

**Noise pollution generated by motor vehicles at different times on
Avenue Paulista, municipality of São Paulo / SP**

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SUMMARY

Cities have shown high rates of population growth since the beginning of the twentieth century (at a greater intensity when compared to their development), which puts pressure on the environment intensifying the need of natural resources exploitation, as well as creating infrastructure problems. Among the impacts caused by the high densification of the population, noise pollution caused mainly by motor vehicles can be highlighted. This kind of urban impact, often ignored by the population and government, in addition to reducing people's quality of life and depreciating urban areas, can cause irreversible damage to public health. In this regard, this research brings, through measurements "in loco", the generation of noise by motor vehicles, in one of the main roads of the city of São Paulo. In addition to the data obtained, this research also analyzes them in the light of recommendations for technical standards and resolutions aimed at noise control. Through the analyzes conducted, it was found that the noise due to traffic, which is subject to the population that occupies (permanently or transiently) the surroundings of the road in studies, is above the recommended levels. In addition to momentary discomfort, the noise levels obtained have the potential to cause damage to the health of the population, such as hearing loss, attention deviations and even psychological problems. Therefore, it is hoped that this research will help to foster the debate about the impacts of noise pollution on the urban environment and the need for measures to be taken by municipal managers.

Keywords: Noise pollution. Motor vehicles noise. Measurement of noise on urban roads.

1. INTRODUCTION

In Brazil, estimates by the Brazilian Institute of Geography and Statistics (IBGE) indicate that country population is expected to reach more than 211 million inhabitants, of which, more than 90% dwell in urban areas (IBGE, 2020). Current census data already indicate that 40% of the Brazilian population reside in the Southeast region of the country, composed of large urban clusters, such as the cities of São Paulo, Minas Gerais and Rio de Janeiro which take in 40% of the Brazilian population.

This population growth generates problems related to the environment, emission of greenhouse gases, propagation of solid urban waste, construction waste, displacement disorders caused by heavy vehicle traffic, and problems related to intense noise generation caused mainly by combustion engine automobiles. IBGE, (2018). In other words, the anthropic pressure existing in large cities cause different types of pollution: atmospheric, soil, water, visual, and noise, which are constantly increasing, due to the intensification of unsustainable practices, lack of effectiveness of legal instruments due to mismanagement from public authorities, in order to improve urban planning.

In the same way as other types of pollution, noise is also related to the densification of cities, the intensive usage of vehicles, the disorganized occupation of the soil, which contributes to a greater propagation of noise in urban areas. Therefore, noise pollution portrays an issue that constrains deeper analysis, as it also affects people's quality of life. It is important to ensure the minimum acoustic comfort in open urban spaces (CEZAR, 2008).

The increase in urban noise raises public health concerns, whereas the theme is little explored in the context of existing pollution in cities, as it is a non-visible pollution. Consequently, noise pollution can cause serious physical, physiological and psychological health issues (LUCIENE, 2005).

There are parameters, laws and standards applicable to noise pollution issues in cities, in Brazil. According to Federal District Law No. 4092 / 2008, noise pollution is "any emission of sound that, directly or indirectly, is offensive or harmful to the health, safety and well-being of the community".

Paragraph IV of CONAMA Resolution 1/1990 highlights that the emission of noise produced by motor vehicles and those produced inside work environments must comply with the rules issued, therefore also meeting the National Traffic Council (CONTRAN).

According to Cremonesi (1985), the main sources of urban noise are distributed among five main sources:

- a) Stationary sources: urban equipment (clubs, restaurants), construction, factories, etc.
- b) Sources from rail traffic: passenger trains, freight trains, subway trains, suburban trains, etc.
- c) Sources from aircraft overflying inhabited areas: turboprop engine passenger aircraft, reaction engine passenger aircraft, military aircraft, small aircraft, helicopters.
- d) Noise sources that make up road traffic: cars, SUVs, motorcycles, buses, trucks etc.
- e) Human-originated sources: dialogues, sports, etc.

