Revista Nacional de
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 09, número 72, 2021

Sound mapping and acoustic simulations in the implementation of the northern stretch of the Green Line in Curitiba, Paraná, Brazil

Paulo Henrique Trombetta Zannin
Prof. Dr.-Ing., Laboratory of Environmental and Industrial Acoustics and Acoustic Comfort, UFPR, Brazil
paulo.zannin@gmail.com

Paulo Eduardo Kirrian Fiedler
MSc in Water Resources and Environmental Engineering, UFPR, Brazil
paulofiedler@gmail.com

Erik de Lima Andrade
PhD student – Environmental Sciences, Institute of Science and Technology of Sorocaba – UNESP, Brazil
eng.erik@hotmail.com

ABSTRACT

The present study aims to study environmental noise pollution in areas close to the northern stretch of the Green Line, in Curitiba, PR, Brazil, which has a length of approximately 8 km. For this purpose, *in situ* measurements of sound levels were carried out and noise pollution was evaluated through the calculation of noise maps in addition to acoustic simulations. Measurements were recorded at 16 points following the guidelines of the NBR 10151. Acoustic maps were made for each point using proper acoustic software. The aim was to verify whether measured values were within a margin error of up to 4.6 dB(A) compared to simulated values. After validating the maps and verifying the noise pollution at the selected points, one of the points, which is close to a hospital, was analyzed alone to evaluate different simulation scenarios. The selected scenarios were replacement of common asphalt for one with porous properties; 90% restriction on the quantity of heavy vehicles; reduction of average speed of vehicles from 80 km/h to 60 km/h; 50% restriction on the number of vehicles of all categories; and acoustic situation of the site, including all the measurements proposed in the previous scenarios. All scenarios presented in this work reveal that the measurements adopted were not sufficient to reach 55 dB(A) near sensitive areas such as hospitals. They also show that just one control measure is not enough to lower noise efficiently. A plan with several joint measures is needed to alleviate the problem.

KEYWORDS: Ambient noise. Noise pollution. Noise maps.

1 INTRODUCTION

Currently, millions of people are exposed to noise from different sources. Noise levels and the consequent noise pollution are directly related to the growth of cities and the urban population. As a consequence, there has been an increase in the number of sound sources in the urban environment, mainly from means of transport (BASNER; MCGUIRE, 2018; WOSNIACK; ZANNIN, 2021).

The issue of noise in cities has been intensively studied around the world (PAIVA et al., 2019). The increase in urbanization and the growth in the number of cars within the urban perimeter of metropolises have contributed to further increase the noise emission in urban environments (KHAN et al., 2018).

The city of Curitiba, PR, Brazil, has more than 1,900,000 inhabitants (IBGE, 2021), which makes it one of the large Brazilian metropolises. Data from the Paraná Transit Department (DETRAN-PR) statistics division reveal that the total vehicle fleet in December 2020 was 1,469,805 (DETRAN-PR, 2021). Such growing population and number of vehicles evidence an undesirable environmental pollutant: urban noise.

Curitiba has undergone urban transformations in its recent history, such as the conversion of the old BR-116 into a “large avenue.” The former BR-116, now called Green Line, was and is being remodeled (ZANNIN; SANT´ANA, 2011). The urban remodeling works of the former BR-116 include the so-called southern stretch (Pinheirinho – Campus of the Federal University of Paraná (UFPR)), which has already been completed, and the so-called northern stretch (UFPR Campus – Atuba).

In this sense, the present study aims to study environmental noise pollution in areas close to the northern stretch of the Green Line, in Curitiba, PR, Brazil, which has a length of approximately 8 km. For this purpose, *in situ* measurements of sound levels were carried out and noise pollution was evaluated through the calculation of noise maps using acoustic simulations.

