MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

The Soundscape Of Sen. Salgado Filho Avenue, Natal/RN-Brazil: The Acoustic Impact Caused By The Insertion Of Semi-exclusive Bus Lane.

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ABSTRACT

Actions have been adopted in brazilian roads in order to prioritize collective transportation over the individual. In Natal/RN, the lane next to the sidewalk was destined to the bus circulation at Senador Salgado Filho Avenue, raising questions about the noise impact felt by people at bus stops and sidewalks. Therefore, the objective is to understand the influence of the road configuration on the environmental sound quality to point out elements for mobility plans. The methodology used was: measuring of sound pressure levels at bus stops; questionnaires to verify the evaluation of the pedestrians on the sound impact of

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the semi-exclusive lane; development of acoustic maps based on the current scenario and the reallocation of public bus lanes to the central site. The results demonstrated that sound levels on sidewalks are higher than those recommended by World Health Organization, and that people are disturbed by the noise due to the proximity of the buses. Through the calibrated models, it was found that the location of the semi-exclusive lane on the right produces less noise than in the central bed (a solution adopted in others roads in the same city), demonstrating how the studies of sound impact can be used in urban and mobility planning to increase the pedestrian's comfort on sidewalks.

Keywords: Environmental Comfort, Public Transport, Urban Planning
I-INCE Classification of Subject Number: 76
http://i-ince.org/files/data/classification.pdf

1. INTRODUCTION

In Natal, state of Rio Grande do Norte (RN), northeast of Brazil, the important avenues with high vehicular traffic, are undergoing changes in the traffic flow, with the implementation of semi-exclusive bus lanes in the right-hand one, delimiting the space for only urban buses and taxis (shared vehicles) to travel. The lane can also be used for emergency vehicles such as police and ambulances, and only in immediate conversions the private cars can cross it and enter the side roads.

This solution seeks to prioritize collective transportation over the individual. However, some questions about the effectiveness of this action are pointed out. On one hand, the mobility policy shows a better articulation between different points of the city, minimizing the time spent on the public transport routes. On the other hand, the speed of the buses tend to rise after the insertion of its semi-exclusive lane, elevating the sound impact on the pedestrians that stand at the bus stops on the sidewalks.

Senador Salgado Filho (BR-101) Avenue is the most important one in Natal, due to its location in the city, accesses provided by it and its surrounding buildings. In 2015, the route has its flow reorganized, with the implementation of the semi-exclusive bus lane.

According to Bistafa (2011), the physical characteristics of the road and the public walkway beds (linear, with traffic lights that promote accelerations and decelerations, and rigid paving), as well as the high flow of traffic, contribute to the increase of the noise levels in the environment.

That presented, the following hypotheses were raised: a) in terms of acoustic comfort, the pedestrian experience was impaired after the implementation of the semi-exclusive bus lane in the right-hand lane, near the sidewalk and; b) the placement of the semi-exclusive bus lane on the left, near the central bed, reduces the sound pressure levels received by the people on the sidewalks.

Thus, this research has as general objective: to understand the influence of the road configuration on the environmental sound quality of the city to point out elements that can base mobility plans. More specifically, it is intended to: verify the impact caused by the semi-exclusive bus lane in the surrounding noise levels; evaluate the sound perception of the pedestrians in relation to the proximity of the exclusive lanes of buses with the walkways; analyse the influence of the semi-exclusive lanes positions in relation to the noise disturbance in the sidewalks; suggest palliative measures of noise control in similar pathways.

The problem mentioned indicates that in Natal, when the local mobility plan, the guidelines of the Municipal Urban Mobility Secretariat and the city's Master Plan (NATAL, 2007) were implemented, the city management did not use the parameters of acoustic environmental quality as an urban planning tool. For this reason, this study becomes fundamental as a reflection for the management practices in operation, as well as those that are still being implemented.

It is also worth mentioning that this study was developed within the discipline of Urban and Regional Planning and Design 6, subject from the Architecture and Urbanism course of the Federal University of Rio Grande do Norte, Brazil.

