model. Identified the independent variables, the model was calibrated and it was compared the accuracy of this through comparison with the actual values measured on the field. Moreover, it was also calculated the absolute mean error for all points of measurement, as will be shown in the following items.

3. TRAFFIC AND SOUND LEVELS IN THE HIGHWAY

As mentioned previously, there was a strong presence on this road of heavy vehicles, as can be seen in Figure 1, shown average of 48% on all traffic recorded.

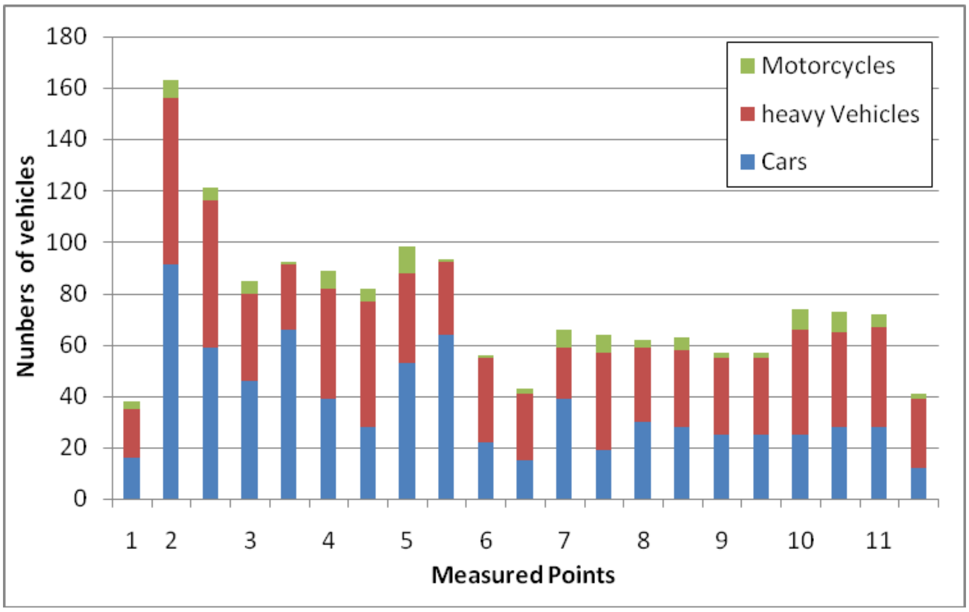

Figure 1. Traffic in the measured points

The measurements showed that, in general, the levels of noise are at the limit of what is recommended by Brazilian legislation and by the Technical Standards. As can be seen in Figure 2, most of the points presented LAeq next to the values of 70 dB (A).

It's also important to note that the lower levels of noise were close to 32 dB (A), while the maximum levels were, except for one point, close to 85 dB (A). The point which showed maximum level above the other points was located in a strong slope and during the measurement there was the passage of a significant number of big trucks.

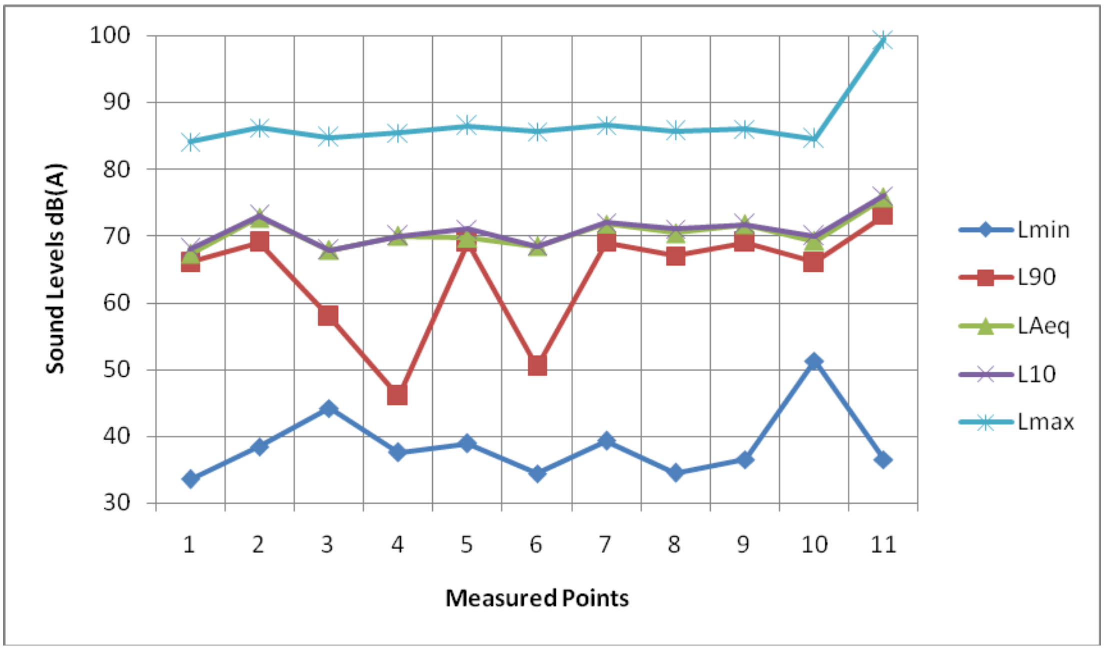

Figure 2. Sounds levels in the measured points

4. MODEL DEVELOPMENT

To calibrate a statistical model it is necessary first to identify the best independent variables whose explain the variable to be predicted. To do this, it was set up a statistical correlation matrix between the LAeq and the variables relating to traffic and specific features of each measuring point.

Based on basic concepts of acoustics, some relationships were taken from the specific characteristics of sound and human perception, for example, take the natural logarithm of the vehicle flow and the inverse of the distance, as can be seen in Table 1.

