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Characterization of the urban sound environment from commercial pedestrian streets: a first approach in São Paulo-Brazil

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ABSTRACT

Environmental noise management is in progress in Brazil, and São Paulo was the first city to establish the mandatory implementation of its noise map in 2016.The law regulation is under development by the city council, and to respond to the technical challenges that will be faced, different studies are being carried out as there are no environmental noise calculation models or standards for Brazilian cities characteristics. One of the main issues to be solved will be how to incorporate the mesh of commercial pedestrian streets on acoustic simulations. In this study a pilot study was carried out at "Calçadão de Osasco", a pedestrian street in the metropolitan area of São Paulo, with a high crowd density, packed with shops and street traders, very representative of the local soundscape. Different techniques of field measurements and soundscape evaluation are applied to propose a first characterization. It is evaluated how this proposal can be incorporated to prediction software and aims to inspire the study of the urban sound environment of commercial streets in Sao Paulo.

Keywords: Noise mapping, Public open spaces, Urban sound planning

1. INTRODUCTION

The concern about the urge on dealing with urban sound planning is becoming more evident in large conurbation areas from Latin America such as São Paulo. Following the European experience [1,2] on environmental noise management combined with all evidence of the effects of environmental noise on people's health and wellbeing [3], in 2016 the city council of São Paulo made its first move by the enforcement of Law 16.499, which establishes the elaboration of the city's first noise map.

Once the mentioned law entered into force, several technical challenges came about concerning the noise map elaboration. One of the main difficulties identified by the stakeholders is that there are no specific noise generation/propagation models for the Brazilian environmental noise context.

Previous studies [4,5] identified that international methods of noise assessment applied in São Paulo converge with field results for traditional sources, such as road or railway noise. But other non-conventional sources have not yet been investigated, of which it is possible to highlight popular commerce streets. As presented in Figure 1, this type of pedestrian street is commonly found in São Paulo and in its metropolitan area, and in this study one of the liveliest commercial streets from a neighboring town was evaluated: the Osasco sidewalk, hereinafter referred as Calçadão de Osasco.

Osasco is a city with 700,000 inhabitants [6], and its downtown is taken over by commercial activities that attracts people from neighboring cities to do shopping, whether in shopping malls or street stores. As São Paulo is giving its first steps on urban sound planning, the Calçadão de Osasco and its high pedestrian volumes and high levels of activity throughout the day, consist on a representative study case to perform an initial study on how to incorporate commercial pedestrian streets in the city's first urban noise map.

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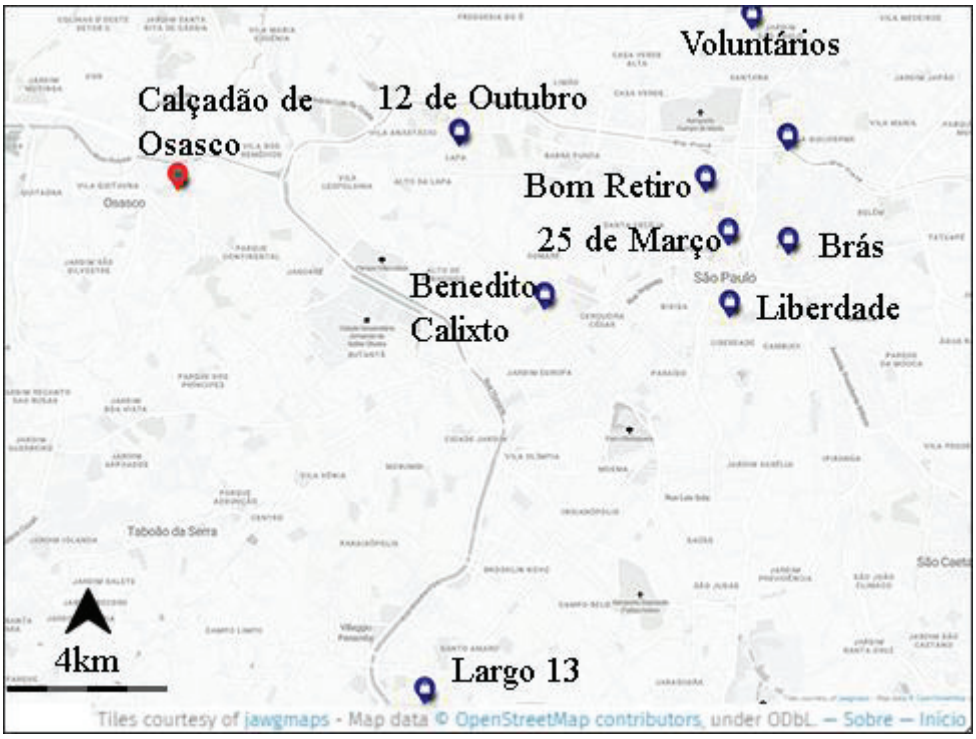