2. GEOMORPHOLOGICAL CHARACTERIZATION OF SENADOR SALGADO FILHO AVENUE

Senador Salgado Filho Avenue is located in Natal/RN, Brazil, and represents a small piece of BR-101, the second largest road of Brazil, interconnecting the country from the northeast to the south.

The section chosen of the analysed road, shown in figure 01, is located entirely in the Lagoa Nova neighborhood. Although the predominance of residential use in this area, the avenue's borders concentrates important buildings of the city, as shoppings, universities, supermarkets and commercial buildings, being a reference for the whole city.

The study area is 1,1 km long and contains six bus stops, indicated in the figure 01 by letters A to F. Letter A represents the bus stop in front of Portugal Center Mall; B is near a residential building and a hotel; C is located next to Corporate Trade Center (business tower); D is in front to Dentistry Department of UFRN; E is in front of Midway Mall; and F is near the Federal Institute of the Rio Grande do Norte (IFRN).

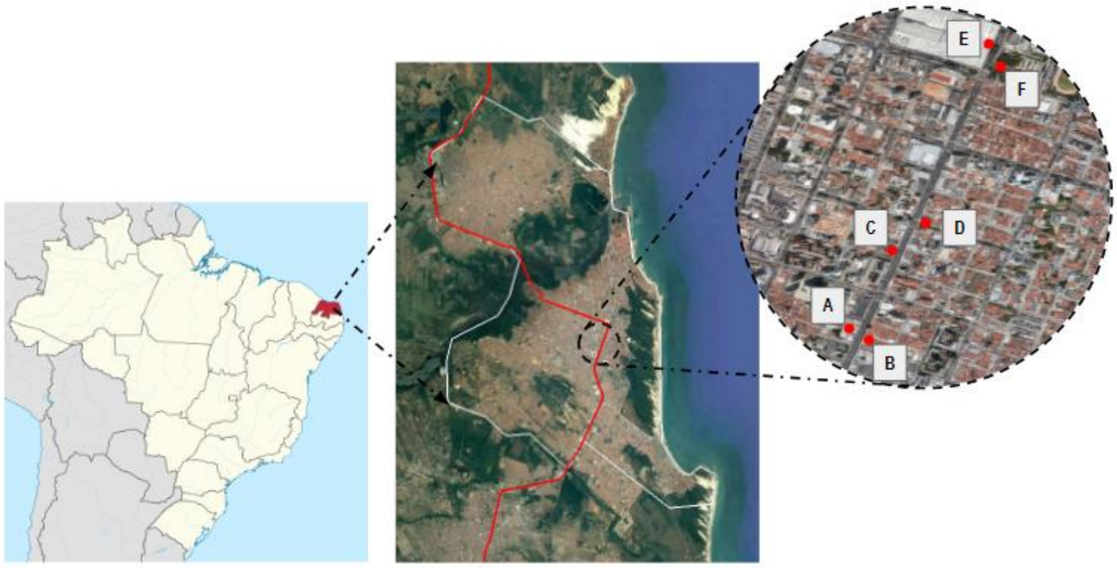

Figure 01: Location of the Natal city, study area and the chosen points. (Source: Google Earth. Edited by the authors.)

The area presents a slightly wavy terrain, as shown in figure 02 of the longitudinal profile of the track in the studied section. It should be emphasized that the topography, in this case, is an important enhancer of the noise caused by automobiles, and should be taken into account for the analysis of each point. In all the points, the sidewalks have widths that vary between 3.40 and 3.80 meters.

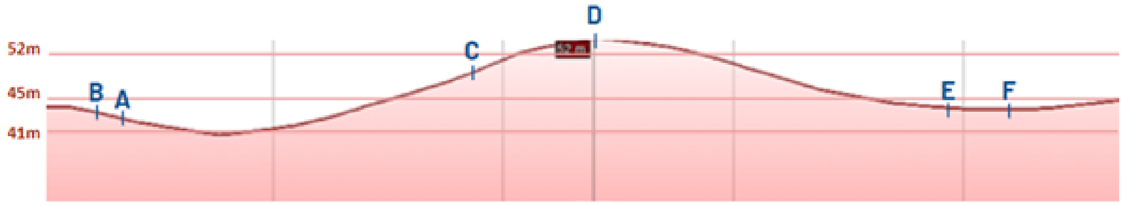

Figure 02: Longitudinal relief profile of the study area. (Source: Google Earth. Edited by the authors.)

