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An experimental procedure to minimize traffic noise inside bus stations: a case study in Brazil

Frederico Rodrigues[1]
PET/COPPE/UFRJ
Rio de Janeiro - RJ - Brazil

Luiza Franco[2]
UFMG-Universidade Federal de Minas Gerais
Belo Horizonte - MG – Brazil

Carlos Alberto Faria[3]
FECIV – Universidade Federal de Uberlândia

ABSTRACT

Bus terminals of public transport are elements often more present in transport systems in urban centers. These environments, which are generally semi-closed buildings, have intense traffic of heavy vehicles during the whole day, which makes this kind of place very noisier and annoying. In this context, this paper makes a review of a large research, which one concerns about the acoustic parameters of urban public transport bus terminals, and performs an experimental procedure to minimize the noise levels at these locations. The study of case has been done in Uberlândia-MG, Brazil. Preliminary results show considerable potential for reducing traffic noise inside bus stations.

1. INTRODUCTION

Noise generated by traffic is a more and more worrying problem today in urban centers of medium and large sizes. One of the main aggravations is the constant increase of the fleet, be it of private vehicles (light) or of public transport (heavy). The world population, in 1950, was around 2.6 billion inhabitants with a fleet of around 50 million automobiles. In 1988, the world population was already around 5.5 billion inhabitants and a fleet of around 500 million automobiles. That is, whereas the world population almost doubled, the number of vehicles was multiplied by ten[1]. Continuing this process, it is verified that the vehicles' fleet has been increasing a lot in the last years currently in Brazil due to the increase of the population's purchasing power, the easiness of credit obtainment, as well as the heating of the country's economy until the midst of 2008.

With the constant increase of traffic volumes, traffic in urban centers impacts the environment more and more due to air, sound and visual pollution. The sound levels are more and more alarming and tend to be aggravated due to a growing number of circulating vehicles. The main parcel of noise in urban centers is derived from the vehicle traffic. Studies realized on the theme demonstrate that in the traffic composition, heavy vehicles (buses and trucks) are the most powerful sound sources[2]. In this context, each travel car (automobile) is a source of noise of about 70-75 dB (A) at a distance of 7 meters, while a heavy vehicle reaches 80-85 dB (A)[3-4].

[1] emaildofred@gmail.com
[2] luizapcfranco@hotmail.com
[3] cafaria@ufu.com.br

In Brazil, public transport is realized mainly by buses and, among the functional components, terminals are the places where trips begin and/or end. Besides that, it has the function of integration when a same modal is utilized or of transfer when more than one transport modality is required for the realization of a trip. In general, terminals are specially designed and built edifications with this purpose[5].

The architecture of these places is very similar, with the presence of façades, walls, gazebos and top floors, however, the projects vary on a case by case basis[6]. Terminals of larger size have various spaces to attend a greater passengers' demand. The architectonical features compromise the noise problematic a little more due to vehicle traffic inside the terminals, once the surfaces present at these environments' architectonic structure function as reflectors of sound waves emitted mainly by motors of the vehicles in traffic.

Usually, terminals have intense pedestrians and buses' traffic all day long, considering that the most critical moments occur in the rush hour, once the generated noise levels are extremely high, mainly due to the great number of circulating buses.

According to noise measurements realized[6] it was verified that the peak values occurred when drivers accelerated their buses, with no apparent need, elevating the motors' rotation. This observation instigates a question: "How smaller sound levels would be if the buses motor's rotation was maintained low while vehicles kept circulating on terminals?" Searching an answer for this question, a pilot experiment has been realized to verify possible reductions of noise levels on terminals with this control procedure in the source that, according to specialized literature, would be the most efficient way[7].

Therefore, with the purpose of collaborating for the minimization of the levels of insalubrities in these public environments, regarding sound levels, the present paper presents the results of the experimental procedure realized in one urban public transport terminal in Brazil.