Figure 1: São Paulo's metropolitan area popular commerce streets (blue) and study case (red). Map data: © OpenStreetMap contributors.

2. OBJECTIVES

The study aims to be a first approach on how to incorporate commercial pedestrian streets on acoustic simulations of São Paulo and its metropolitan area, evaluating the Calçadão de Osasco by two methods:

- Quantitative: field measurements to evaluate Sound pressure level in different scenarios of the study case followed by acoustic simulation by prediction software.
- Qualitative: soundwalkings supported by recordings and questionnaires to identify the main sound sources to be considered when evaluating the acoustic environment of commercial pedestrian streets in São Paulo.

3. METHODOLOGY

For the purposes of the study, a field measurement campaign was carried out in order to characterize the area under evaluation from a sound pressure level perspective. Simultaneously, sound walks were performed by 4 subjects aiming to evaluate the sound sources that compose the Calçadão and afterwards the obtained input data was used to build an acoustic simulation of the area for two different scenarios.

3.1 Study case area

The Calçadão de Osasco, highlighted in red in Figure 2, is a high activity pedestrian street with 500m of extension and more than 250 business premises [7], most of them shops and restaurants. The area is surrounded by secondary roads, an urban train station and two bus terminals, and everyday more than 350 thousand people attend the Calçadão. The trade is diversified, with stores of all categories, from shoes, clothing, bags and cosmetics, to hot dog cars licensed by the city hall. As it can be observed in Figure 3 a) and b), the sidewalk has a 12m wide central promenade and the public lightning, in addition to the palm trees lines on each side, creates a cozy atmosphere.

Four points were selected for the sound pressure level measurements. Points 1 and 4 are located at the limits of the Calçadão and could be influenced by urban traffic or railway noise. Point 2 is placed

in front of Osasco Plaza Shopping, where the Calçadão doubles its width, and Point 3 in a regular area highly affected by the crowds and street traders.

