

**Evaluation of road traffic noise near tube-shaped bus rapid transit shelters**

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## ABSTRACT

Noise pollution is generally imperceptible, but it can cause various disorders, including psychological disorders, hearing loss and cardiovascular disease. Curitiba Municipal Law 10.625:2002 establishes upper limits of daytime noise exposure according to zoning areas and land use in the City of Curitiba. The purpose of this study was to evaluate noise immissions of urban traffic in the proximities of Bus Rapid Transit (BRT) shelters in Curitiba, Brazil. Daytime traffic noise levels were measured between 8am and 5pm near the entrance of these bus shelters in July and August 2014. Fifty-four measurement points at parks, residences, stores, schools, universities and hospitals in different zoning groups of the municipality were selected as a function of the type of population. The noise levels were recorded using a class I sound level meter. Brazil has no specific standard or law for traffic noise immissions, so the guidelines of the Brazilian standard ABNT NBR 10151:2000 were used. It was concluded that 74% of the measured noise levels varied from 70 to 76 dB(A). Only point 48, close to the Antônio Meireles Sobrinho BRT Shelter, was considered free of noise pollution. Traffic noise accounts for an overall average of 73 dB(A). A few bus shelters installed on the same street had an absolute average difference of 3 dB(A), while bus shelters located farther away from roads were the least noisy. The lowest average traffic noise levels, i.e., 71 dB(A), were recorded on roads for exclusive use by BRT buses.

Keywords – Sound measurement; Urban planning; Traffic noise;

## 1 INTRODUCTION

In 1991, the city of Curitiba pioneered the use of the bus rapid transit (BRT) system. This system consists of tube-shaped bus shelters on raised platforms that enable passengers to enter and exit from buses rapidly because their height from the ground matches that of bus floors. This is one of the factors that makes the system faster, which is why it is locally known as the “speedy bus” system (PRESTES and DUARTE, 2009; BRT BRASIL, 2013).

Users of these bus shelters are exposed to the sound of speedy buses as well as traffic noise from light vehicles. The number of vehicles in Curitiba increased sharply from 722,997 in December 2001 to 1,004,256 in January 2014, i.e., a 39% increase in 13 years, contributing to the increase in the average equivalent continuous sound pressure level (DENATRAN, 2014).

Environmental noise pollution is a worldwide problem with toxic effects (PAZ and ZANNIN, 2012), which interferes in the physical and mental health of humans, particularly the central nervous system, digestive system and cardiovascular system (SOBOTOVÁ et al., 2001; BRAUBACH, JACOBS and ORMANDY, 2011 and HELLMUTH et al., 2012).

In developing countries such as Brazil, India and China, the growing number of vehicles on public roads correlates with the increase in noise pollution levels (ZANNIN; SANT’ANA, 2011 and SOARES et al., 2014).

Vehicle traffic noise is the main annoyance factor perceived by residents, followed by noise caused by neighbors (ZANNIN, et al., 2003), respondents reported the following effects of urban noise: irritability (58%), difficulty in concentrating (42%), insomnia (20%), and headaches (20%).

Brazil has no specific standard for the evaluation of road traffic noise impacts. Therefore, the guidelines of the Brazilian Association of Technical Standards (ABNT), NBR 10151:2000 on "Noise Assessment in Populated Areas, Seeking the Comfort of the Community" were adopted as reference in this study, which evaluates road traffic noise in the surroundings of Bus Rapid Transit (BRT) shelters. This standard was implemented in the year 2000 and revised in 2019 (ABNT, 2000 and ABNT, 2019). Noise immission data collected from streets and bus lanes were compared to the permissible limits of equivalent continuous sound pressure levels ( $LA_{eq}$ ) for various areas of the city according to their use, e.g., residential areas, commercial areas,

industrial areas, etc. established by Curitiba Municipal Law No. 10.625:2002.

Therefore, this study evaluates road traffic noise surrounding the aforementioned BRT shelters and compares them to the maximum ( $LA_{eq}$ ) allowed by Curitiba Municipal Law 10.625:2002. The findings regarding the types of traffic lanes and the distance from the bus shelters to the traffic lanes are also discussed.