3. OPERATIONAL METHODOLOGY

3.1 The structuring and application of questionnaires

To understand the impact caused by road noise in people's quality of life, it was applied a previously structured questionnaire to people in the bus stops located at Senador Salgado Filho Avenue. These places were chosen based on where people spend more time with more frequency in the sidewalks, located near to the buses, receiving directly the sound waves.

The questionnaire was structured to capture the social context, the levels of sound perception and the agents that cause the most annoyance on the road in the perspective of the interviewees. It was considered in it, the characterization of the population (age, gender and hearing health conditions), verification of auditory problems, collection of information about work and what type of activity they performs (as it can interfere with their level of audibility), as well as the global perceptions about traffic noise and perceived sound sources causing the greatest annoyance in the road.

For each questionnaire, the average time was one minute for each application. In order to be compatible with the sound measurement time (10 minutes), the number of 60 questionnaires for the entire area was established to be applied in six bus stops along the selected area. The sample made possible the extraction of the global diagnosis and the relation of perception and sound measurement between the points.

3.2 Vehicle traffic counting and sound measurements

As well as the questionnaires, the sound pressure levels were measured on the sidewalks, with the aim to quantify the noise level received by the people that wait for the buses and sell products at bus stops.

The measurements were done on Tuesday, Wednesday and Thursday, at the time of the highest vehicular traffic, between 5 pm and 6 pm (FLORÊNCIO et al, 2018). The choice of these three days is justified by the changes that the traffic flow undergoes on Mondays and Fridays.

The instrument used to collect the equivalent continuous sound pressure levels (LAeq) was the sound level meter type 01dB SOLO SLM BLACK, class 1, configured for real-time measurements during a period of 10 minutes.

During the measurements, the road in its respective chosen point were filmed for posterious counting of the vehicle traffic. The counting was divided by lane and by vehicle weight (light and heavy), considering the cars as light vehicles, and the bus, motorcycle and trucks as heavy ones, according to the noise produced by them (Bistafa, 2011).

3.3 Acoustic maps and simulations

Based on the counting of vehicles performed simultaneously to the sound pressure levels measurement, acoustic maps were elaborated using the software *SoundPLAN*, version 7. From the counting of vehicle traffic data by track, in the period of ten minutes, the system calculated the sound pressure level emitted at each point. With the calculated value, the calibration of the model was verified, according to the recommendation of ISO 1996-2, by comparing the results in the program with the local measures.

The simulation created two scenarios, generating:

Scenario 1: The bus lane next to the sidewalk, as it currently stands and;

Scenario 2: The track away from the sidewalk, next to the central bed in each direction of the road.

As a result, two sound maps were made for the same area, each corresponding to its respective scenario.

4. THE SOUND COMPOSITION THROUGH THE USER PERCEPTION

The questionnaires were applied to 60 people in the 6 bus stops of the study, but four interviewees were discarded due to non-finalization of the questionnaires because they had to leave the site, resulting in a sample of 56 questionnaires.

In general, the people interviewed were annoyed by the loudness of the road, either on a medium level or a very annoyed one - 34 people, representing 60% of the sample. Only four people stated that the noise in the avenue is low. In counterpoint to the perception of the loudness results, 52 people (92%) considered the loudness of the road from normal to high.

These two questions and their respective answers showed that the nuisance and the loudness are not directly related, proving that people can get used to the noise and do not view high noise levels negatively.