In terms of noise pollution, it is essential to implement mitigating measures, as a way to dissipate noise generated by different sources. Some of the quoted measures are:

- The reduction of noise at the source, such as vehicle maintenance and incentives from the automobile industry itself with technologies aimed at reducing engine noise and reducing atmospheric pollution.
- Noise propagation control and attenuation by urban planning measures, on the main roads, with the implementation of barriers strategically placed in areas with a high flow of vehicles.

One of the examples for reduction occurred in 2017 on Avenida Marginal Pinheiros next to the University of São Paulo (USP), the concrete border wall of the Olympic streak was demolished and replaced by glass panels wall, which have more efficient acoustics capacity. The Project also presented urban attributes, as transparent glass was used, which provides better view of the forested area of the University campus.

The issues caused by the noise generated by combustion engine vehicles reassured the collection of data at 610/620, Paulista Avenue - by the driveway, as a way to attest the emission of noise pollution caused by private and collective vehicles in the city of São Paulo, comparing the limits established by the rules and regulations of the national environment council.

1.1 NOISE POLLUTION AND ITS IMPACT ON PUBLIC HEALTH

Noise takes place in every open space as a result of the usual activities, be it children playing, commercial activities, traffic. The blend of all noise, intrinsic to social interaction, is considered ambient noise.

For Gerges (2000), noise is defined by a combination of sounds whose frequencies do not follow specific law. Gerges (2000) points out that environmental or domestic noise is the noise generated by several sources, such as commercial activities, vehicle traffic, interaction between people and other forms.

Sound pressure is used to determine noise levels or intensity. The Decibel (dB) is the logarithmic unit that expresses the ratio between the sound pressure - which is being measured - and a reference. (GERGES, 2000; PIVOTO et al., 2009).

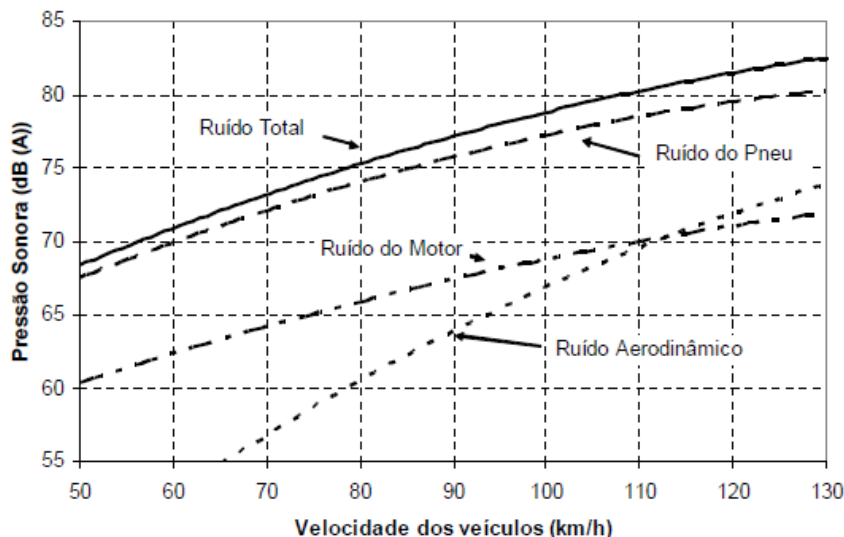
In Brazil, 63% of cargo and 97% of passengers are transported by heavy and light vehicles. The modals travel in large urban centers with the purpose of supplying and meeting the needs of the population (LUCIANO et al., 2009).

Due to the development of the population, credit convenience, the city of São Paulo and its surroundings have approximately 8.3 million motor vehicles (DETRAN, 2020). A large share of its fleet is made up of private vehicles, which add to the emission of air pollutants and generate significant noise pollution.