This paper does not analyze worker comfort at bus shelters as a function of exposure to noise. This paper is divided into four sections. Section II explains the steps involved in structuring this survey and the traffic noise sampling method employed at locations in the surroundings of bus shelters. Section III describes and discusses the noise immission findings. Lastly, section IV summarizes the conclusions of this study.

## 2 METHODOLOGY

The architecture of tube-shaped bus shelters is unique and very pleasing compared to most urban bus shelters, attracting the attention of thousands of tourists who come to Curitiba (MOURA, 2007). Today, about 508,000 passengers a day use the tube bus shelters of the Integrated Transport Network – ITN (URBS, 2014). The bus shelters are located in areas classified by zoning and land use sectors, according to Curitiba Municipal Law No. 9.800 of 03 Jan 2000 – On Zoning, Land Use and Occupancy in the Municipality of Curitiba. These bus shelters have the practicality of subway platforms in terms of access to BRT buses and are usually close to parks, homes, businesses, schools, universities and hospitals in densely populated and noisy urban areas (PRESTES and DUARTE, 2009).

In Curitiba and its metropolitan region there are 357 tube bus shelters set up on sidewalks for access to buses traveling along four types of bus lanes (URBS, 2014), as follows:

- Express Bus Lane: This is a central lane destined exclusively for use by BRT buses, with a one-way traffic lane for light vehicles on each side of the central lane. This central lane has a sidewalk on each side that separates it physically from the one-way traffic lanes and allows for the installation of tube bus shelters;
- Exclusive Bus Lane: This is a street which has a lane intended for use solely by BRT buses. There are no sidewalks separating buses from light vehicles. Tube bus shelters are installed on pedestrian sidewalks;
- Shared Bus Lane: Thoroughfares where BRT buses and light and heavy vehicles use the same lanes. Tube bus shelters can be installed on pedestrian sidewalks, or on a median strip in the thoroughfare when the traffic is two-way;
- Exclusive Bus Road: This type of road is used exclusively by BRT buses. There are no car lanes at its ends and tube bus shelters can be installed on pedestrian sidewalks.

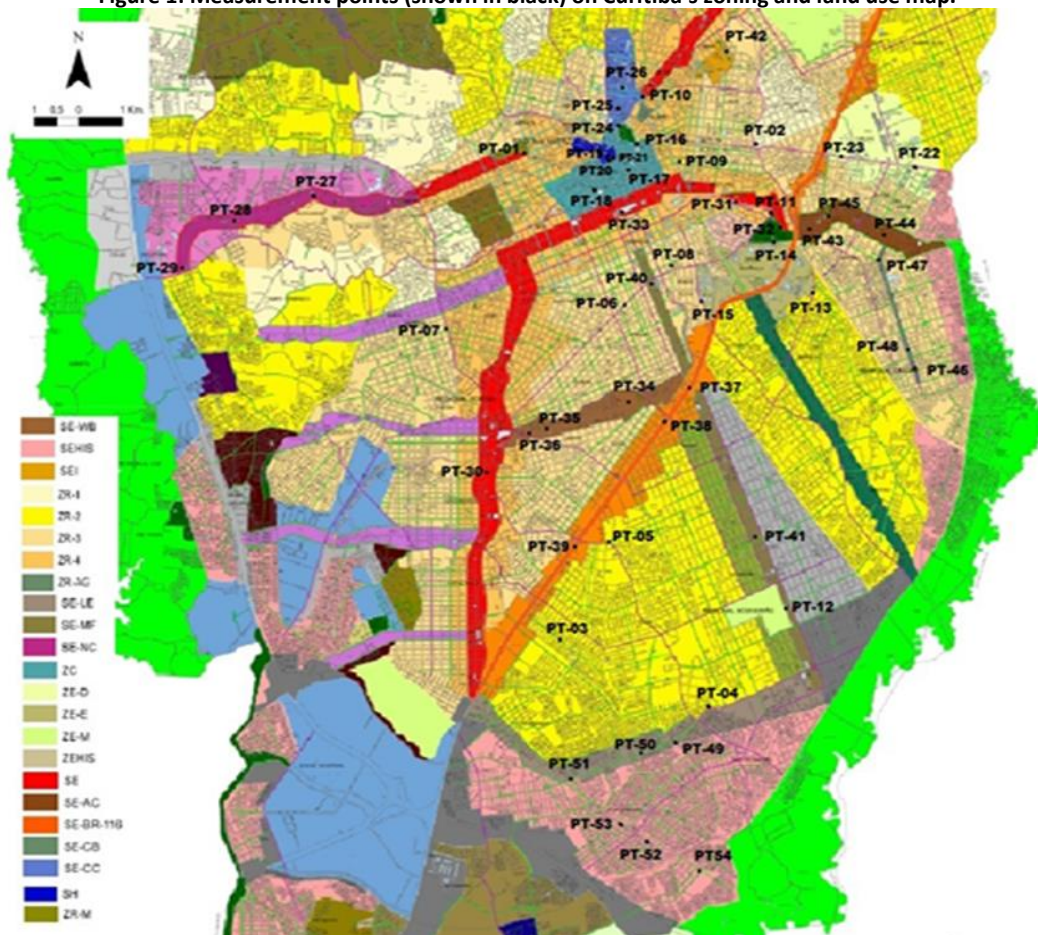
The website [www.google.com.br/maps](http://www.google.com.br/maps) was consulted using the keywords “Curitiba” and “Estação-Tubo” (Tube Bus Shelter). The 357 tube bus shelters in the city and metropolitan area of Curitiba were matched with information from the zoning and land use map that is part of Curitiba Municipal Law No. 9.800 mentioned earlier herein.