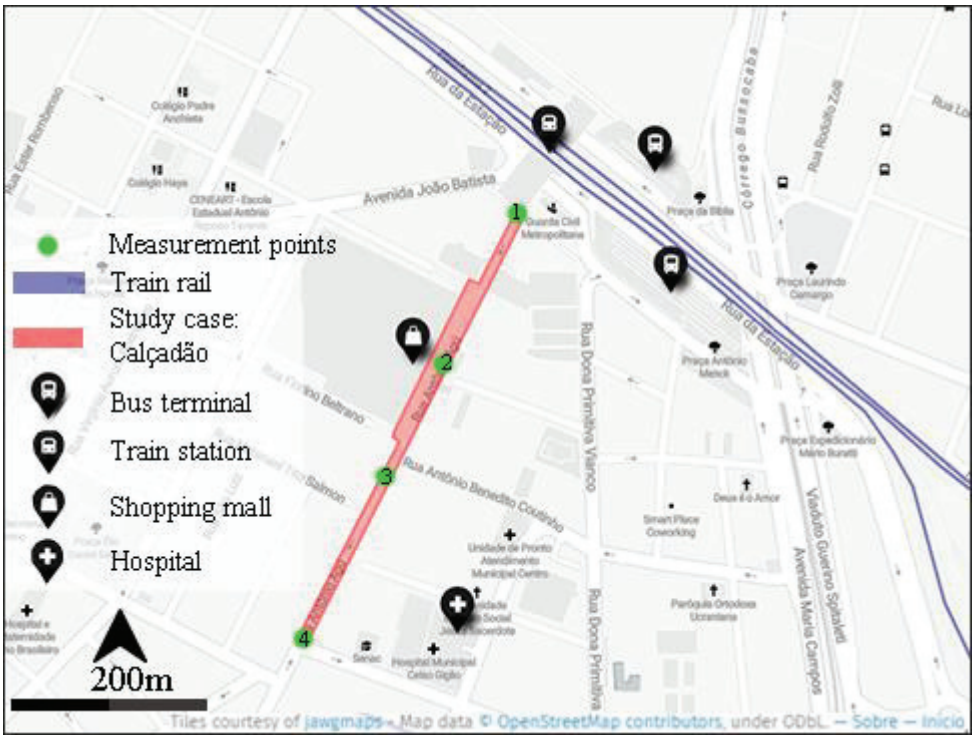


Figure 2: Calçadão de Osasco and its surroundings. Map data: © OpenStreetMap contributors.

Figure 3: a) schematic section of the Calçadão b) Calçadão de Osasco on weekends

3.2 Field measurements

Sound pressure level (SPL) measurements were carried out in two different days and time, in order to evaluate the Calçadão in different conditions. To characterize a quite weekday, the first campaign took place on a Tuesday between 10am and 12am. The second measurement took place on a Saturday from 12pm to 2pm, when the Calçadão and its surroundings receive the largest number of visitors. All measurements were performed with a duration time of 10 to 15 min, using a calibrated sound level

meter Larson Davis model 831. The microphones were positioned at 1.50 m height following Brazilian national standard ABNT NBR 10151[8]. However, international standards indicate that measurements should be made at 4 m height to avoid the first reflections from the floor. For this reason, extra measurements were performed, with microphones positioned at 4.1m and 7.9m high close to buildings facades to verify the sound propagation accuracy in the simulation model.

3.3 Soundwalks

As this study consists on a first approach on how to incorporate Brazilian commercial pedestrian streets in acoustics simulation for noise environment management, a more holistic approach [9] was necessary to evaluate the sound source types beyond sound pressure level, which does not fully represent the acoustic experience of this urban space.

To help the comprehension of the acoustic environment of the Calçadão, an individual soundwalk procedure [10] was carried out to investigate the participants responses. A pilot soundwalk campaign was performed by five participants, being all acousticians, São Paulo residents, aged between 20 and 40 years, and none have never visited the Calçadão before. The soundwalks took place in a weekday, at the same time de SPL measurements were being carried out. Participants walked for around 18 minutes along the full extent of Calçadão, with both start and finishing point at the train station. During the soundwalk participants walked and were asked to evaluate the acoustics environment and to focus on listening practice to emphasize their own viewpoints. Just after going through the route, participants were asked to fill a questionnaire based on [11] to evaluate the soundscape qualities of the Calçadão.

As input for future studies aiming to have a wider description of subjects' impressions of the elements in the acoustic environment of the Calçadão, all participants wore binaural microphones and a backpack, where a recording device was installed. In addition, while a participant was walking, a researcher was following him from a certain distance in order to take pictures of the evaluation positions selected by subjects.

The answers obtained through this preliminary questionnaire and the observation of local sounds by the five subjects enabled identifying the following sound sources in Calçadão in order of prevalence:

- Road traffic noise → Cars and buses
- Individual people sound → Conversations, Loud laughing, Children, Street traders screaming
- Crowds sounds →Crowds babble
- Music → Shops and restaurants loudspeakers facing the sidewalk
- Air Traffic noise → Airplanes
- Natural sounds → Birds
- Railway noise → Train station
- Other sound sources →Such as sirens, public works, loading and unloading.