2. AREA OF STUDY

The case study was realized in Uberlândia (MG – Brazil), with estimated population of 608,000 inhabitants[8] (IBGE, 2007), out of which 487,887 live in the urban area. In our country, medium size cities need an efficient and operative public transport system. In Uberlândia, public transport is realized almost totally by the bus structured as a feeding branch system, containing five terminals that receive its surroundings' users or through feeding lines[9]. The chosen terminal for the realization of this pilot procedure was the Terminal Santa Luzia that operates with two vehicle entries and two corridors where the stop points are located, according to what can be seen in the simplified layout presented in Figure 1.

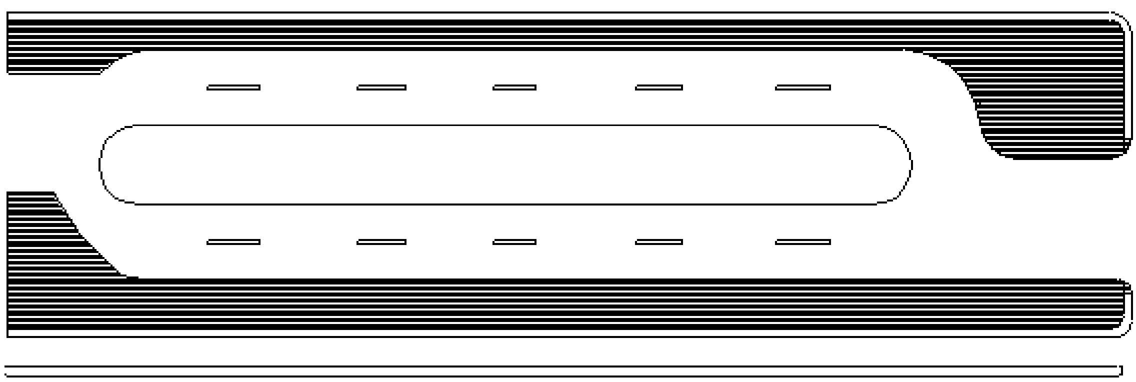

Figure 1: Simplified layout of Terminal Santa Luzia

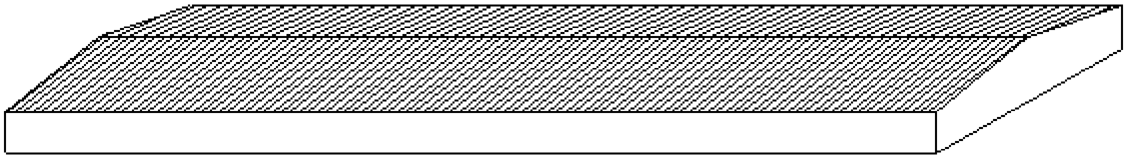

Figure 2: Edification's geometry of Terminal Santa Luzia

In a work of sound characterization in this terminal, it was verified that the $L_{eq,5min}$ values obtained are all above 70 dB (A). The lowest $L_{eq,5min}$ found was of 71 dB (A) whereas the highest value was of 81 dB (A). The values found for the percentage levels L_{90} (background noise) and L_{10} (noise peaks) were, respectively, 64.9 and 77 dB (A). The vehicles' flow varied during all the measurement interval presenting as lowest and highest values, respectively, 5 and 15 vehicles for 5 minutes' intervals. These data were obtained during measurements in regular operation conditions at the terminal. Such values will be compared with the values obtained during the measurement in experimental character, to be detailed as follows.

3. METHODOLOGY

Two procedures were realized for verification of how big could be the noise reduction at this terminal in study, considering the procedure of motors' rotation variation caused by drivers.

Initially, a circular letter was disclosed by the municipal transports managing organ (Municipal Secretary of Traffic and Transport/Secretaria Municipal de Trânsito e Transportes – SETTRAN), where the objectives of the research were explained and there was a collaboration request for the buses' companies once in a determined day a noise measurement in experimental character would be realized at Terminal Santa Luzia as well as for the drivers to keep the buses motors' rotation level low during the circulation on the terminal.