Some of the tube bus shelters were selected to represent different conditions of zoning areas and thoroughfares, as follows:

- One measuring point was selected in all the zoning and planned land use areas where there was a tube bus shelter;
- Two to four measuring points were selected in zoning and land use areas that had more than one tube bus shelter. Priority was given to tube bus shelters installed on busy avenues and in the proximities of schools, universities, hospitals, sports halls, public parks and businesses.

The addresses of the tube bus shelters were matched to the zoning and land use map, resulting in the formation of an irregular grid (BROWN; LAM, 1987 and LESTER, MALCHAIRE and THIERY, 1992) of 54 different measurement points scattered across Curitiba, as illustrated in Figure 1.

**Figure 1: Measurement points (shown in black) on Curitiba's zoning and land use map.**



Source: ADAPTED FROM CURITIBA, 2000

Fifty-four tube bus shelters located at important points were selected because of their proximity to schools and hospitals and their intense foot traffic. The measurements were taken over a period of 30 days, between 7am and 7pm, in the months of July and August 2014.

Each tube bus shelter is set on the ground in a different way, depending on the available space and the characteristics of the street. According to these conditions and the guidelines of the Brazilian technical standard ABNT 10.151:2000, the following rules for the installation of noise measuring instruments were defined and adopted:

- The sound level meter was set up on a tripod at a height of 1.2 m from ground

level, and;

- The distance between tripod and tube bus shelter was equal to or more than 2 m. The measurement reference was the cylindrical glass surface of the tube shelter.

At all the evaluated locations, the measurement system was set up close to the urban thoroughfare (Figure 2).

Figure 2: External view of a tube bus shelter and a B&K 2238 sound level meter mounted on a tripod



Source: THE AUTHORS, 2021

The measurements were taken using a B&K 2238 sound level meter, as specified by the Brazilian standard NBR 10.151:2000. The measurement time at each point was 15 min, following the methodology employed in other studies of environmental noise measurement (MATOS et al., 2011 and MILANEZ, 2013).

The measured sound pressure levels were compared to those established by Curitiba Municipal Law No. 10.625: 2002 (Table 1).