When linking the noise with the vehicles that travel along the road, the interviewees were asked to respond to the sounds they were listening to at the moment, being unanimous the mentioning of the vehicles traveling. Following this question, it was asked which vehicle people considered most influential to the noise of the road, being observed that 63% of the interviewees believed that the buses are those responsible for elevating the noise of the track. The influence of motorcycles on the indicated responses - categorized in the research together with the trucks - is also emphasized, with 32% of the responses destined to those vehicles. Cars represented only 5% of the sample, with 3 responses.

It is also worth noting that 28 (64.3%) of the 56 people who responded that have frequented the area for more than 5 years stated that road noise increased after the insertion of the exclusive bus lanes.

Restricting from the people who answered that the noise of the track is high, at the moment of the application of the questionnaire, to those who think that the noise of the road increased after the insertion of the exclusive bus lane, there is a total of 15 people, of which 14 believed that the noise is related to the fact that the bus is closer to the sidewalk.

5. ROAD ACOUSTIC INDEXES

In the analysed section, there were levels of noise well above that recommended by the World Health Organization (WHO): 70 dB. Figure 03 compiles the vehicle traffic information by lane and the respective sound pressure levels collected at the six measurement points. Lane 1, colored in blue, refers to the semi-exclusive bus lanes and the other lanes for other vehicles.

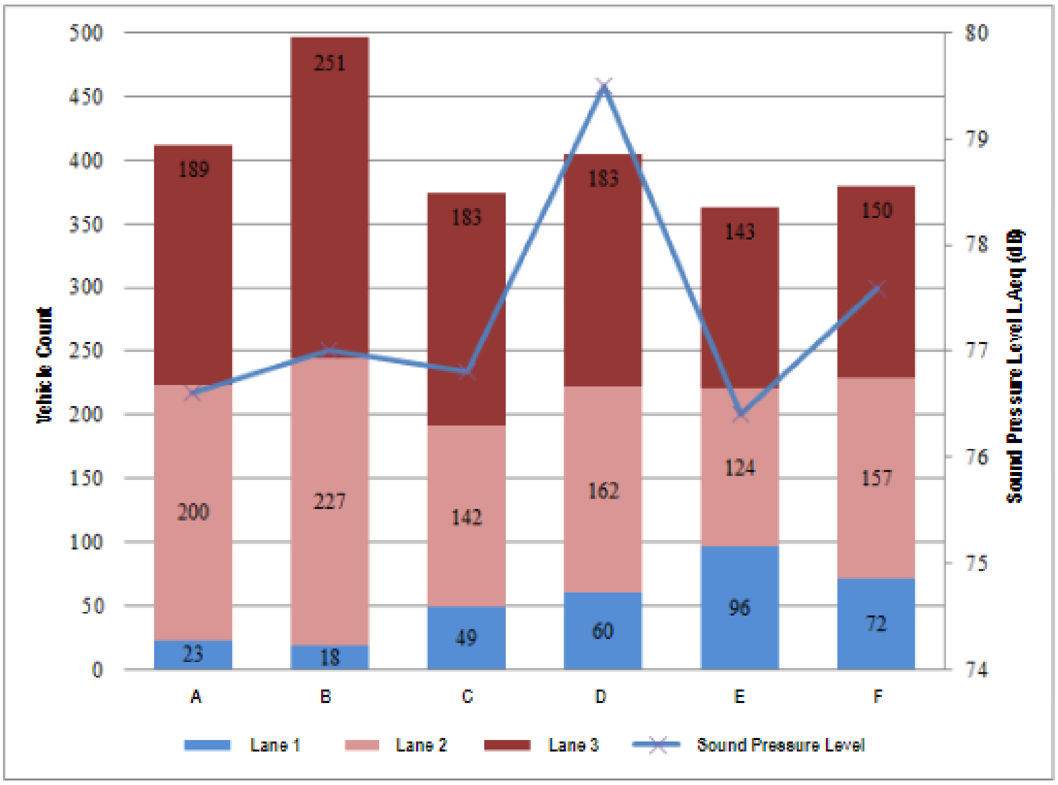

Figure 03: Indexes acoustics. (Source: the authors.)

In all the measurement points, it is verified that in the semi-exclusive bus lane there were fewer vehicles. However, in the other lanes, the number of vehicles that used them are superior to the bus lane (Lane 1), proving the idleness of it in comparison to the others.