From this result, it is interesting to remark, that although the Calçadão is close to a train station, railway traffic was not noticeable to 3 of the 5 subjects.

When asked to classify Calçadão sound environment according to categories presented in [11], respondents indicated that the Calçadão's soundscape is chaotic, full of life, stressful and eventful as presented in Figure 4:

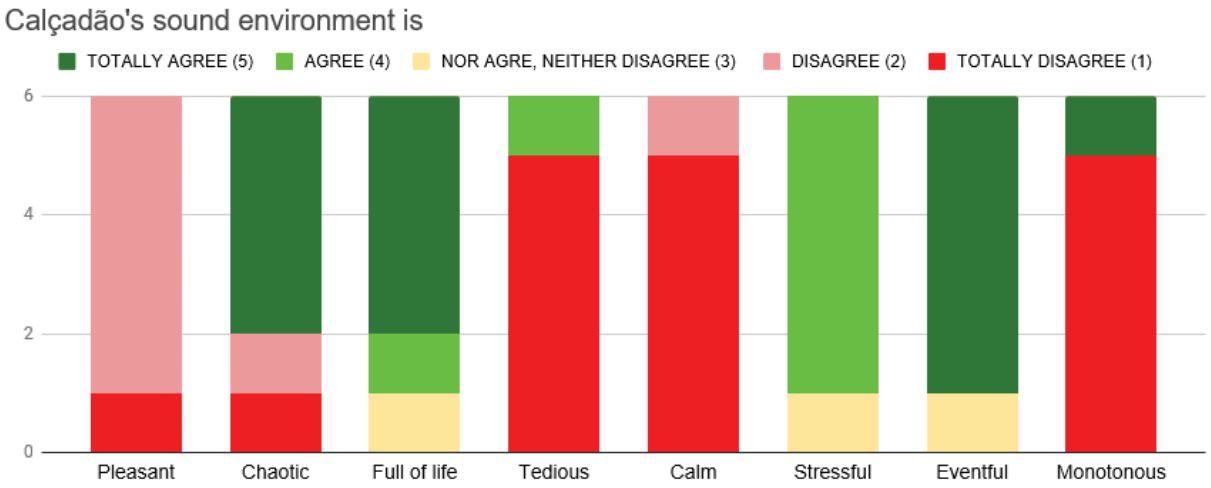


Figure 4: Subjcets responses to the Calçadão's Soudscape classification

When asked about the activities that they considered suitable to carry out at the Calçadão, subjects considered that it is an ideal place to shopping. Other activities like outdoor recreation activities (such as ball games and kite), enjoying peace and quiet, practicing physical exercises, socializing with family and friends, escaping from urban stress, were considered unsuitable or less suitable as they are difficult things to be done at the Calçadão.

3.4 Acoustic simulation

After the filed measurements campaign, the results of the sound pressure levels measurements were used as input data for calculating a noise map of the area using software CadnaA. For characterizing the noise source, "area source " tool was used, positioned 1.5m above ground level. CNOSSOS, NMPB 2008 and RLS 90 were used as calculations models, with sound power level PWL and sound power level per unit area (PWL); and spectrum of type Lw and Lw from Lp + distance + Sphere partition.

During the computational experiments, it was found that it is not ideal to use the source emission type as PWL because the obtained results were higher than the SPL levels measured in field. For Calçadão's noise map, the calculation method that best converged with field results was: NMPB / PWL / LW / with 2 reflexions and grid size 10m x 10m.

4. RESULTS

4.1 Field measurements

In Table 1 the results of the field measurements are presented. As it can be observed, the Calçadão consists on a relevant urban noise source, as the obtained values for L_{Aeq} are over 67 dB on average.