CONAMA resolution 1/1990 considers that excessive noise levels should be included in the Environmental Pollution Control, which determines that the ABNT standards are respected, through NBR 10151/2020 - Acoustics - Measurement and evaluation of sound pressure levels in inhabited areas - General application, regarding the emission of noise as a result of any activities: industrial, commercial, social or recreational. According to PIVOTO et. al (2009), the generation of noise from the use of motor vehicles is caused by the engine, car exhaust, transmission system, tire-pavement contact and dynamic effect.

Figure 01 shows the noise contribution from each part in a vehicle.

Figure 01: Influence of different sources on noise



Source: Hanson et al. (2005).

It is possible to analyze among the elements, the influence of noise caused by the ejection of air between the tire and the pavement, which, at lower speeds, results in high sound pressure. This fact justifies the main causes of excessive noise in large urban centers, since the vehicle speed, in central areas, does not exceed 60 km / h (Figure 01). In places and collector roads with high traffic flow, at rush hours, vehicles reinforce the increase and perpetuation of noise pollution.

For Lopes (2003), even the alleged normal sounds, which do not present inharmoniousness or high intensity, can comprise noise, such as the sound of television or conversations between people, the disturbing character of a sound will depend on:

- a) Its intensity and duration;
- b) the hearing capacity of the people exposed to the sound;
- c) the prompting source, which may be attractive or not - from the point of view of the perceiver;
- d) sound quality, whether low-pitched or acute;
- e) the message, by the kind of information it presents;

Based on duration and volume, the effects of noise on human health and comfort are assorted into four categories (EVANS; HYGGE 2000; STANSFELD et. al, 2000):

- (i) physical effects, such as hearing shortage.
- (ii) physiological effects, such as increased blood pressure, irregular heart rate and ulcer.
- (iii) psychological effects such as insomnia, few hours of sleep, irritability, stress and other disorders.
- (iv) negative effects on work performance, such as reduced productivity and misunderstanding of what is heard.

Considering that the sound waves propagated by different means, the human hearing aid can perceive sounds in the frequency ranging of 20 Hz to 20,000 Hz (20 Hz). Unlike our vision, which can be ceased by closing our eyes, we are always hearing, despite of our wish or awareness. One cannot decide whether hearing or not, therefore, at a certain intensity and time of exposure, sounds can cause negative effects on people SCHIMITT and ROOT, (1998).

In order to achieve acoustic comfort goals and to objectively guarantee compliance with the law, all noise must abide within the limits presented as indicated (Chart 1).

Table 01: Level of NCA evaluation criteria for external environments, in dB (A).

Monitoring Area Categories	Daytime (7am to 10pm)	Evening
Rural areas	40 dB(A)	35 db (A)
Strictly residential urban area, hospitals or schools	50 dB (A)	45 dB (A)
Mixed area, predominantly residential	55 dB (A)	50 dB (A)
Mixed area, commercial and administrative office	60 dB (A)	55 dB (A)
Mixed area, with recreational office	65 dB (A)	55 dB (A)
Predominantly industrial area	70 dB (A)	60 dB (A)

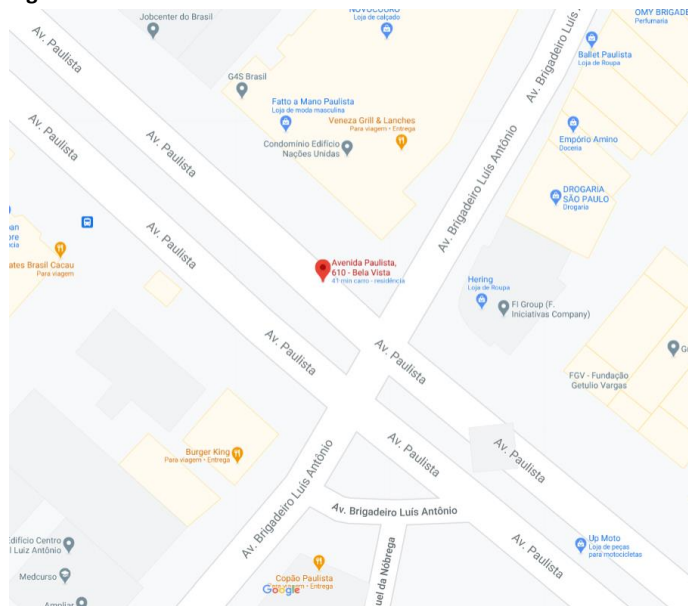
Source: ABNT - NBR 10151/2020.