In the survey performed at the measurement points, the sound pressure levels remained constant, except for the recording on the sidewalk of the Department of Dentistry of UFRN (point D), where it measured 79.5dB. This is because the point is located in a topographical slope, according to geomorphological characterization, where the vehicles demand more of their motors (NUNES, 1998).

By investigating point-to-point exclusively the semi-exclusive band (figure 04), it is noted that the results of average sound pressure levels (LAeq) were not altered by the quantity and weight of vehicle closer to the sidewalk. At Point D (DOD), only 17 heavy vehicles passed through it, but still the noise level measured was higher than E (Midway Mall). At this point, 50 heavy vehicles transited the lane, although the LAeq registered as the smallest.

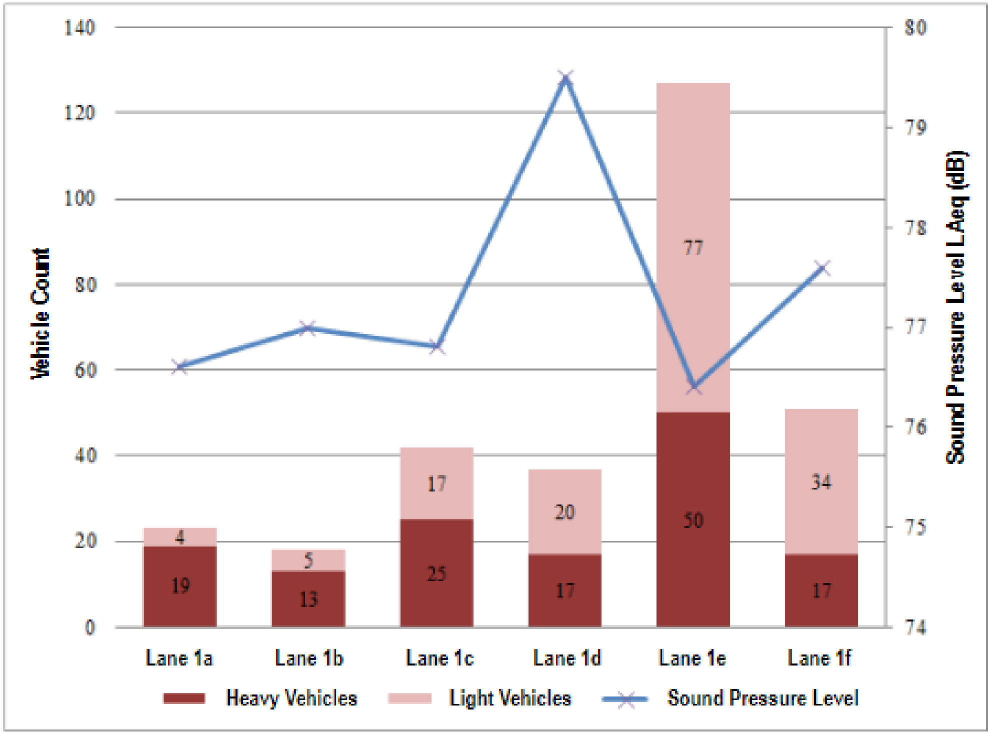

Figure 04: Indexes acoustics in the bus lane. (Source: the authors)

It is recorded that the terrain, ventilation, width of the sidewalks, the traffic lights and the accesses influenced the field measurements in the different places, evidencing their specificities. For this reason, the analysis together with the perceptions of each user becomes fundamental.

6. THE INFLUENCE OF THE LOCATION OF THE EXCLUSIVE BUS LANE ON THE SOUND PERCEIVED BY PEDESTRIANS

In order to evaluate the acoustic impact of the location of the semi-exclusive bus lane on the sidewalk, two comparative scenarios were created: a) scenario 1 referring to the calculation considering the lane next to the sidewalk, as it currently is and; b) scenario 2, which illustrates the calculation considering the lane next to the central plot (figure 05).