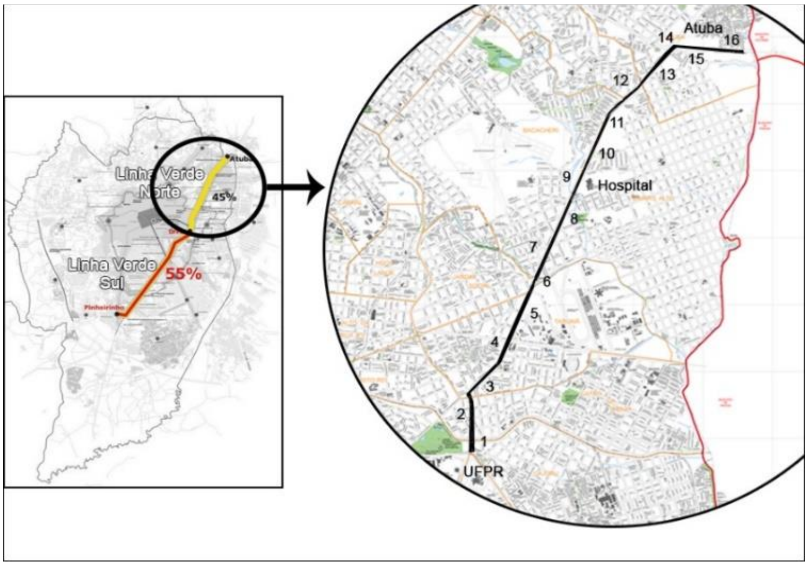
ISSN eletrônico 2318-8472, volume 09, número 72, 2021

2 METHODOLOGY

2.1 SOUND MEASUREMENTS

Sound measurements were made at 16 points for ten minutes at each point, which was spaced 500 m apart, totaling a total stretch of approximately 8 km. The measurement results for the equivalent sound level (L_{eq}) were expressed in dB(A). For each measurement point, a noise map was plotted considering the main factors that determine road traffic noise. The measurements followed the recommendations of the Brazilian standard NBR 10.151, and the equipment used was a sound analyzer BK 2250 and a BK 4231 acoustic calibrator. Simultaneously with the sound measurements, light and heavy vehicles and motorcycles were counted. Figure 1 shows the measurement points and the location of the studied stretch.

Figure 1: Location of the North Green Line and the measurement points



Source: Prepared by the authors (2021).

2.2 ACOUSTIC MAPPING

To plot the noise maps of the study area using the acoustic analysis software Predictor 6.2, model 7810, georeferenced cartographic data were used, namely topography, street layout, and orthophotograph charts of the region. They were obtained from a database called Curitiba Digital – 2006/CD-ROM Edition published by the Institute for Research and Urban Planning of Curitiba (IPPUC). The buildings were designed manually. Other input data were needed, including vehicle flow divided into categories (light vehicles, motorcycles, and heavy vehicles), average speed the vehicles travel, and type of asphalt. The average speed of vehicles on the analyzed roads was defined considering the maximum speed allowed on traffic lanes, which ranged from 60 to 80 km/h. For heavy vehicles, the speed considered was 5 km/h below the speeds of motorcycles and light vehicles. The grid of receiving points (grid noise map) had a distance between points defined as 15 x 15 m. The grid height used was 4 m in order to follow the recommendation of the Environmental Noise Directive (2002/49/EC).

2.3 ACOUSTIC SIMULATIONS

One of the sections of the acoustic mapping (near point 9, where there is a hospital) was selected to apply simulations of hypothetical scenarios using the software Predictor 6.2, model 7810, in order to verify whether some mitigating measures can reduce sound levels. To apply simulations, five scenarios were proposed. Each scenario presented a different situation, as follows:

- Reference scenario: shows the current acoustic situation, after acoustic mapping, in front of a large hospital located on North Green Line;
- Scenario 1: same reference site after replacing common asphalt for one with porous properties;
- Scenario 2: 90% restriction on the number of heavy vehicles in circulation;
- Scenario 3: reduction of the average speed of vehicles from 80 km/h to 60 km/h;
- Scenario 4: 50% restriction on the number of vehicles in all categories;
- Scenario 5: shows the acoustic situation of the site including all measures proposed in scenarios 1, 2, and 3.

3 RESULTS AND DISCUSSION

3.1 NOISE MAPS

Initially, the model was calibrated. Calibration consists of verifying whether the sound levels generated by the model are compatible with the sound levels measured in the field. This comparison is made by adding receivers to the model at the same site where measurements are taken. The maps were calibrated considering the measurements, and the difference between L_{eq} measured and the simulated value must be lower than 4.6 dB(A), the value recommended by the "Working Group Assessment of Exposure to Noise" (WG-AEN, 2002). Table 1 shows the difference between measured and simulated values.