Table 1: Measurement points and their respective maximum (SPLs ) for zoning areas in the city of Curitiba

Measurement points	Use zones	SPLs permitted by Law No. 10.625:2002 Daytime $L_{eq}$ dB(A)
1 to 8	Residential zones (RZ-M, RZ-1, RZ-2, RZ-3)	55
12 to 15 and 24 to 26	Special Military and Educational Zone ( SZ-E, SZ-M) and Special Sector Civic Center (SS-CC)	60
9 to 11	Residential zone 4 (RZ-4)	65
16 to 23 and 27 to 54	Special Sectors and Special Zone for Sports (SSI, SZ-S, SS, SH, SS-BR-116, SS-MF, SS-WB, SS-AC, SS-NC, SS-CB, SSHIS, SS-LE and SZ-D)	65

Source: THE AUTHORS, 2021

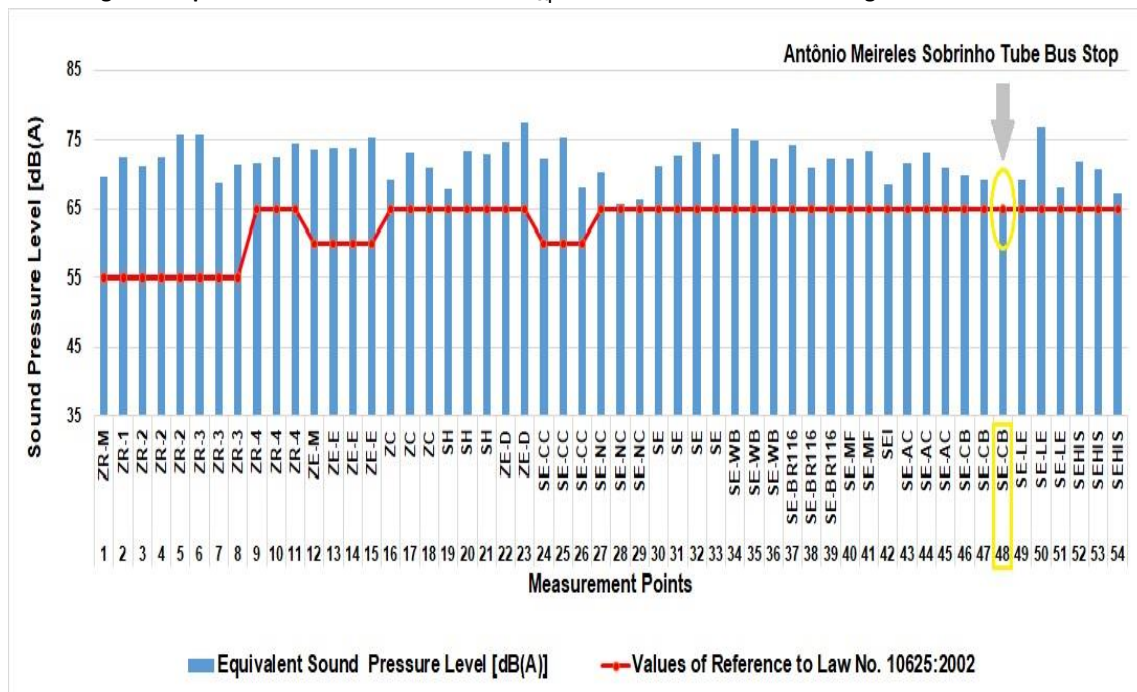
#### 4 RESULTS AND DISCUSSION

The environment was considered noise polluted when its recorded  $LA_{eq}$  value exceeded the reference levels of Curitiba Municipal Law No. 10.625:2002. Measurement point



number 48 (SS-CB), circled in yellow in Figure 3, located near the Antônio Meireles Sobrinho tube bus shelter, was the only place where the Sound Pressure Level was in accordance with the reference level, i.e., that stipulated by Law No. 10.625:2002.