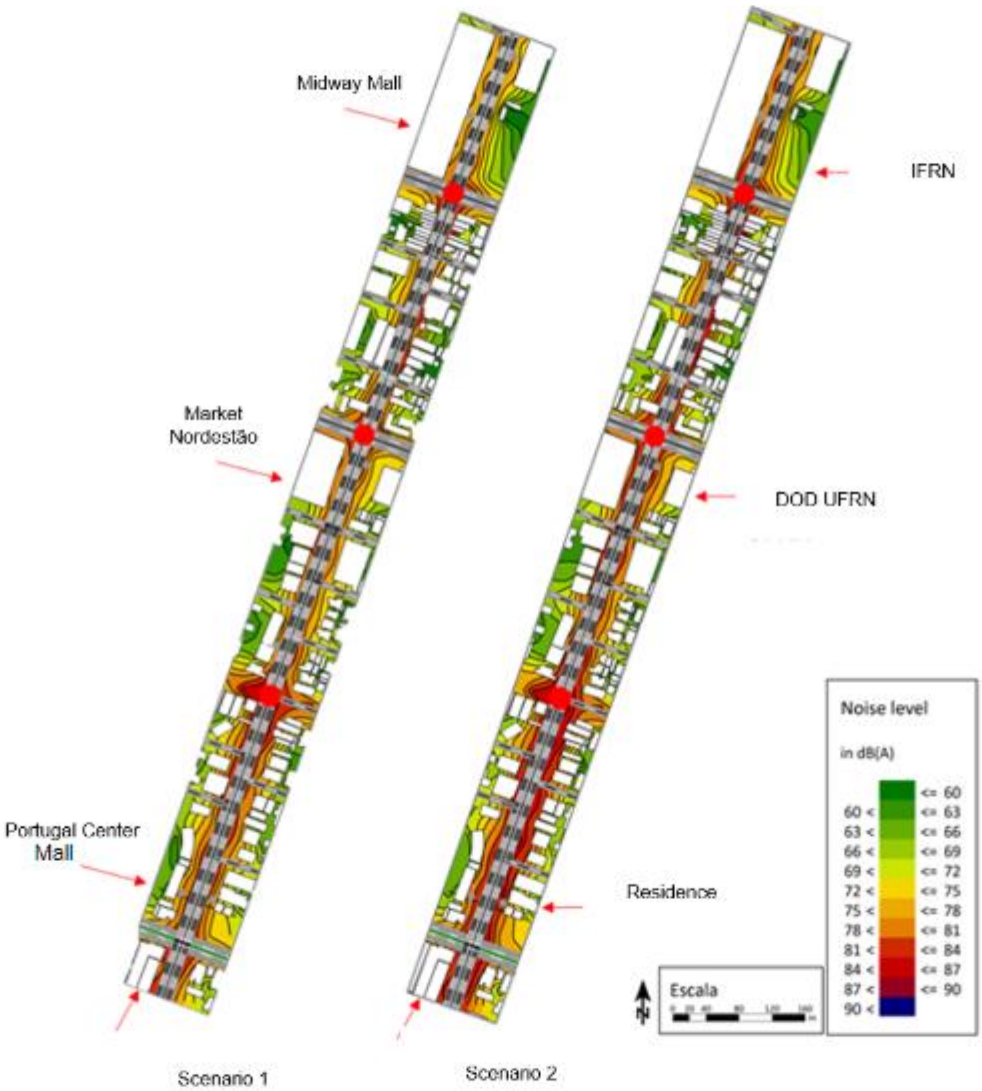

Figure 05: Acoustic maps performed by computer simulation, according to the two scenarios created. (Source: the authors)

The maps show that, in Scenario 1 (with the lane near the sidewalk), seen in figure 06, there is a lower level of noise generated by the lane than in Scenario 2 (with it near to the central site), shown in figure 07. In general, the same behavior is observed for the entire section analysed. In none of the points (A to F), the sound pressure levels emitted in situation 2 are lower than those currently present (situation 1), exemplified below with the road's cross section near points A and B of the analysed section.

