

## EFFECTS OF TRAFFIC COMPOSITION ON NOISE GENERATED BY TYPICAL BRAZILIAN ROADS

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The effects of traffic composition on the noise generated by typical Brazilian roads are analyzed in this work. Composition is defined as the percentage of heavy vehicles (trucks and buses) with respect to the overall number of vehicles. Noise measurements were made at 10 m from lane edges of three typical roads at the city of Florianópolis, SC. All sites had identical characteristics, such as, long and horizontal straights, free of reflections from buildings and walls, traffic flowing with average speed of 80 km/h, and distant from traffic lights and roundabouts. Measurements were made on the same days of the week and at the same time (from 06:00 h to 10:10 h). On these three roads a total of 149 measurements were made and for each of them the percentile level  $L_{10}$  and the equivalent level  $L_{eq}$  were calculated. These levels were plotted against the composition of the traffic from which were obtained empirical expressions, with reasonably good correlation indexes, which can be used for predicting road traffic noise levels based on the knowledge of traffic parameters. Informations obtained in this work will help authorities to foresee the response of communities to typical Brazilian road traffic noise.

**Keywords:** Road traffic noise, Vehicle Noise; Community Noise, Traffic Volume Composition

### 1. Introduction

The traffic noise is one of the most aggressive types of noise pollution, being considered of great importance when compared to the other types, such as industrial noise, airport noise and community noise.

A survey conducted by FIDEL [6] in United States has showed that 46% out of the total population surveyed felt annoyed by the urban noise, from which 86% out of them has indicated the traffic noise as the main source of annoyance. LANDGDON [10] has performed interviews with 2933 people in London, asking about their sensitiveness to the noise, their dissatisfaction to it, and the disturbances induced by the noise in their everyday lives, also taking measurements on the traffic noise levels where the interviews have been conducted. Among the conclusions, some can be highlighted: 1) Between 60 and 80 dB(A), under free traffic conditions, the dissatisfaction degree can be predicted with a good precision departing from the percentile noise level  $L_{10}$ , which is the noise level measured in dB(A) exceeded in 10% out of the total measurement period [12]; and from the equivalent noise level  $L_{eq}$  also measured in dB(A); 2) The best correlation ( $r = 0,85$ ) has occurred between the populational dissatisfaction and the noise level  $L_{10}$ . GRIFFITHS and [10] in a survey conducted in the city of London, have also pointed the road traffic noise as the main source of annoyance for 40% out of the interviewed people, followed by the aircraft noise, 20%, and by the civil construction noise, 10%. The report from 2000 from Umweltbundesamt of Germany [13], where 2006 people have been interviewed, points the main noise sources of annoyance for the population: urban traffic, 64.6%, followed by the neighborhood noise, 39.5%, aircraft noise, 32.5%, industrial noise, 28.2% and the noise generated by trains, 23.4%. ZANNIN *et. al.* [14] have interviewed 860 people in the city of Curitiba, Southern Brazil, and have concluded that the main sources of annoyance were: urban traffic noise, 70%, and neighborhood noise, 38%.

Based on thesesurvey results it is noticeable the evident importance of the traffic noise as a source of annoyance manifested by the citizens, mainly in urban centers, which justify the constant studies and surveys that are being conducted in this subject.

The main parameters that directly influence the noise generated by a road are: traffic volume, composition and speed, road gradient and distance to the noise source. Among them, the first three cited parameters present outstanding importance [3, 7, 8 12].

It has been verified that the heaviest vehicles are noisier, and the increase in their proportion to the other vehicles causes an increase in the noise level. The different becomes more evident under high engine torque conditions. The rate among the light and heavy vehicles is represented by the traffic composition [3]. The effects of the road gradient and the type of surface over the noise generated by the traffic are less important, although not despicable. These parameters will not be evaluated here.

The criteria developed in other countries which refer to the subjective response of communities to the road traffic noise are fundamentally based on statistical levels, and they can be estimated according to the traffic parameters such as: vehicle flow and traffic composition.

