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The Development of a Model for the Prediction of Noise Inside Bus Stations: A Comparison with the CRTN Method

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As the use of public transportation in medium and large cities becomes more and more popular, the number of urban bus stations connecting transport systems increases dramatically. As a result, the continuous traffic of heavy vehicles has produced disturbing noise levels inside the stations. Thus, a large research about traffic noise inside bus stations was recently developed in two Brazilian cities: Uberlândia and Belo Horizonte. Using the database from the field measurement, a statistical relation between the equivalent sound level (L_{eq}) and the percentile level L_{10} was implemented. Hence, the main goal of this paper is to analyze the precision of this relation as a predictor of traffic noise in urban terminals (L_{10}), and moreover, compare the results with the traditional method CRTN. Once that the bus stations are places with particular characteristics, it will be considered on the application of the CRTN method, corrections due reflections, percent of heavy vehicles, traffic speed, distance and position between the source and the receptor. This analysis's conclusion will be one more indicator to validate the model developed in this research to predict the L_{10}.

1 INTRODUCTION

The Calculation of Road Traffic Noise – CRTN method, is an appraised model already being used worldwide to predict traffic noise, especially in highways and roads of urban centers. This model predicts the level L_{10} percentile and considers correction values due to several factors such as the percentage of trucks, the distance between source and receiver, sound reflections on the surfaces, sound propagation and phase speed [1].

As far as the authors are concern, the CRTN model seems to be not completely representative of traffic noise inside bus terminals. Recently, an interesting research on traffic noise prediction has been done in bus terminals for public transportation in two cities of Brazil, named Belo Horizonte e Uberlândia. Thus, the main goal of this work is to develop a statistical model for the prediction of noise levels inside bus terminals [2]. Some parameters considered on the formulation, for example the percentage of trucks and sound reflection, were adjusted for the testing and application of the CRTN model.

The statistical model was developed using the database obtained from field measurements. In addition, the results obtained using the CRTN method were compared to those using the statistical model. Moreover, in ref. [2] it was also investigated the statistical relationship between the parameters L_{eq} and L_{10}.

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2 THE CRTN METHOD FOR CALCULATING THE L10 PERCENTILE: A COMPARISION WITH THE DEVELOPED MODEL

The main objective of this section is to present the CRTN method. Although a brief description of the model is presented, a more detailed explanation can be found on the Department of Transport, Welsh Government [1].

The equation which predicts the parameter L_{10} percentile is given by:

$$L_{10} = 42{,}2. + 10\text{Log}_{10}q \qquad (1)$$

where: 'q' is the flow of vehicles.

However, beyond the flow, it should be necessary to add some correction factors to this equation in order to take into account the influence of trucks, sound reflections and distance from the source in the terminals. Thus, the calculation of these factors is given by the formulation below as follows:

$$p = \frac{100.f}{q} \qquad (2)$$

$$cvp = 33.\text{Log}_{10}\left(v + 40 + \frac{500}{v}\right) + 10.\text{Log}_{10}\left(1 + \frac{5p}{v}\right) - 68{,}8 \qquad (3)$$

$$d' = \left[h^2 + \left(d \; + 3{,}5\right)^2\right]^{\frac{1}{2}} \qquad (4)$$

$$cd = 10.\text{Log}_{10}\left(\frac{d'}{13{,}5}\right) \qquad (5)$$

where 'p' is the percentage of trucks, f is the hourly flow only of trucks, 'q' is the hourly flow rate, 'cvp' is the correction due the trucks, 'v' is the average speed of the flow, 'd´' is the root mean squared (RMS) distance from the source to the receiver, h is the height between the source and the receiver, 'd' is in the distance of the receiver to the curb and 'cd' is the correction due to distance.

The method also considers the effect of the sound reflection due to reflecting surfaces next to the noise source, i.e. the buses themselves. It is suggested that 1.5 dB(A) be added to surfaces without openings and $1{,}5\left(\theta'/\theta\right)$ (in dB(A)) to surfaces with openings, where θ' is the arc for the opened surfaces and θ represents the segment of the whole arc [1].

For the application of the CRTN method, some simplifications had to be done. For example, the speed of the vehicles inside the terminals was very low and an average vehicle speed of 20 Km/h was considered. The noise from the engines was the main noise source, as expected. It was considered to be 0.5m above the floor. The measurements were made using a sound level meter (receiver) installed 1.20m above the terminal floor. The relative height (h) between the source and the receiver was equal to 0.70 m. As each platform had a particular width, the measurement device was placed in the middle of every platform. The influence of sound reflections was also considered. For each surface without opening, a value of 1.5 dB(A) was added. Also for the ceiling surfaces with openings, the same procedure was adopted. The percentage of trucks was obtained from the terminal traffic, which is composed of big and small buses. Thus, the big buses were considered as heavy vehicles.

For some terminals, the percentage of heavy vehicles was equal the 100%. Table 1 shows all parameters which are necessary for the application of the CRTN method. The "θ/θ'ceiling" refers only to existing openings in the ceiling. Therefore, all lateral surfaces (walls, surfaces etc) were considered to be continuous. The column "cr" represent the correction values due to the sound reflection effects (in dB(A)).