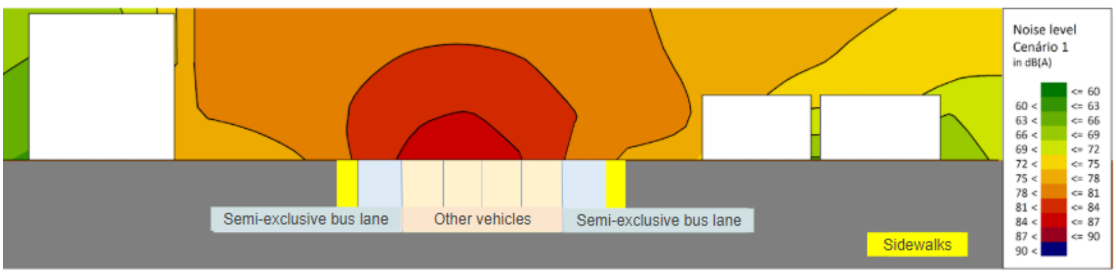

Figure 06: Cross section: scenario 1. (Source: the authors)

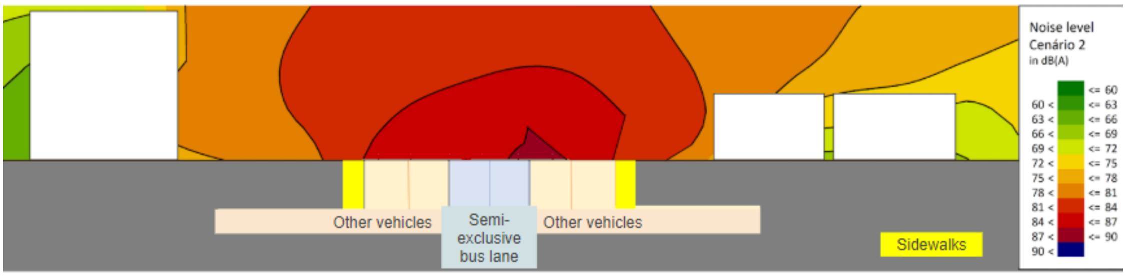

Figure 07: Cross section: scenario 2. (Source: the authors)

In scenario 1, the idleness of the semi-exclusive bus lane (in the time period of counting) dilutes the sound impact generated by the buses, even though it is a very loud type of vehicle. In this case, when doing the analysis by measurement time, it is verified that the flow impacts more than the weight of vehicles.

When the semi-exclusive lanes are removed from the central bed (scenario 1) the noise distribution on the sidewalk is less disturbing, from 78 to 81 dB. In the second case (scenario 2), the two sound sources tend to sum up, producing a higher and more powerful sound pressure level on the sidewalks, from 81 to 84 dB.

Figure 08 illustrates the detail of local measurements, seeking to evidence the sound impact caused at the moment the bus passes in the semi-exclusive lane. The analysis parameter is the blue line, representing the type A sound filter (which considers the sound attenuation in the open air).