The differences in emitted noise, attributed to the maintenance conditions of the vehicles, to the conservation conditions of the roads, to the driving skills and to the

changes induced by the upgrades performed by the modern vehicle manufacturers which induce less noise emission, cause the results obtained in other countries not to apply to the traffic conditions in Brazil.

The goal of this survey is to determine the characteristics of the noise levels used in subjective evaluation indexes, in relation to the Brazilian road traffic volume and composition. The field of work is the city of Florianópolis (300,000 inhabitants) situated in the Southern Brazil.

The conclusions obtained from this study may be used, in the future, in environmental impact studies caused by roads, and may help diminishing the problem of the urban noise pollution, which is a growing problem in Brazil.

## 2. Indexes of subjective response to noise

Road traffic is the most widespread source of noise in all countries and the most prevalent cause of annoyance and interference. Therefore, traffic noise reduction measures and traffic noise prediction should have the highest priority.

The noise indexes that are frequently used in the evaluation of the noise emissions generated by the traffic of vehicles are: The equivalent noise level  $L_{eq}$  measured in dB(A), and the percentile levels  $L_n$  also expressed in dB(A) [2, 5, 9].

### 2.1. Continuous equivalent noise level – $L_{eq}$

The continuous equivalent noise level has turned out to be a basic parameter to express the emitted noise in urban environments, being defined as:

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T 10^{\frac{L_p(t)}{10}} dt \quad \text{dB(A)} \quad (1)$$

where  $T$  is the total measurement or observation period in s, and  $L_p(t)$  is the instantaneous noise level in dB(A).

The  $L_{eq}$  provides us a good noise emission estimation, putting more emphasis on the high occasional noise levels, which can be very disturbing [5, 9].

### 2.2. Percentile levels – $L_n$

Due to its huge variation in time, the traffic noise presents measurement difficulties. Thereafter the usage of statistical aspects becomes of great importance and is a secure method of evaluation. According to [12], the most frequently used statistical

verification for the percentile levels is done through the cumulative distribution curves which show the percentile of time that the noise level exceeds the total measurement time. The international technical literature [2, 5, 9] recommends the usage of the following percentile levels indexes for the traffic noise study:

$L_{10}$  – noise level measured in dB(A) which is exceeded in 10% out of the total measurement period;

$L_{eq}$  – equivalent noise level and the percentile level  $L_{10}$  will be analysed here according to the traffic composition.

### 3. Measurement sites and proceedings

The road segments which have been selected for the measurements have similar characteristics, such as: straight and flat segments, asphalt paving, two way roads, no speed controllers (traffic lights, ramps), no central reservation and identical widths.

The selected segments were:

- a) SC 404 road, 2<sup>nd</sup> kilometer, situated in Santa Catarina island, in Florianópolis, a 300 m long segment. The percentage of heavy vehicles in this segment is 5 to 10% out of the total number of vehicles. 50 measurements have been conducted in this site;
- b) SC 401 road, 5<sup>th</sup> kilometer, also situated in Santa Catarina island, which has a straight and flat segment about 1 kilometer long. This road presents 25% to 30% of heavy vehicles out of the total traffic. 50 measurements have been carried out in this segment;
- c) BR 101 road, in Palhoça town, which belongs to the metropolitan area of Florianópolis. The selected segment is 500 meters long and is straight and flat, on which the traffic volume presents 35% to 45% of heavy vehicles out of the total vehicle flow. 49 measurements have been carried out in this segment.

Every selected segment did not have any construction (buildings, residences, walls) and bus stops in the vicinity of the measurement sites, or any other factor which could induce the traffic flow to deviate from its normal course.

The measurements have always been done in the same weekday, from Monday to Friday, and in the same time of the day, from 06 am to 10 am. The measurements have only been conducted under non-wet pavements (no rain) and under light wind conditions. The vehicle speed has been measured by a radar system, furnished by the Military Police of the state of Santa Catarina. The traffic speed in the selected segments has varied from 75 km/h to 90 km/h, and the speed of the majority of the vehicles was very close to 80 km/h. The counting of the number of vehicles have been done by two people, who took notes on the number of light and heavy vehicles passing on both ways on the road, during a period of 5 minutes.