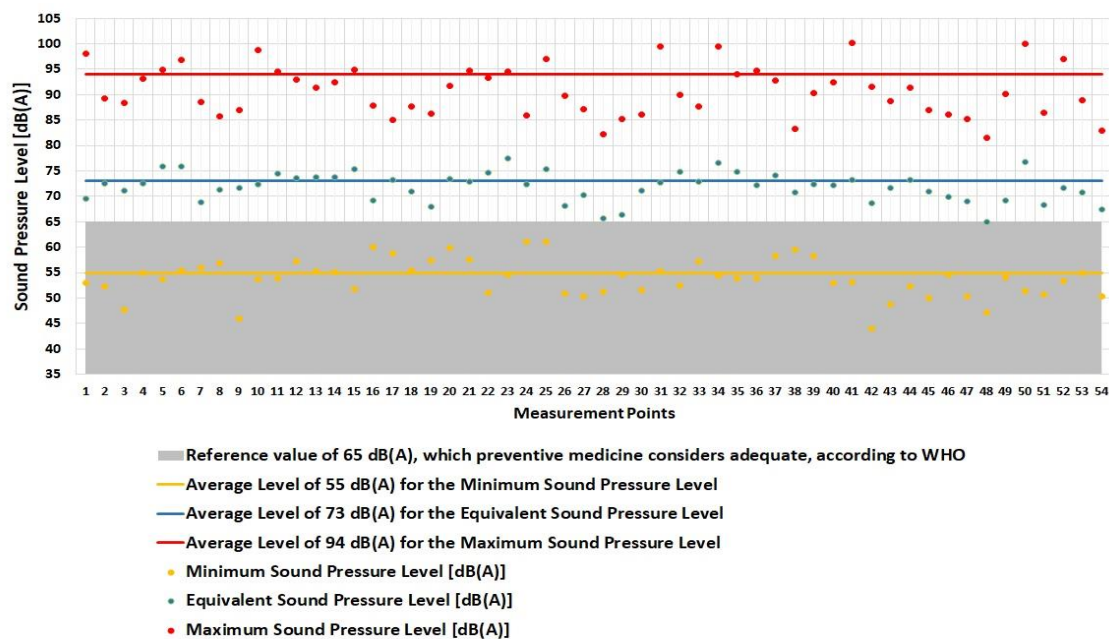
Figure 3: Equivalent Sound Pressure Levels  $LA_{eq}$  recorded as a function of zoning areas and land use



Source: THE AUTHORS, 2021

About 74% of the measured sound pressure levels ranged from 70 to 76 dB(A). Most of the overall average noise level – 73 dB(A) – was caused by traffic noise, as indicated by the horizontal blue line in Figure 4.

Figure 4: Records of Sound Pressure Levels [ $LA_{min}$ ,  $LA_{eq}$  and  $LA_{max}$ ] at the evaluated locations and their respective global averages.



Source: THE AUTHORS, 2021

A global average noise level of 74 dB (A) was found in noise pollution assessments of residential zones (RZ) and commercial zones (CZ) in the city of Curitiba (CALIXTO, DINIZ and ZANNIN, 2003). It was concluded that the main source of noise emissions come from urban thoroughfares and that noise pollution in Curitiba is caused by road traffic noise.

An assessment of 350 points measured in surveys in Curitiba's residential zones shows that 80.6% of the total locations measured had noise levels above 65 dB(A) (ZANNIN, 2002).

Zannin et al. (2002) evaluated 1000 measurement points in the city of Curitiba, including the city's residential zones. They found that the noise levels at 93.3% of these measurement points were higher than 65 dB(A).

The noise levels measured at tube bus shelters located farther away from thoroughfares were lower than at bus shelters located on those streets and hence closer to vehicle traffic. Table 2 describes the difference in noise levels measured at points along same street.