After cataloguing the data, values and comparisons will be presented in face of the study case regarding the noise emission limit in external environments.

2. METHOD OF ANALYSIS

The data was collected in one of the main urban roads in the city of São Paulo at 610/620 Paulista Avenue, towards Consolação District versus Brigadeiro Luís Antonio Avenue Fa on July 9, 2020, Thursday, from 9 am to 11 am, at temperatures ranging from 19 C to 21 C. Find below the location of the measurements.

Figure 02: Location of the measurements.



Source: Google / Maps - Location of measurements made - July / 2020.

The choice of location is relevant, due to the transit of countless pedestrians, in addition to the mixed-use area, with commercial and residential buildings, with the excessive contribution of vehicles in the morning, afternoon and night times.

In order to quantify the emission of noise pollution, measurements were made according to NBR 10.151 / 2020, with protocol for the assessment of noise in inhabited areas, specifying the method for measuring noise, the application of corrections in the measured levels.

According to NBR 10.151 / 2020, in outdoor environments, measurements should be carried out at distant sites, at approximately 1.2 m from the ground and at least 2 m from the property boundary and from any other reflecting surfaces, such as walls.

As the noise of the vehicle flow is irregular, it varies over time, it is recommended the statistical treatment of the data, from analog records in time intervals, determining the equivalent sound level (Leq) as described in Equation 1:

$$Leq = 10 \log_{10} \frac{1}{n} \sum_{i=1}^n 10 Li/10$$

In which:

Leq = equivalent sound level;

L_i = sound pressure level, in dB, read in fast response (fast) every 5 seconds, during the noise measurement time;

n = total number of readings.

The chosen location must be free for measurements and free from obstacles that may interfere with the measurements.

In this study, the equipment used was a Minipa MSL-1351 C decibel meter - with digital display, microphone at 90° of 1/2", using dynamic measurement ranges between 50dB, accuracy of +/- 1.5dB (94dB / 1kHz) ; a tripod at 1.20m from the ground was used to position the decibel meter.

A vehicle counter was used in the study, and the break between measurements was determined by the opening and closing of the traffic lights, whose opening cycle last 1 minute and 10 seconds.

Figure 3: Data collection location.



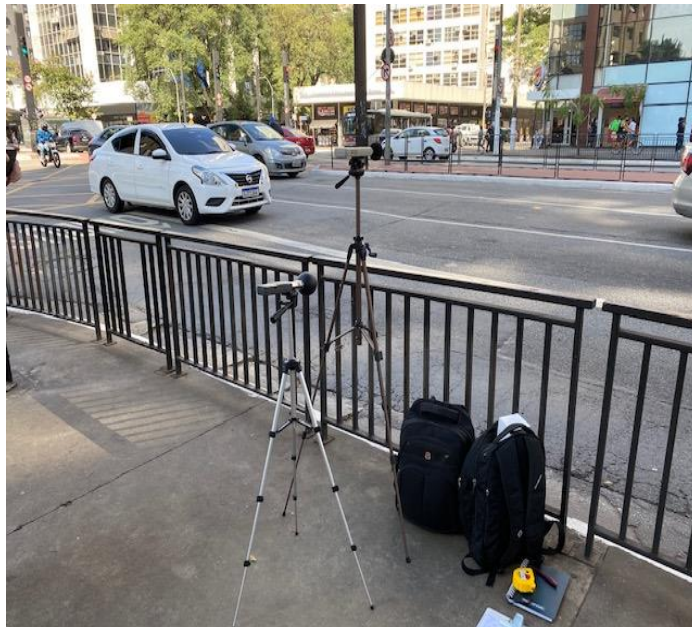
Source: <https://www.google.com/maps/place/Av.+Paulista,+610>.