Table 1: Difference between L_{eq} dB(A) in measurements and in computer simulations

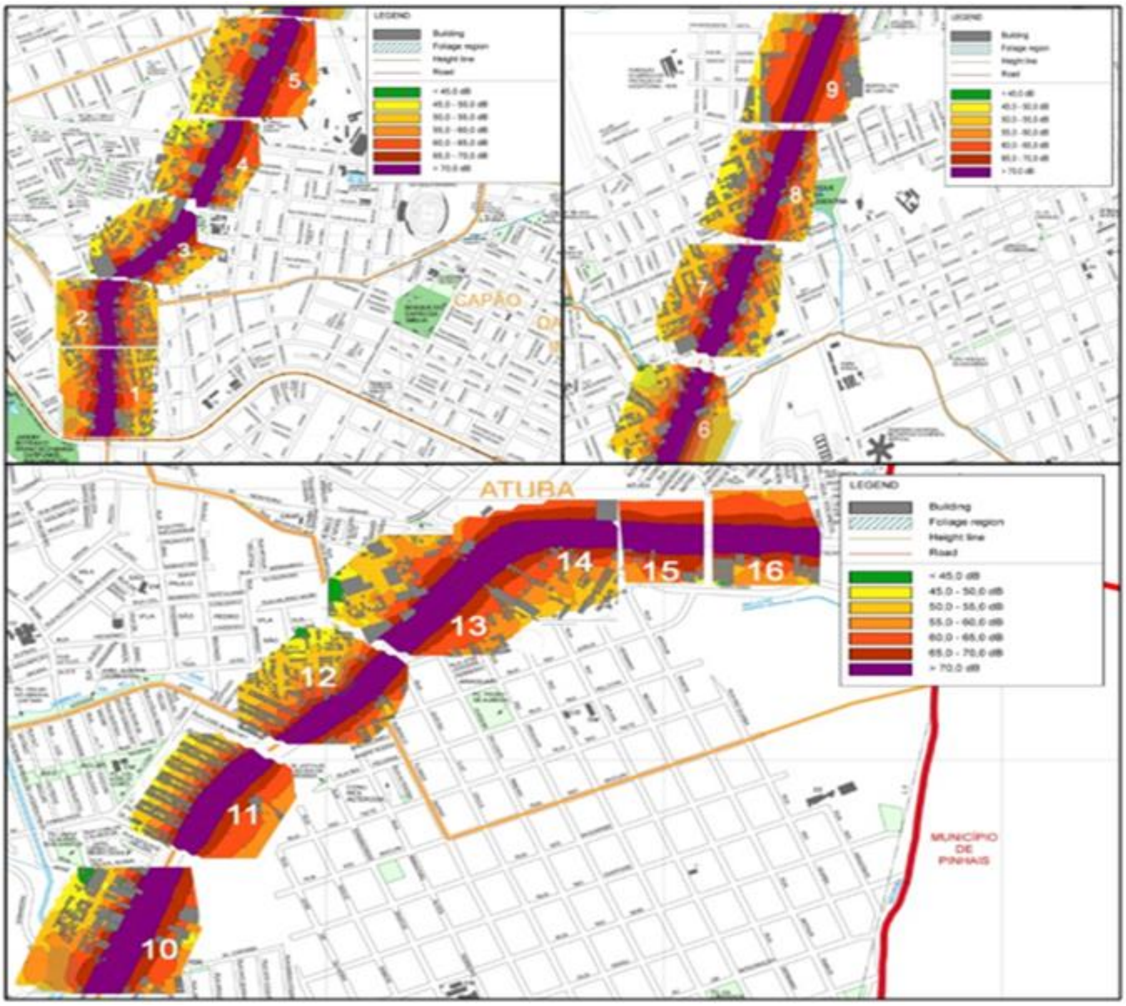
Measurement point	Measured value	Simulated value	Difference
1	79.1	80.3	+1.2
2	79.9	79.6	-0.3
3	80.9	79.7	-1.2
4	81.7	82.4	+0.7
5	81.6	82.4	+0.8
6	80.2	76.9	-3.3
7	75.5	75.2	-0.3
8	76.1	77.5	+1.4
9	79.5	77.1	-2.4
10	76.7	77.2	+0.5
11	80.6	80.7	+0.1
12	76.3	73.0	-3.3
13	73.6	74.2	+0.6
14	74.1	74.6	+0.5
15	76.5	75.1	-1.4
16	78.4	76.9	-1.5

Source: Prepared by the authors (2021).