Table 1 – Parameters of the terminals for application of the CRTN method

	Terminal	P	v	D	h	θ/θ' teto	Cr
Belo Horizonte	Barreiro	100	20	2,70	1,20	1,00	1,50
	Diamante	100	20	3,50	1,20	0,55	2,30
	São Gabriel	100	20	2,50	1,20	0,37	2,06
	Venda Nova	100	20	2,35	1,20	0,65	2,48
Uberlândia	Central	100	20	3,95	1,20	1,00	4,50
	Umuarama	92	20	3,70	1,20	1,00	3,00
	Planalto	75	20	5,00	1,20	1,00	3,00
	Santa Luzia	90	20	5,00	1,20	1,00	1,50
	Industrial	79	20	6,00	1,20	1,00	3,00

Diamante, São Gabriel and Venda Nova terminals do not have continuous ceiling at the platforms. The ways, however, where the buses circulate inside the terminals are covered. Hence, the value adopted for the parameter θ/θ' was not equal to 1. For each wall and ceiling value added was 1.5 dB(A).

In Table 2 the corrections are presented. The values corresponding to the trucks (cvp) and distance from the source (cd) parameters were calculated using Equations 3 and 5 respectively. Both must be added to the results of each terminal. The values are expressed in dB(A).

Table 2 – Corrections due to the heavy vehicles and distance parameters

	Terminal	Cvp	Cd
Belo Horizonte	Barreiro	9,02	3,35
	Diamante	9,02	2,83
	São Gabriel	9,02	3,49
	Venda Nova	9,02	3,60
Uberlândia	Central	9,02	2,56
	Umuarama	8,69	2,71
	Planalto	7,84	1,99
	Santa Luzia	8,61	1,99
	Industrial	8,05	1,51

Thus, the equation for the CRTN L_{10} method, and according to the pertinent corrections, is given by:

$$L_{10} = 42,2. + 10\text{Log}_{10}q + cvp + cd + cr \qquad (6)$$

3 THE STATISTICAL MODEL DEVELOPED FOR THE PREDICTION OF NOISE LEVELS IN BUS TERMINALS

The developed L_{10} level percentil model was based on the theory of linear regression [3]. The model considers L_{eq} as independent variable.

$$L_{10} = 1{,}22.L_{eq} - 13{,}27 \quad (7)$$

$R^2 = 0{,}96$
$t_{(b)} = 1{,}84$

where:R^2 is the determination coefficient and $t_{(b)}$ is the value of the test t-student.

4 RESULTS AND DISCUSSION

Figure 1 shows the values of L_{10} obtained for field measurements, the CRTN method (Equation 6) and the statistical model developed herein (Equation 7).

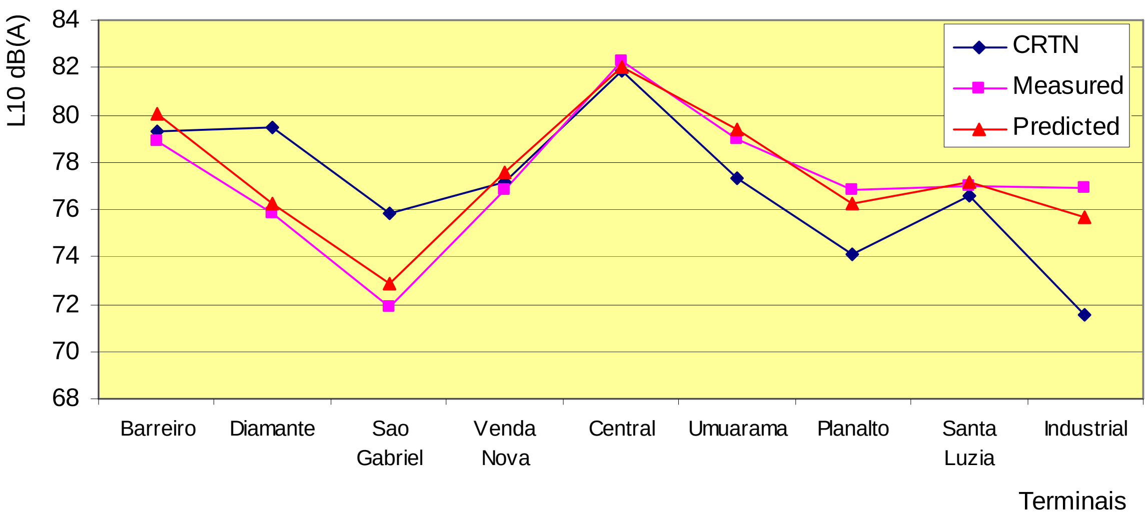

Figure 1 –L_{10} Values obtained using the CRTN method, field measurements and the statistical model developed.

It can be seen that the predicted values shows good convergence. In addition, the CRTN and predicted curves show similar trends. On the other hand, the results for he CRTN method shows significant differences in comparison with those obtained by field measurements. Some discrepancies can be observed for the CRTN method. It is seen that the less the flow of vehicles in the terminals, the lower the noise levels. It is well known that the noise levels decrease rapidly as the vehicles leave the terminal. This decrease remains until a new ‘fleet’ of buses passes-by. The CRTN method showed to be more precise for a noise range between 80 and 85 dB(A). This might be an indicator of low convergence at some terminals [4].

Another factor that might explain the divergence presented is that the CRTN model was initially calibrated for a flow corresponding to zero percent of heavy vehicles and an average speed of 75Km/h [1]. This differs significantly from the actual characteristics of the vehicle flows considered on the terminals.

5 CONCLUSION

A comparison between the models has showed that overall the results in terms of L_{10} percentile are fairly similar, especially those between the statistical model (predicted values) and the field measurement values. The best results obtained using the CRTN method were for the terminals with higher noise levels.

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