Figure 4: Device - Minipa MSL-1351 C - Decibel meter - capturing the sound pressure level Db.



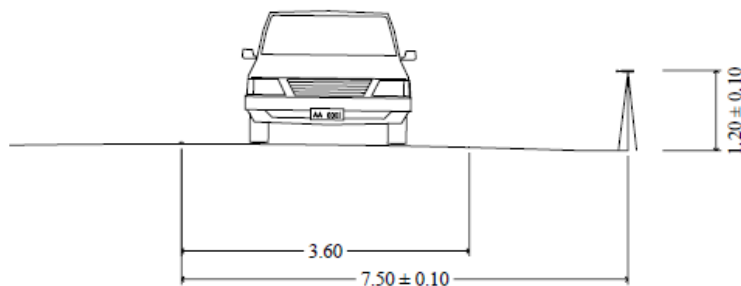
Source: The Author - July / 2020.

Figure 5: Device - Minipa MSL-1351 C - decibel meter positioned 7.50 m from the track axis.



Source: The Author - July / 2020.

Figure 6: Position of the decibel meter (m).



Source: PIVOTO et al. (2009).

The positioning between the decibel meter, up to the center of the carriageway comprises the value of 7.50 m, the vehicle flow of the road remained constant throughout the measurement. The road pavement is characterized as flexible, bituminous material for the bearing cover. It had irregularities as to its flatness. The maximum speed in the place is 50 km / h, the measurement point was located close to the pedestrian lane, next to a bus stop and a newsstand.

Because the sound emitted by the vehicles directly impacts people in this area for sitting or reading newspapers and magazines.

The 610/620 Paulista Avenue lane, towards Consolação, location at which the measurement took place, is 10 m wide, according to a survey by the Traffic Engineering Company (CET). The number of vehicles counted at every 5 minutes comprised an average of 350 vehicles including, private cars, public transport buses, and motorcycles, values obtained in accordance with the measurement table of CET itself, as shown below.

Table 02: Vehicle volumes - Paulista Avenue - São Paulo - SP

Período	Sentido		
	Paraíso / Consolação	Consolação / Paraíso	Ambos os sentidos
Manhã	4.007 veículos/hora (09-10h)	2.877 veículos/hora (09-10h)	6.884 veículos/hora (09-10h)
	11.844 veículos (07-10h)	8.365 veículos (07-10h)	20.209 veículos (07-10h)
Tarde	3.419 veículos/hora (17-18h)	2.631 veículos/hora (17-18h)	6.050 veículos/hora (17-18h)
	9.730 veículos (17-20h)	6.825 veículos (17-20h)	16.555 veículos (17-20h)

Source: CET - Traffic Engineering Company / 2007.

3. RESULTS

The values of measurements and analysis of noise caused by vehicles, data collected in the city of São Paulo at Paulista Avenue towards Consolação District and Brigadeiro Luís Antonio Avenue Fa from 9am to 11 am can be found below.

Table 03: Measurements performed according to the procedure specified by the regulation.

Minuto/Medições - Decibéis - Db	1º	2º	3º	4º	5º	6º	7º	8º	9º	10º	11º
1º Minuto	71,70	71,60	71,40	76,10	71,40	69,00	72,60	75,10	70,40	70,40	88,40
2º Minuto	68,50	73,90	69,50	74,30	74,70	71,40	72,10	73,30	69,50	69,50	73,40
3º Minuto	61,50	71,80	73,50	72,60	73,40	72,90	73,40	68,90	73,10	73,10	71,60
4º Minuto	69,00	72,90	73,30	70,20	73,00	71,60	70,70	75,40	67,10	67,10	68,90
5º Minuto	71,20	73,50	69,80	77,40	69,90	73,10	72,30	69,80	80,10	80,10	71,70
Média a cada 5 - minutos	68,38	72,74	71,50	74,12	72,48	71,60	72,22	72,50	72,04	72,04	74,80
Nº de veículos a cada 5 minutos	136	341	422	377	417	400	390	396	378	400	342,00
Horário de início	09:20	09:30	09:40	09:50	10:00	10:10	10:20	10:30	10:40	10:50	11:00
Horário de término	09:25	09:35	09:45	09:55	10:05	10:15	10:25	10:35	10:45	10:55	11:05

Source: The Author - July / 2020.