The second reinforcement procedure, disposed during all the measurement period, was to let two collaborators available at the terminal's entries warning the drivers to transit at the terminal with low motors' rotation. However, despite the fact that the value was not established, a reference had already been indicated.

The data collection was made with a type 2 sound pressure measurement device, model SL 4001, of the Lutron brand. The noise levels were measured during 1 hour in 15 seconds' intervals and, simultaneously, the counting of the buses' flow in the terminal was made. The totalizations occurred in 5 minutes' intervals and the schedule chosen was during the afternoon rush period, once it is the most critical one.

The equivalent sound level (L_{eq}) was obtained in 5 minutes' interval, during the rush hour. Afterwards, the comparison of these values was made with the buses transiting with the motors' rotation control. The option of adopting five minutes' intervals was due to the number of vehicles being practically constant.

4. RESULTS' PRESENTATION AND DISCUSSION

At Table 1, the L_{eq}`s are presented for the five minutes' intervals during the measurement period. Little variation on the sound levels was verified due to the variation of the number of buses by each 5 minutes' interval, that is, the minimum value measured was of 72.56 dB (A), the medium value was of 73.27 dB (A) and the maximum value was of 75.26 dB (A).

Table 1: Equivalent sound level

Time	L_{eq} (dB(A))	Flow of buses/5 min
17:00-17:05	73,08	8
17:05-17:10	73,55	9
17:10-17:15	75,26	9
17:15-17:20	72,78	10
17:20-17:25	73,09	10
17:25-17:30	74,14	10
17:30-17:35	73,14	12
17:35-17:40	72,56	13
17:40-17:45	72,67	13
17:45-17:50	72,90	15
17:50-17:55	73,35	15
17:55-18:00	72,71	16

The rotations' control procedure was not totally accurate when buses circulated at Terminal Santa Luzia. Nevertheless, even though it was possible to verify reductions at the noise levels. At Figure 3, the values obtained in the measurement without motors' spinning control are demonstrated, that is, in regular day-by-day operation condition as well as with the reduced rotation procedure, that is, low motors' spinning. In order to avoid interferences in the L_{eq} values, five minutes' intervals were adopted, which, in the end, were totalized during one hour: the rush hour.