In general, the results obtained for Saturday are higher than those from the weekday. Whether is a weekday or a Saturday, the Calçadão receives a continuous flow of people and of urban traffic flow in its surroundings. Like in other commercial pedestrian areas of São Paulo, on Saturdays the Calçadão gets more crowded, thousands of people go shopping, there are more stores with their sound speakers directed to the sidewalk and more street traders screaming along the pathway.

Table 1: SPL results (L_{Aeq} and $L_{ASmax)}$ for a weekday and on a Saturday

	Weekday (Tuesday)		**Saturday**		**Saturday - Weekday**	
	L_{Aeq} (dB)	L_{ASmax} (dB)	L_{Aeq} (dB)	L_{ASmax} (dB)	ΔL_{Aeq} (dB)	ΔL_{ASmax} (dB)
Point 1	68,3	76,3	74	77,2	5,7	0,9
Point 2	61,3	77,2	68,4	75,9	7,1	-1,3
Point 3*	69,7	80,5	-	-	-	-
Point 4	68,4	77,2	71,5	80,3	3,1	3,1

Average	**67**	**78**	**71**	**78**		

* On Saturday's measurements, it was not possible to get Point 3's SPL.

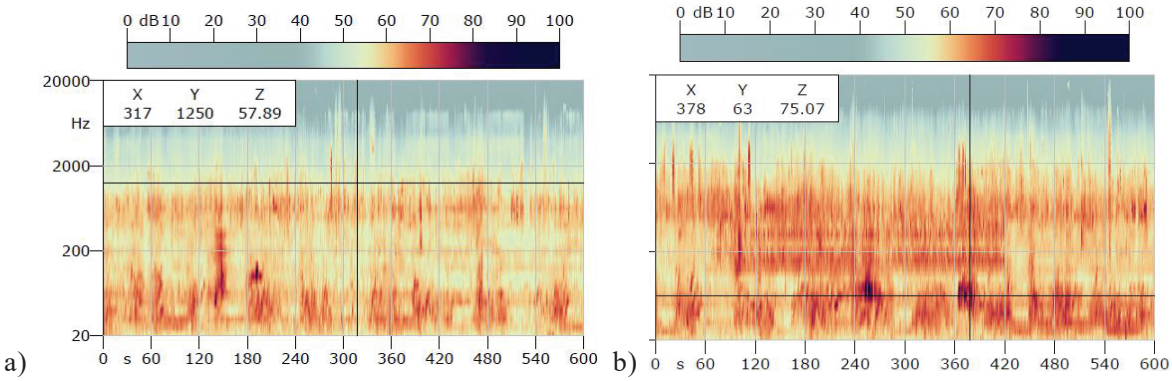
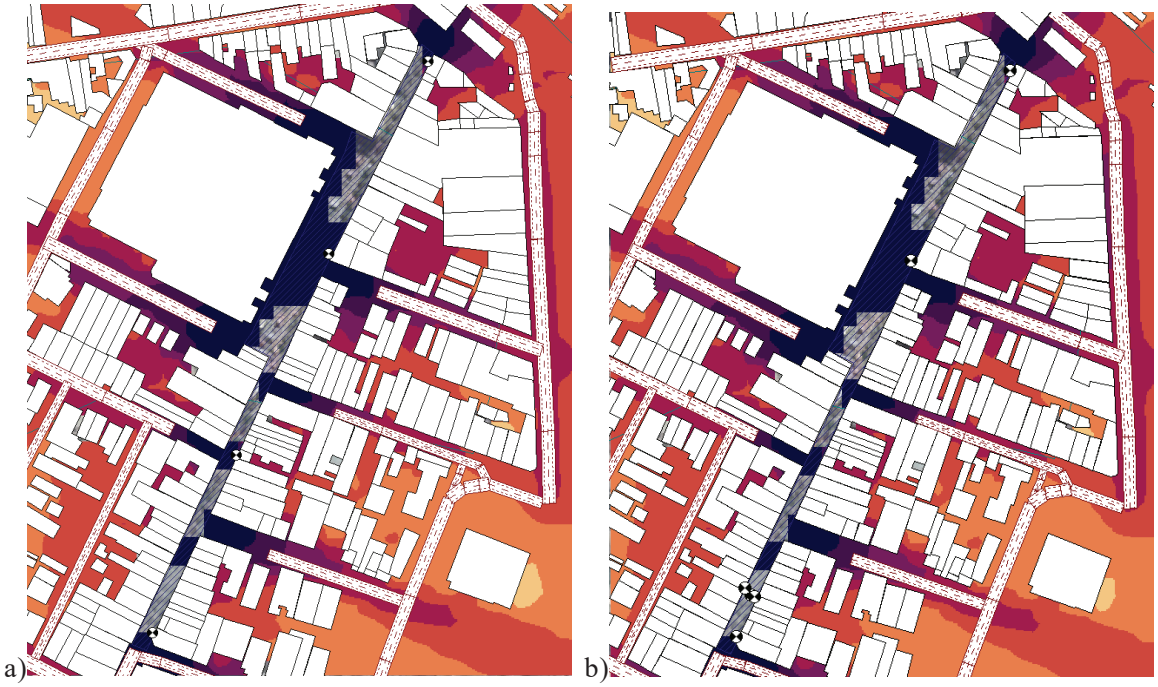