Noise levels were measured by means of the following equipment: Brüel and Kjaer Mediator 2238 type 1 integrating and logging sound level meter [2], installed on

a tripod at 1.2 m above the ground and at 10 m from the road margins, provided with wind protector. A total of 149 measurements have been carried out. Each noise emission measurement has been conducted during a 5 minute interval, with no interrupts. The measured noise levels were the equivalent noise level  $L_{eq}$  and the percentile level  $L_{10}$ .

#### 4. Relationships between the statistical levels $L_{eq}$ , $L_{10}$ , and $L_{90}$ , and the traffic composition

In similar surveys, where the influence of the traffic noise in the overall measured noise was investigated [3, 11], the influence of the traffic noise in the overall equivalent noise level  $L_{eq}$  and percentile level  $L_{10}$  has been established. Similarly as in the other cited surveys [3, 11], this survey has searched mathematical relationships which were able to express the dependency between the  $L_{eq}$  and  $L_{10}$  in relation to the traffic composition for the analyzed roads.

The used mathematical expressions are of the form:

$$L_{eq} \text{ versus } 10\text{Log}_{10}(QP + A_i * QL) \quad 0 \leq A_i \leq 1 \quad (2)$$

$$L_{10} \text{ versus } 10\text{Log}_{10}(QP + A_i * QL) \quad 0 \leq A_i \leq 1 \quad (3)$$

where:  $QP$  is the volume of heavy vehicles expressed in (vehicles per hour),  $QL$  is the volume of light vehicles expressed in (vehicles per hour),  $A_i$  is a pondering factor which considers the light vehicle flow,  $L_{eq}$  is the equivalent noise level and  $L_{10}$  is the percentile level.

In the expressions (2 and 3) above it is noticeable the influence of the traffic composition over the noise emission levels. It is also noticeable that the pondering factor for light vehicles varies within the  $0 \leq A_i \leq 1$  interval, therefore when  $A_i = 0$  only the influence of the heavy vehicles is accounted, whereas when  $A_i = 1$  the influence of the total vehicle composition ( $QP + QL$ ) is accounted over the overall noise emission levels. The simple linear regression has been used, as indicated by Eq. (4), in order to establish mathematical relationships which can describe the noise emission levels and the traffic composition.

$$L_x = a + bL_k \quad (4)$$

where:  $a$  and  $b$  are the linear regression line coefficients;  $L_k = 10\log_{10}(QP + A_i * QL)$  has been used to describe the relationship between the equivalent noise level  $L_{eq}$ , the percentile level  $L_{10}$  and the traffic composition. So, the noise emission levels can be estimated by means of the following equation:

$$L_x = a + b * 10 \log_{10} (QP + A_i * QL) \quad (5)$$

where the equations that best express the noise emission levels ( $L_{eq}$ ,  $L_{10}$ ) are those which the  $A_i$  value conduct to the highest values of the correlation coefficients  $r$ .

Figures 1 and 2 show the variation of the correlation coefficients  $r$  in relation to the pondering factor  $A_i$ , by considering the percentile level  $L_{10}$  and the equivalent noise level  $L_{eq}$ .