Analyzing the sound pressure levels obtained by measurements at each point confirms that all levels are quite above the values allowed by the municipal law of Curitiba no. 10.625/2002, which is 65 dB(A). Traffic composition is a factor of great importance for the analysis of environmental noise impact, as it directly affects the measured sound levels. The large percentage of light (74.5%) and heavy (15.5%) vehicles help to justify the high noise levels along the stretch (FIEDLER; ZANNIN, 2015).

Figure 2 shows the 16 noise maps obtained for each measurement point.

Figure 2: Acoustic maps of points 1 to 16



Source: Prepared by the authors (2021).

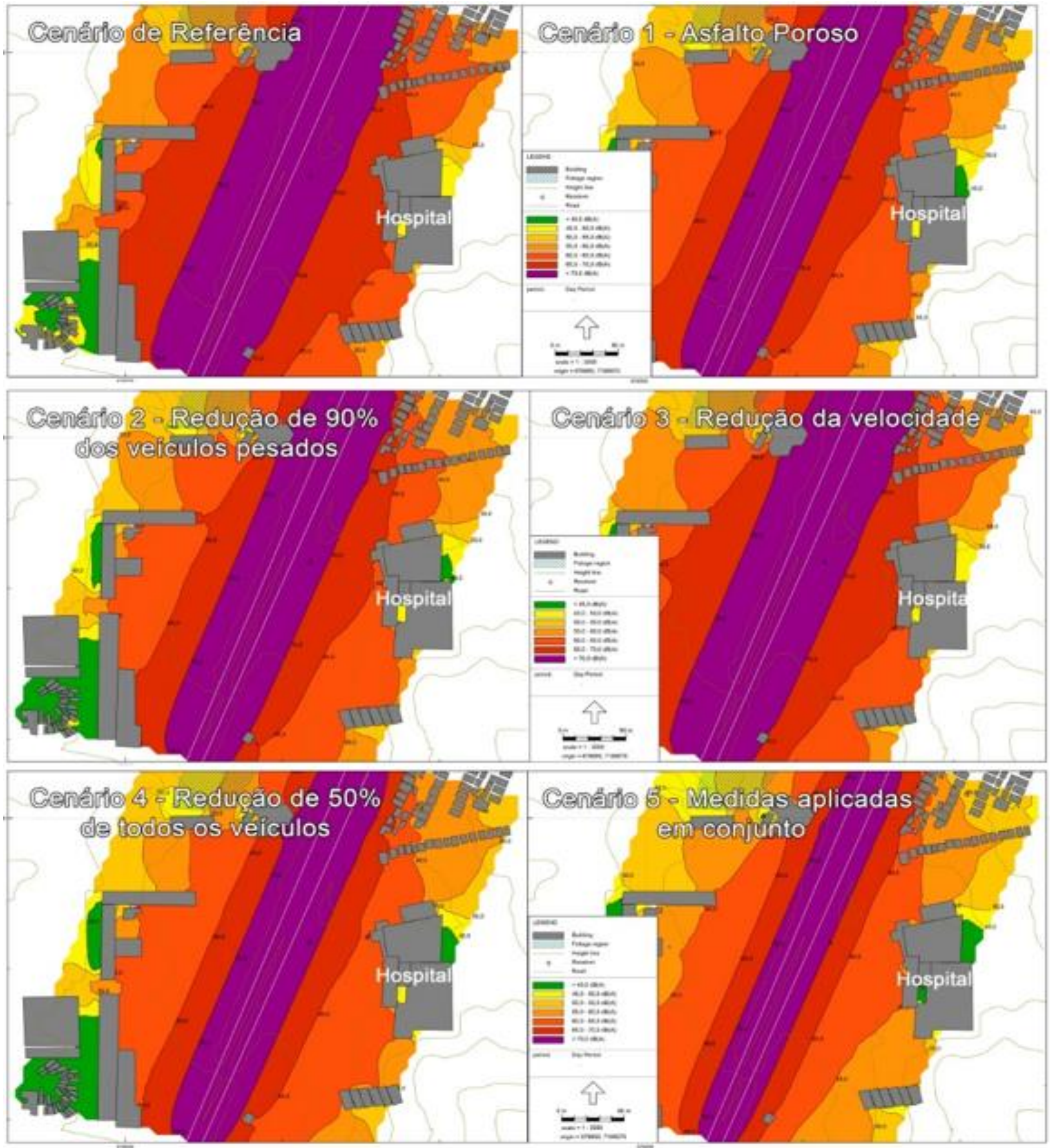
All maps show that the noise levels that reach the facades of buildings are high compared to the maximum levels allowed by the legislation in force in the city of Curitiba (Law no. 10.625/2002). The values were all above 70 dB(A). Such high levels can be justified due to the large flow of vehicles and the high average speed observed in the field survey.