NBR 10151/2000 establishes that mixed urban areas, with recreational capacity, or mixed area, with commercial and recreational capacities, must not exceed 65 dB or 60 dB.

In order to demonstrate the permitted sound level intensity, an equation is used to determine it.

the values found in the average of the data obtained experimentally the average obtained of, M = 72.22 Db, for 620, Paulista Avenue towards Consolação District and Brigadeiro Luís Antonio Avenue Fa from 9 to 11 am.

$$Leq = 10 \log_{10} \frac{1}{n} \sum_{i=1}^n 10^{Li/10}$$

In which:

Leq = equivalent sound level;

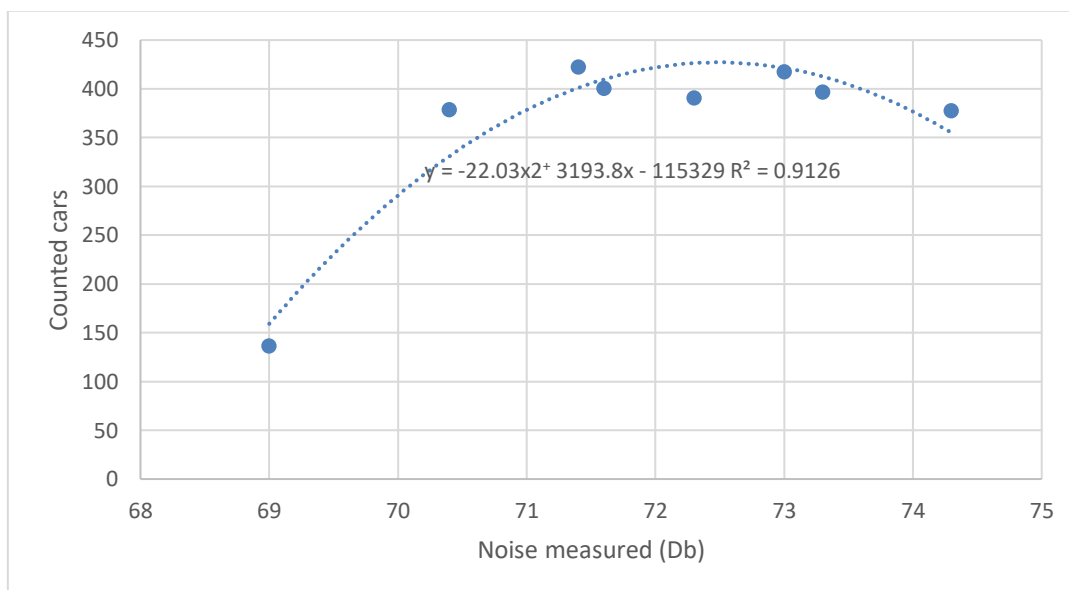
Li = sound pressure level, in dB, obtained from fast response reading (fast) every 5 seconds, during the noise measurement time;

n = total number of readings every 5 minutes = 5 readings

$$Leq = 10 \log_{10} \frac{1}{5} \sum_{i=1}^5 10^{72,22/10}$$

$Leq = 144.4$ Db.