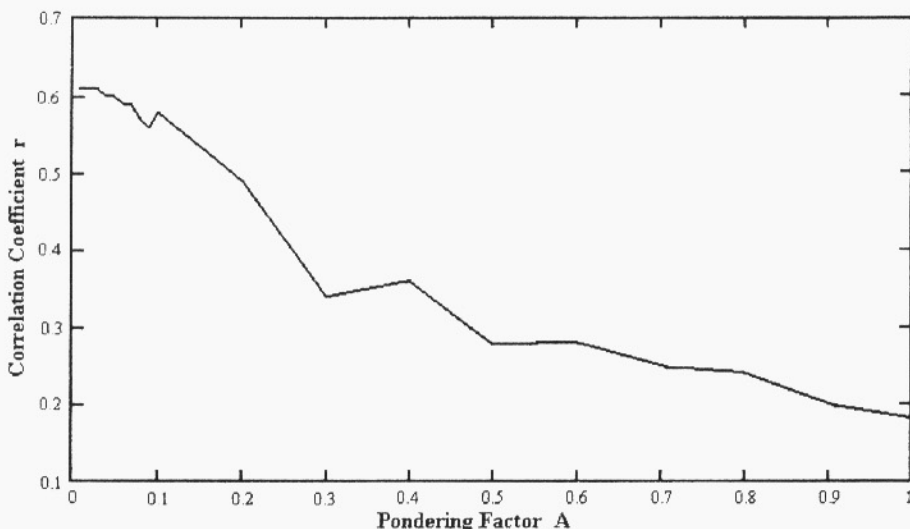


Fig. 1. Relationship between the correlation coefficient  $r$  and the pondering factor  $A_i$ , by considering the percentile level  $L_{10}$ .

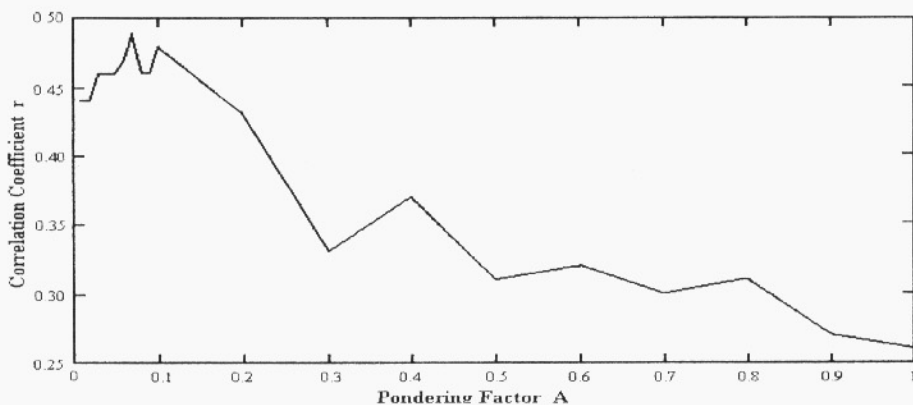


Fig. 2. Relationship between the correlation coefficient  $r$  and the pondering factor  $A_i$ , by considering the equivalent noise level  $L_{10}$ .

By observing the figures 1 and 2, it is noticeable that the correlation coefficients vary more when the pondering factors are  $A_i \leq 0.2$ , in other words, when the light vehicle volume is small, being observed a predominance of heavy vehicles. This means that the heavy vehicles are the main sources of noise emission, represented by the percentile level  $L_{10}$  and by the equivalent noise level  $L_{eq}$ . This result is similar to those reported by other authors [3, 11].

The fitting line which has presented the highest correlation coefficient between the percentile level  $L_{10}$  and the traffic composition, has been obtained for  $A_i = 0.03$ , resulting in a correlation coefficient  $r = 0.61$ . Figure 3 shows the percentile level  $L_{10}$  in relation to the logarithm of the vehicle flow for all the 3 roads evaluated in this survey.