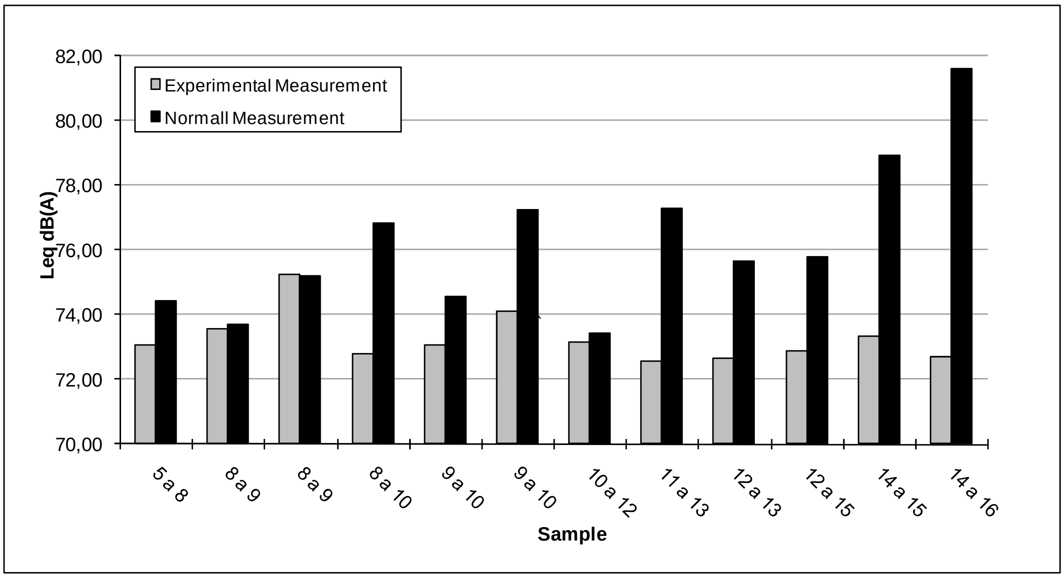

Figure 3: Measurements with and without the motors' low spinning procedure

The graphic clearly demonstrates that in all intervals there was a decrease of the equivalent sound level. Besides that, it is possible to verify that there is a greater difference in the L_{eq} values, as the number of vehicles increases. That is, the result of the experiment is more perceptible for the flows.

The $L_{eq,1h}$ reduction was of a little more than 3 dB (A), decreasing from 76.9 dB (A) to 73.3 dB (A), when compared to the measurement in regular day-by-day operational conditions. The average realized for the 12 $L_{eq,5min}$ values (calculated in five minutes' intervals during 1 measurement hour) also pointed out a reduction of approximately 3 dB (A), decreasing from 76.23 dB (A) to 73.27 dB (A).

One verification obtained when evaluating Figure 3 is that the major reductions occurred for the greater vehicles' flow. Figure 4 presents the relation among buses' flow and the noise reduction observed, confirming that the bigger the number of circulating buses, the bigger the reduction in the equivalent sound level.

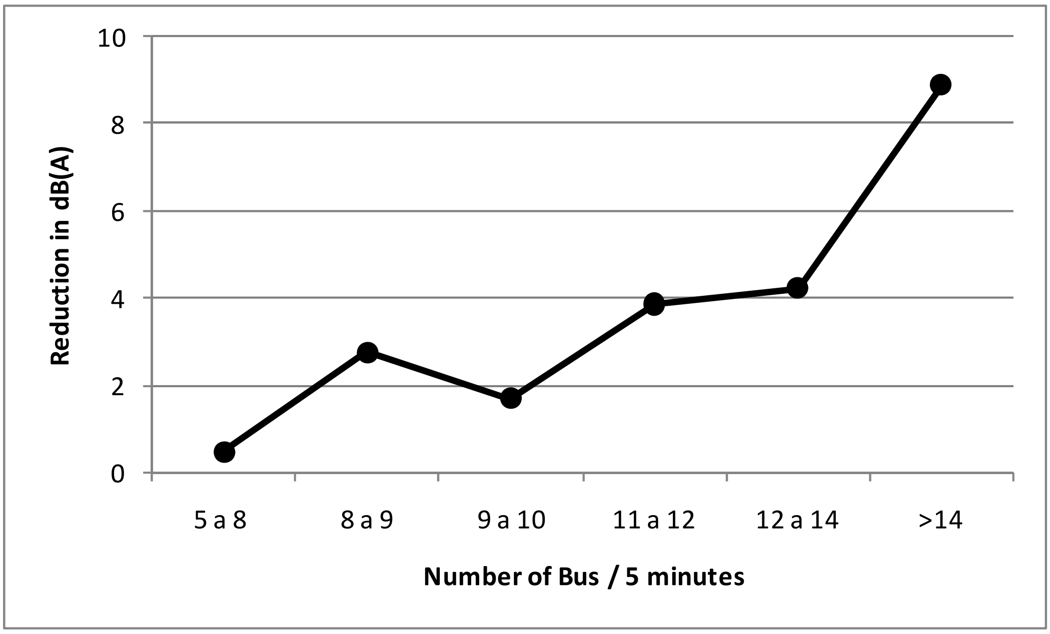

Figure 4: Relation among the number of buses and the potential reduction with the experiment

From this verification, it was possible to calibrate a model that expresses the potential reduction in decibels, measured in the A scale, due to the flow of buses in operation with motors' low spinning on the terminals. Based on the linear regression theory, the determination coefficient (R^2) equal to 0.85 was obtained, standard error of estimate of 1.28 dB (A) and the value of t from Student, associated to the model's "b" constant, of 4.7 dB higher than the reference value in the distribution table of t from Student equal to 2.1 for the significance level lower than 5% and with 4 tem freedom degrees. The model is presented in Equation 1.

$$R = 0{,}86.Q - 5{,}53 \qquad (1)$$

Where:

- R is the potential reduction in decibels;
- Q is the flow of vehicles in the terminal operating with low motor's spinning.