**Table 2: Difference between equivalent noise levels,  $LA_{eq}$ , at measurement points on the same street.**

Measurement points	Street names	Geographic coordinates of measurement points	Absolute difference of equivalent noise levels [dB(A)]
22 and 23	Victor Ferreira do Amaral Avenue	25°25'48.8"S; 49°12'40.5"W and 25°25'43.3"S; 49°13'30.6"W	2.7
37 and 39	Green Line Expressway	25°28'07.6"S; 49°15'14.4"W and 25°29'47.4"S; 49°16'34.1"W	3.4
53 and 54	Tijucas do Sul Street	25°32'39.6"S; 49°15'56.8"W and 25°33'10.4"S; 49°15'03.4"W	3.3

Source: THE AUTHORS, 2021

It can be stated that in locations with lower  $LA_{eq}$  values, such as the tube bus shelters Detran (22), Fanny (39) and Osternack (54), sound power were about 50% lower than those in the surrounding environments on the same street. Another important finding is that, at the evaluated points, the noise immission levels along exclusive bus roads and on streets with express bus lanes were lower than on streets with shared bus lanes and exclusive bus lanes. Table 3 lists the measured sound pressure levels.

**Table. 3. Average equivalent sound pressure levels on the streets**

Types of streets	Average equivalent sound pressure levels in dB(A)
Express bus lanes	72
Exclusive bus roads	71
Exclusive bus lanes	74
Shared bus lanes	73

Source: THE AUTHORS, 2021

On average, noise levels on exclusive bus roads are lower than on other types of streets, since only BRT buses are allowed to travel on them (BROWN and LAM, 1987).

Curitiba Municipal Law No. 10.625:2002 establishes the sound pressure levels of reference. However, in many zoning areas, the lowest sound pressure levels, or Minimum Levels ( $L_{min}$ , see Figure 4), are equal to or higher than the legally established  $LA_{eq}$  ones. This is the case of areas surrounding the following tube bus shelters: Alto-Boqueirão, measurement point 4 (RZ-2); Presidente Kennedy, point 6 (RZ-3); Santa Quitéria, point 7 (RZ-3); Paiol, point 8 (RZ-3); Passeio Público, point 24 (SS-CC) and Comendador Fontana, point 25 (SS-CC).

The global average of the lowest recorded Minimum Sound Pressure Levels,  $L_{\min}$  (see Figure 4, in yellow), was 55 dB(A). Measuring point 24 (Passeio Público tube bus shelter) in the downtown area, where the second highest  $L_{\min}$  was recorded, is considered a green area. Green areas in Curitiba are highly sound polluted due to traffic noise (ZANNIN, FERREIRA and SZEREMETTA, 2006).

The global average of the highest sound pressure levels,  $L_{\max}$  (shown in red in Figure 4) was 94 dB(A), with measured levels ranging from 82 to 100 dB(A). Those were the highest sound pressure levels recorded at each measurement point. The most worrisome levels were recorded at the Coronel Luiz José dos Santos (measuring point 41) and Coqueiros (point 50) tube bus shelters, where measured  $L_{\max}$  values reached about 100 dB(A). The high levels of vehicle traffic noise, especially from urban buses, was attributed to age of the fleet, irregular fleet maintenance, and also bad driving habits such as improper use of horns, brakes and high speed driving in urban areas (ALVES FILHO, LENZI and ZANNIN, (2004).

#### **4 CONCLUSIONS**

People who use Curitiba's tube bus shelters to travel on the city's integrated public transport system and move around in their vicinity are affected by the noise generated by surrounding vehicle traffic.

The equivalent sound pressure levels,  $L_{eq}$ , measured at about 74% of the evaluated environments ranged from 70 to 76 dB(A). In addition, the minimum sound pressure levels,  $L_{A_{\min}}$ , measured at 37% of the locations exceeded 55 dB(A), while the maximum sound pressure levels,  $L_{\max}$ , measured at two of the locations were equal to or above 100 dB(A).

The equivalent sound pressure levels,  $LA_{eq}$ , measured around the tube bus shelters in the evaluated environments differed from the reference levels established by Curitiba Municipal Law 10.625:2002. The main contributing factor to the measured global average equivalent sound pressure level of 73 dB(A) was attributed to surrounding urban traffic noise.

Only one measuring point (48) close to the Antônio Meireles Sobrinho tube bus shelter was considered devoid of noise pollution, because it showed the same 65 dB(A) limit as that of the Special Sector of Engenheiro Costa Barros Street.



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