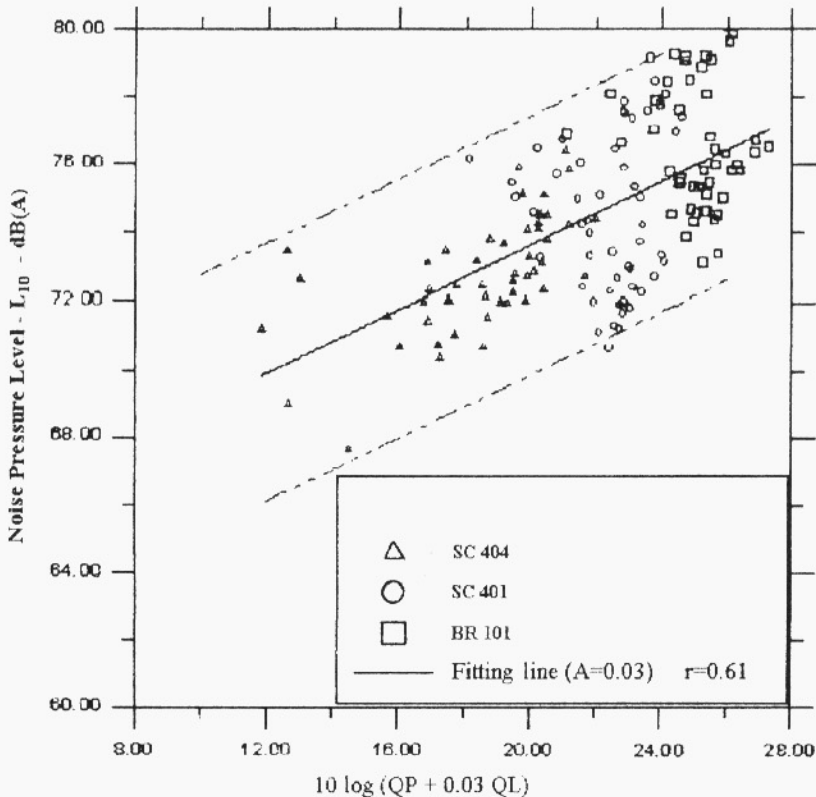


Fig. 3. Relationship between the percentile level  $L_{10}$  and the traffic composition for all the 149 measurement sites, by considering  $A_i = 0.03$ .

The fitting line which has presented the highest correlation coefficient between the equivalent noise level  $L_{eq}$  and traffic composition has been obtained for  $A_i = 0.07$ , resulting in a correlation coefficient  $r = 0.49$ . Figure 4 shows the equivalent noise level  $L_{eq}$  in relation to the logarithm of the vehicle flow for all the 3 roads surveyed.

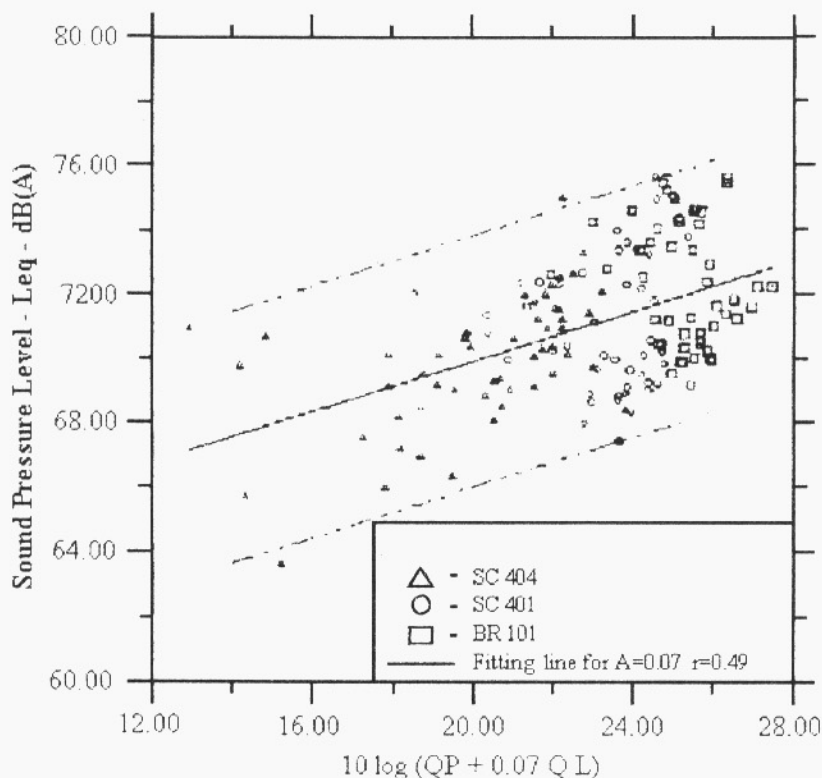


Fig. 4. Relationship between the equivalent noise level  $L_{eq}$  and the traffic composition for all the 149 measurement sites, by considering  $A_i = 0.07$ .