To change the current acoustic scenario, some mitigating measures can be taken, such as pavement changes (generally porous asphalts are quieter), limiting the flow of heavy vehicles, and reducing the average speed of vehicles (FIEDLER; ZANNIN, 2015; MONTES-GONZÁLEZ et al., 2019; ROSSI et al., 2020).

3.2 ACOUSTIC SIMULATIONS

Figure 3 shows the results of the maps plotted for different scenarios compared to the reference scenario. The selected stretch to verify the different hypothetical scenarios is near a hospital, which is considered an area sensitive to noise (ANDRADE et al., 2021a), needing more restrictive sound levels (55 dB(A)).

Figure 3: Comparison between all simulated scenarios and the reference scenario



Source: Prepared by the authors (2021).

After the change proposed in scenario 1, sound levels predominate within a range of 60 to 65 dB(A) around the hospital. The sound levels that reach the hospital facade are about 5 dB(A) below the reference scenario, a result similar as that of scenario 2. This reduction is not enough to be within the maximum allowed limit of 55 dB(A) around sensitive regions such as hospitals and schools. The study of Montes-González et al. (2019) reported similar reductions in noise levels during the night with a simulation of the implementation of porous asphalt around a hospital. Fiedler and Zannin (2015) performed a simulation of a 50% reduction in the number of heavy vehicles and verified a reduction of 3 dB(A) near the facades of two hospitals.

Scenario 3 shows that the decrease in sound levels is very small, and the change is almost imperceptible on the map, with values close to those obtained in the reference scenario. Another study found that the reduction in vehicle speed to 30 km/h decreases the sound levels by 3 to 5 dB(A) (ROSSI et al., 2020).

On the map of scenario 4, the difference between the reference scenario is marked and indicates that the sound levels that reach the hospital facade are about 5 dB(A) below the reference scenario. However, this reduction is also not enough to be within the maximum allowed limit of 55 dB(A). Andrade et al. (2021b) found that, even with a high rate of reduction in total vehicle circulation around a hospital in the city of Sorocaba, SP, Brazil, due to the COVID-19 pandemic, there was a reduction below 1 dB(A) in the avenue with the greatest flow and speed of vehicles.

The previous scenarios show that only one mitigation measure is not enough to reduce noise levels in order to comply with the current legislation. Thus, in scenario 5, the simulation adopted a set of measures. The measures adopted in this simulation are the same as those of scenarios 1, 2, and 3. The results show that the difference between the reference scenario and scenario 5 is marked and indicates that the noise levels that reach the hospital facade are lower than that of the reference scenario.

4 CONCLUSION

The noise levels measured at the sixteen points along the northern stretch of the Green Line in Curitiba, PR, Brazil are above the allowed in the current municipal legislation, which is up to 65 dB(A). The values that reach the facade of the buildings are above 70 dB(A).

At the point selected for the simulations of possible noise pollution mitigation measures, all the scenarios analyzed are not sufficient to reach 55 dB(A), the maximum level allowed for sensitive areas such as near hospitals. It is possible to determine that just one control measure is not enough to lower noise efficiently. A plan with several joint measures is needed to alleviate the problem. Although scenario 5 with several measures did not reach the limit proposed by the current legislation, it has the greatest difference in relation to the other scenarios.

In this study, computational models are possible allies in urban planning for noise control and may help public managers to make decisions seeking to ensure and improve the population's quality of life.

REFERENCES

ANDRADE, E. L.; SILVA, D. C. C.; LIMA, E. A.; OLIVEIRA, R. A.; ZANNIN, P. H. T.; MARTINS, A. C. G. Environmental noise in hospitals: a systematic review. **Environmental Science and Pollution Research**, v. 28, p. 19629–19642, 2021a. DOI: https://doi.org/10.1007/s11356-021-13211-2.