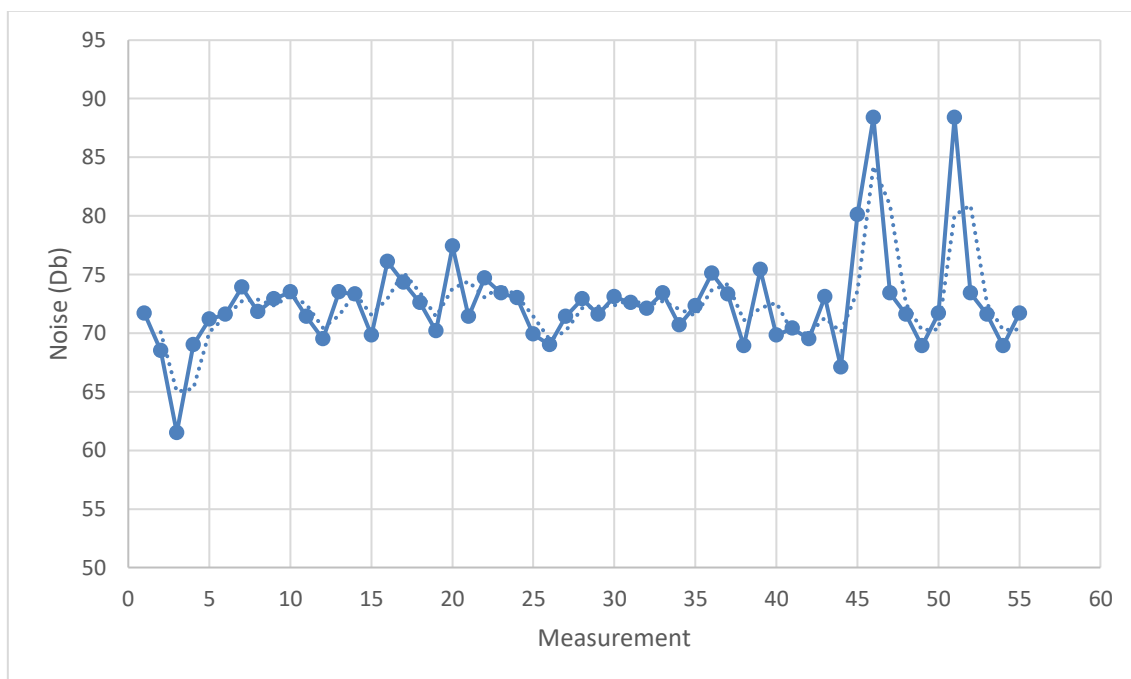
Graph 01: Ratio of vehicles and measured noise



Source: The Author - July / 2020.

It is important to highlight that the measurement took place on an atypical day, due to the pandemic and the social distancing restrictions imposed by the State of São Paulo which caused the flow of vehicles to be reduced. The social distancing also influenced the economic activities in the studied region.

Graph 02: Ratio of vehicles and measured noise



Source: The Author - July / 2020.

Therefore, for statistical analysis of the data, we have values with an upper range than 73.4 Db and values with a lower range than 71.50 Db, standard deviation of 4.14 and standard error of 0.49.

We can evidence a satisfactory linear correlation as shown in graph 01, between the number of vehicles and the sound intensity, the sound noises shown are above the levels acceptable by Brazilian legislation, exposing the population to health damages regarding noise pollution.

According to Deuox (1996), the noise caused by the traffic of motor vehicles vary according to parameters such as speed, number of heavy vehicles, buses and trucks, greater effort of the engine when going uphill. Thus, a flat location was chosen for this study in order to provide better representativity of the data, without interventions in which many people circulate, and consequently, absorb a share of this noise daily.

4. CONCLUSION

Based on the results analysis, given the rules and legislation regarding noise pollution issues, it allows us to rethink the noise in large urban centers, as a way to pay attention to the problems generated by the intense and daily exposure caused by motor vehicles in the city of São Paulo.

This effort can serve the public manager with ample data, to propose improvements to the urban roads and enable new construction systems aiming to mitigating noise pollution in city centers and areas with intense traffic of people and vehicles with a high incidence of noise, pollution that goes unnoticed by most of the population.

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