Figure 5: Spectrograms for a) weekday and b) saturday measurements of Point 4

For each measurement point,a spectrogram was obtained in order to identify any specific frequency component that can indicate a proeminent sound source. In Figure 5, only spectrograms of the weekday and saturday measurements of Point 4 are presented, thus no remarkable sound source was identified. A broadband spectrum from 20 Hz and 2000 Hz is observed, what implies that further studies should be carried out in order to obtain the isolated spectrum of each sound source.

4.2 Acoustic Simulation

As a result of the method described in item 3.4, a preliminary acoustic simulation of the Calçadão is presented in Figure 6 for L_{day}. Despite the slightly difference observed between weekday's and Saturday's sound pressure levels, it is remarkable that the people who attend the Calçadão and its surroundings are exposed to high L_{day} levels and the incorporation of this type of public space should not be underestimated in the São Paulos public policies related to urban sound management.



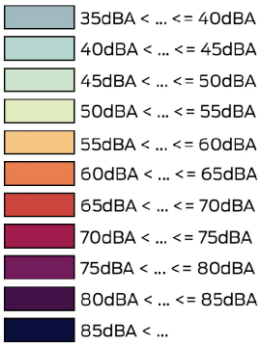


Figure 6: Calçadão's L_{day} map genereted with NMPB 2008 for a) weekday and b) weekend

5. CONCLUSIONS AND FUTURE WORK

The Calçadão of Osasco is a representative study case for the acoustic characterization of commercial pedestrian streets of São Paulo and its metropolitan area. Such public spaces are of high importance in the city dynamic as they handle with high pedestrian volumes and levels of activity throughout the day.

A first approach on how to deal with this unconventional urban sound source in noise mapping elaboration is presented in this paper and the results indicates that the commercial pedestrian streets of São Paulo presents high L_{day} values. In this study, NMPB 2008 calculation method was the one that better converged with field measurements, but further studies should be carried out in order to evaluate if international calculation models could be used, or a specific one should be developed to attend the Brazilian urban sound management demand.

Also, in future studies, it is intended to deepen in the study of the acoustic behavior of several sound sources identified by soundwalkings that need to be taken into account for the acoustic prediction e.g. individual people sound, street traders screaming, crowds babble.

The approach presented in the study aims to inspire more research on how to incorporate commercial pedestrian streets in São Paulo's first noise map elaboration Conducting an accurate diagnosis will enable the public administration to set realistic targets for noise reduction and/or preservation of the soundscape of remarkable areas while improving the acoustic experience of the city public spaces.

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