Table 1. Correlation matrix

	Col. 1	Col.2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
Ln 1	1,000	0,657	0,672	0,319	0,568	0,302	0,450	0,649
Ln 2	0,657	1,000	0,781	-0,195	0,945	0,251	0,479	0,998
Ln 3	0,672	0,781	1,000	-0,239	0,715	0,130	0,319	0,788
Ln 4	0,319	-0,195	-0,239	1,000	-0,214	0,377	0,320	-0,196
Ln 5	0,568	0,945	0,715	-0,214	1,000	0,168	0,413	0,953
Ln 6	0,302	0,251	0,130	0,377	0,168	1,000	0,964	0,250
Ln 7	0,450	0,479	0,319	0,320	0,413	0,964	1,000	0,481
Ln 8	0,649	0,998	0,788	-0,196	0,953	0,250	0,481	1,000

Where:

1. LAeq;
2. Natural logarithm of vehicles (heavy vehicles x 2 and motorcycles x 2);
3. Natural logarithm of heavy vehicles;
4. Natural logarithm of 1/d;
5. Natural logarithm of vehicles;
6. Ramp;
7. Natural logarithm of vehicles to the power ramp ln[vehicles^ramp];
8. Natural logarithm of vehicles (heavy vehicles x 2).

In addition to the variables shown in the matrix, it were also tested the influence of floor conservation, slope and speed, but it could not get good correlation values. Despite knowing, through specialized literature, that these parameters are relevant in determining the traffic noise, it is believed that the sample was not statistically representative. That is, the data collected were insufficient to determine any correlation with these parameters.

Evaluating the correlation matrix, we could see that the most explanatory independent variables were the natural logarithm of the total vehicles, considering trucks and motorcycles weighing 2, the natural logarithm of total heavy vehicles and the natural logarithm of the inverse of the distance.

However, models were tested with all possible combinations, in order to obtain the best statistical adjustment. With the help of Minitab software it was conducted the calibration processes through linear regression. The model that best fitted is presented below:

$$y(x) = 47{,}8 + \ln\left[\frac{[2(hv+mt)+c]^{2{,}82} x (hv)^{4{,}5}}{d^{3{,}15}}\right] \quad (1)$$

Where:

- LAeq (15min) is the equivalent sound level in fifteen minutes;
- hv is the heavy vehicles flow;
- mt is the motorcycles flow;
- c is the cars flow;
- d is distance;
- ln is natural logarithm.

Note that heavy vehicles is present at two terms of the equation, which emphasizes how influential is this variable in the case of this particular road because of the significant volume of trucks present.

The model showed a statistical determination coefficient equal to 0.86. In addition, all variables showed, according to the test t-distribution, satisfactory values to 95% confidence.

To verify the accuracy of the model, it was tested for the points measured, as can be seen in Figure 3.

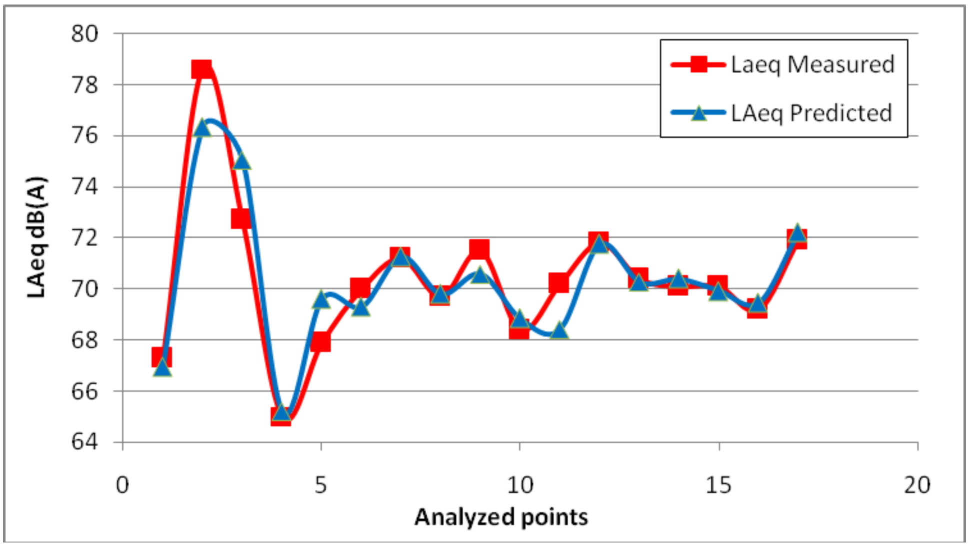

Figure 3. Real and predicted sound level comparison

Looking at the chart it is possible realize, visually, that the curves are quite coincidental, which shows a significant accuracy for the model. It's worth a specific note for the point number 2 who had the lower adherence regarding the curves agreement. This fact should be explained because this point, as mentioned earlier, besides presenting a significant slope, had a significant flow of big trucks, vehicles which have a greater sound power.

Another verification of the model can be made by the Absolute Average Error, given by the following equation:

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

This parameter is the average difference between the real and model predicted value for each point analyzed. The result shows an error equal to 0.7 dB (A). This value is low, especially when considering that the sound level meter used to perform measurements has precision of 1 dB (A) for more, or less.

5. CONCLUSIONS

Based on what was explained, it could be inferred that the model calibrated in this work shows significant precision and, therefore, fit to be used. However, according to the peculiarity of the database, it is recommended that it be applied to rural roads with significant parcels of heavy vehicles (in the order of 50%).

The processes used to validate the model showed good results, corroborating the possibility of application. However, as an experimental model, it is recommended, as further work to researchers, test it in various situations, including comparing its accuracy with existing models in the literature.

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