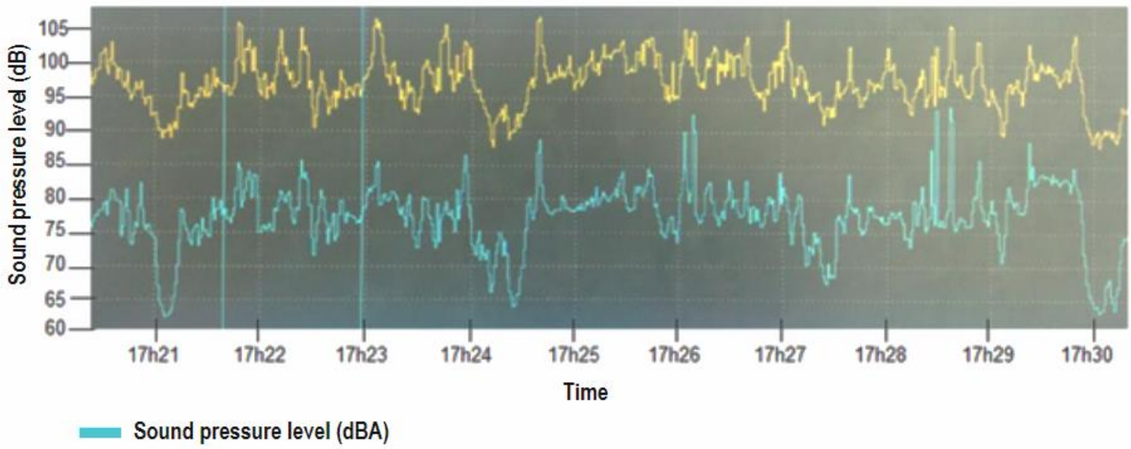

Figure 08: detailed sound measurement graph during the period of 10 minutes. (Source: sound level meter type 01dB SOLO SLM BLACK)

Compared with video recording, it was found that the peaks of the blue line in figure 08 represent the sound pressure level emitted as the bus passes. Most of the time, it's the moment when the bus brakes or accelerates. It can be noticed at 5:28 p.m., the exact time a bus passed, that the sound pressure level elevated 5 dB, considering the average measure over time.

7. THE STUDY AS A BASIS FOR URBAN PLANNING

During the bibliographical studies carried out, there was a lack of studies and legislation in the country on the noise produced by the bus and the effects caused by it on human health, either considering users inside the bus or outside it.

On one hand, the simulations carried out indicated the right lane as the best location for the semi-exclusive lane, near the sidewalk, being a base for future mobility plans establishing criteria related to acoustic comfort in urban planning. In addition to this solution, we must also work on improving the shelters for those waiting for the buses, proposing to make an acoustic treatment in the junctions or arrange them so that the public transport user is protected from the sounds emitted by the vehicles.

In addition to this, the implantation of norms for the use of materials that absorb the noise in the façades facing the roads of great circulation is also interesting as a way to attenuate the sound impact

On the other hand, it is important to affirm the influence of the quality of the vehicles in the sound pressure levels. The vehicles that circulate in the capital of the state of Rio Grande do Norte are obsolete and have poor braking and maintenance of their structure and engines (MAZDA, 2017), as reported by the interviewed users of the public transport system.

8. CONCLUSION

Vehicular traffic noise, as the main cause of noise pollution in the urban environment, is directly associated with the acoustic discomfort perceived by people. In this case, the *soundscape* of the urban environment is impaired, because the high levels of traffic noise, added to the physiological factors of each individual, negatively interfere in the quality of people’s experiences.

The problem is aggravated in countries whose urban planning does not consider acoustic comfort, expressing a mismatch between policies of urban mobility and local environmental quality. In Brazil, only three cities have sound maps until 2018, with Natal being one of them. Studies are even scarcer when one seeks to understand particular cases, such as portions of the city or segments of avenues.

Through this work, it was verified that in Natal by this study carried out at av. Sen. Salgado Filho, the acoustic levels generated in the road are well above those recommended by WHO (70dB) and the experience of pedestrians who walk on sidewalks is impaired by the vehicular traffic noise, especially when related to the noise caused by urban buses.

In addition, through this research it was noted that the current position of semi exclusive bus lane has better acoustic performance as it currently is (next to the sidewalks), disproving the hypothesis that the reverse scenario (with concentrated clues away from the sidewalks) would be better. Nevertheless, through detailed measurements and popular opinion, it was noticed a direct annoyance regarding the acoustic quality of the buses.

It is concluded that the *soundscape* of the most connected segment of Senador Salgado Filho Avenue (and Natal) is negatively marked by the presence of loud vehicles, especially buses, which affect the pedestrian experience on the sidewalks. In the local scene, it was found that the intentions planned in urban mobility policies are not accompanied by two factors: the proper development of public transport and attention to local acoustic comfort on the road margins.

The contribution of this study is mainly due to the perception about the city demands that cannot be neglected. Local traffic noise data and the view of pedestrians at the bus stop provide important basis to urban planning policies, whether in the area of traffic engineering, public transport or urban acoustics.

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