Figure 5 presents the values observed and the predicted by the model. The model's accuracy may be graphically verified. The absolute average error calculated according to equation 2 was of 0.45 dB (A).

$$E_{ma} = \sum_{i=1}^{n} \frac{\sqrt{(R_o - R_e)^2}}{n} \qquad (2)$$

Where:

- E_{ma} is the absolute average error;

- R_0 is the observed reduction;
- R_e is the estimated reduction.

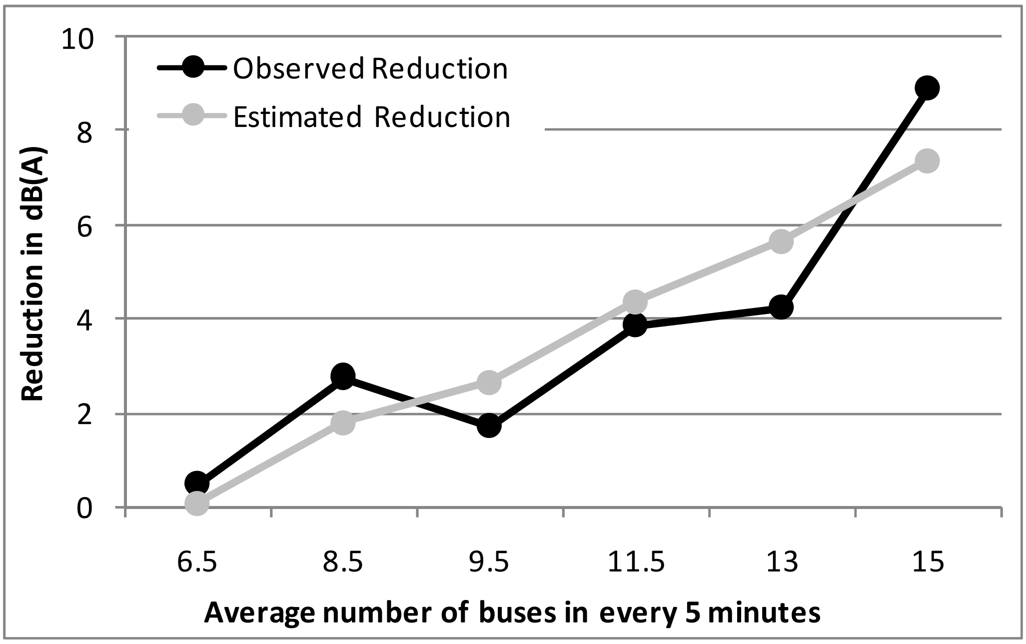

Figure 5: Comparison between the values predicted and observed in filed

The model demonstrates that the bigger the number of buses circulating at the terminal is and, if the motor rotations' reduction procedure is adopted, it is possible to reduce the equivalent sound level according to what is presented in Figure 5.

5. CONCLUSIONS

The possibility of reducing the sound levels in public transport terminals was verified with the buses motor's spinning control strategy in reduced levels, while they are circulating at the terminal.

Besides that, it was verified that the bigger the vehicles' flow, the bigger the sound levels' reduction potential may be. The reduction prediction calibrated model is statistically significant and the reductions that were observed occurred both in the L_{eq} for one hour and in the five minutes' intervals.

This adopted procedure may be a low cost solution to minimize the sound levels in these urban public environments, once the costs involved are basically from educational campaigns together with the operators, as well as from inspection during the circulation on the terminals.

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