Based on the above results, the following expressions have been obtained for the prediction of the noise emission levels for the roads surveyed:

$$L_{10} = 64.29 + 4.67 \log_{10} (QP + 0.03 QL) \text{ dB(A)}, \text{ with } r = 0.61 \quad (6)$$

and

$$L_{eq} = 62.10 + 3.88 \log_{10} (QP + 0.07 QL) \text{ dB(A)}, \text{ with } r = 0.49 \quad (7)$$

where:  $L_{10}$  is the percentile level which is surpassed in 10% out of the measurement period expressed in dB(A);  $L_{eq}$  is the equivalent noise level expressed in dB(A);  $QP$  is the heavy vehicle flow expressed in (vehicles/hour) and  $QL$  is the light vehicle flow expressed in (vehicles/hour).



Figure 5 shows the comparison between the presently obtained expression for the percentile level  $L_{10}$  and the expression obtained by CROMPTON and GILBERT [4]. The expression found by Crompton and Gilbert for the percentile level  $L_{10}$  is the following:

$$L_{10} = 61.8 + 5.13 \log_{10} (QP + 0.2QL) \text{ dB(A), with } r = 0.49 \quad (8)$$

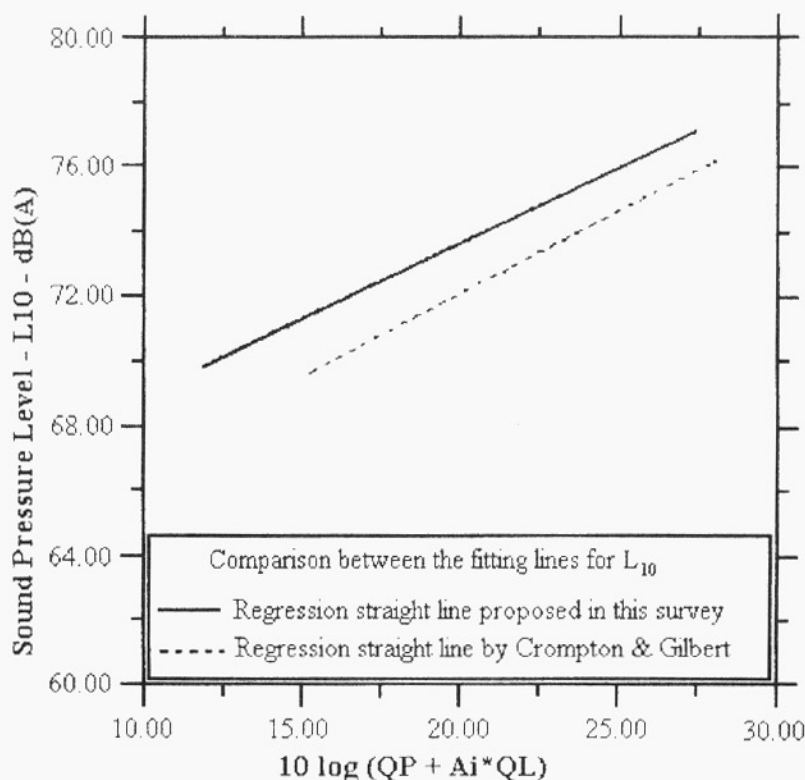


Fig. 5. Comparison between the linear regression lines obtained by Crompton and Gilbert, and the linear regression lines proposed by this survey for the percentile level  $L_{10}$ .

It is noticeable that the slope of the regression line obtained by the formulation from Crompton and Gilbert [4] is slightly superior than the one proposed by this survey, however, it presents noise levels 2 dB(A) lower, approximately.

## 5. Conclusions

The present survey has showed that the most commonly used noise emission levels in the road noise emission evaluation, such as the percentile level  $L_{10}$  and the equivalent

noise level  $L_{eq}$ , can be estimated by knowing the traffic composition with reasonably good precision.

The difference between the findings of this survey, equation (4), and the findings of Crompton and Gilbert, equation 4.6, may be due to the highest noise emission levels individually generated by the vehicles circulating on the Brazilian roads in comparison to those that circulate on the British roads. This variation is attributed to the bad conservation of a good portion of the vehicle fleet circulating in the Brazilian roads, to the non-standardization of the exhaust system position and also to the bad habits, in general, of the Brazilian drivers: a) Using the horn for any purpose, with or without apparent reason to do so; b) Accelerating the vehicle during traffic jams or while waiting for green traffic light; c) High speed driving inside urban regions. It is not rare to find people driving over 80 km/h.

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