ANDRADE, E. L.; LIMA, E. A.; SIMONETTI, V. C.; OLIVEIRA, R. A.; ZANNIN, P. H. T.; SILVA, D. C. C.; MARTINS, A. C. G. Influence of the COVID-19 pandemic on the external environmental noise of a public hospital in Sorocaba, Brazil. **Revista Nacional de Gerenciamento de Cidades**, v. 9, n. 69, p. 44-51, 2021b. DOI: http://dx.doi.org/10.17271/23188472966920212790.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). **NBR 10151: Acústica – Medição e avaliação de níveis de pressão sonora em áreas habitadas – Aplicação de uso geral**. Rio de Janeiro, 2019.

BASNER, M., MCGUIRE, S. WHO environmental noise Guidelines for the European Region: A systematic review on environmental noise and effects on sleep. **International Journal of Environmental Research and Public Health**, v. 15, p. 519, 2018. DOI: https://doi.org/10.3390/ijerph15030519.

DEPARTAMENTO DE TRÂNSITO DO PARANÁ (DETRAN-PR). **Estatísticas de Trânsito**. Disponível em: http://www.detran.pr.gov.br/Pagina/Estatisticas-de-transito. Acesso em: 11 fev. 2021.

EUROPEAN COMMISSION WORKING GROUP ASSESSMENT OF EXPOSURE TO NOISE (WG-AEN): **"Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure"**– v.2, p. 1-129, 13th Jan 2006.

EUROPEAN UNION DIRECTIVE 2002/49/EC **relating to the Assessment and Management of Environmental Noise**. Official Journal of the European Communities; 2002. No. L 189.

FIEDLER, P. E. K.; ZANNIN, P. H. T. Evaluation of noise pollution in urban traffic hubs—Noise maps and measurements. **Environmental Impact Assessment Review**, v. 51, p. 1-9, 2015. DOI: https://doi.org/10.1016/j.eiar.2014.09.014.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **População de Curitiba** – Disponível em: https://cidades.ibge.gov.br/brasil/pr/curitiba/panorama. Acesso em: 11 fev. 2021.

KHAN, J.; KETZEL, M.; KAKOSIMOS, K.; SORENSEN, M.; JENSEN, S. S. Road traffic air and noise pollution exposure assessment–A review of tools and techniques. **Science of the Total Environment**, v. 634, p. 661–676, 2018. DOI: https://doi.org/10.1016/j.scitotenv.2018.03.374.

MONTES-GONZÁLEZ, D.; BARRIGÓN-MORILLAS, J. M.; GÓMEZ ESCOBAR, V.; VÍLCHEZ-GÓMEZ, R.; REY-GOZALO, G.; ATANASIO-MORAGA, P.; MÉNDEZ-SIERRA, J. A. Environmental Noise around Hospital Areas: A Case Study. **Environments**, v. 6, p. 41, 2019. DOI: https://doi.org/10.3390/environments6040041.

PAIVA, K. M.; CARDOSO, M. R. A.; ZANNIN, P. H. T. Exposure to road traffic noise: Annoyance, perception and associated factors among Brazil's adult population. **Science of the Total Environment**, v. 650, p. 978–986, 2019. DOI: https://doi.org/10.1016/j.scitotenv.2018.09.041.

ROSSI, I. A.; VIENNEAU, D.; RAGETTLI, M. S.; FLUCKIGER, B.; ROOSLI, M. Estimating the health benefits associated with a speed limit reduction to thirty kilometers per hour: A health impact assessment of noise and road traffic crashes for the Swiss city of Lausanne. **Environment International**, v. 145, p. 106126, 2020. DOI: https://doi.org/10.1016/j.envint.2020.106126.

WOSNIACK, G.; ZANNIN, P. H. T. Framework to manage railway noise exposure in Brazil based on field measurements and strategic noise mapping at the local level. **Science of the Total Environment**, v. 757, p. 143721, 2021. DOI: https://doi.org/10.1016/j.scitotenv.2020.143721.

ZANNIN, P. H. T.; SANT'ANA, D. Q. Noise mapping at different stages of a freeway redevelopment project – A case study in Brazil. **Applied Acoustics**, v. 72, n. 8, p. 479-486, 2011. DOI: https://doi.org/10.1016/j.apacoust.2010.09.014.