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ARTIGO ORIGINAL

Evaluation of acoustics in shopping centers in Maceio: a study on sound pressure levels and speech intelligibility

Avaliação da acústica em *Shopping Centers* de Maceió: um estudo sobre os níveis de pressão sonora e inteligibilidade da fala

Evaluación de la acústica en los centros comerciales de Maceió: un estudio sobre los niveles de presión sonora e inteligibilidad del habla

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Abstract

Shopping centers are increasingly becoming popular as a leisure option in urban centers, as they offer security and provide protection against high urban temperatures. However, these spaces have become places of agglomeration, which results in very noisy environments due to the intense flow of people. Thus, this work aims to evaluate the acoustic environment of the three largest shopping centers in the city of Maceio, Brazil. The methodological steps of this study included the selection of shopping centers, sound measurements, the identification of noise sources in the spaces, and the analysis and discussion of the results, made through the collection of sound pressure levels and speech intelligibility levels. The results indicated that, in some of the scenarios studied, the sound levels were above what is allowed by the standards and may be harmful to hearing health in case of prolonged permanence. It was concluded

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that the lack of adequate acoustic materials in projects can contribute to high sound pressure levels and noise exposure.

KEYWORDS: environmental analysis; acoustic comfort; environmental risk; occupational noise.

RESUMO

Os shopping centers estão se tornando cada vez mais populares como opção de lazer nos centros urbanos, visto que oferecem segurança e proporcionam proteção contra as altas temperaturas urbanas. No entanto, esses espaços têm se tornado locais de aglomeração, o que resulta em ambientes muito ruidosos devido ao intenso fluxo de pessoas. Sendo assim, o objetivo do trabalho é avaliar o ambiente acústico dos três maiores shoppings da cidade de Maceió, AL, Brasil. As etapas metodológicas desse estudo incluíram a seleção dos shoppings, as medições sonoras, a identificação das fontes de ruído nos espaços e a análise e discussão dos resultados, feita através da coleta dos níveis de pressão sonora e níveis de inteligibilidade da fala. Os resultados indicaram que, em alguns dos cenários estudados, os níveis sonoros estavam acima do permitido pelas normas, podendo ser prejudiciais à saúde auditiva, em caso de permanência prolongada. Concluiu-se que a falta de materiais acústicos adequados em projetos pode contribuir para altos níveis de pressão sonora e exposição a ruídos.

PALAVRAS-CHAVE: análise ambiental; conforto acústico; risco ambiental; ruído ocupacional.

RESUMEN

Los centros comerciales son cada vez más populares como opción de ocio en los centros urbanos. Ofrecen seguridad y protegen de las altas temperaturas urbanas. Sin embargo, estos espacios se han convertido en lugares de aglomeración, lo que se traduce en ambientes más ruidosos debido al intenso flujo de personas. Por lo tanto, el objetivo de este estudio fue evaluar el ambiente acústico de los tres mayores centros comerciales de la ciudad de Maceió, AL, Brasil. Las etapas metodológicas del estudio incluyeron la selección de los centros comerciales, la realización de mediciones sonoras y la identificación de las fuentes de ruido en los espacios, así como el análisis y la discusión de los resultados mediante la recopilación de los niveles de presión sonora y los niveles de inteligibilidad del habla. Los resultados indicaron que en algunos escenarios los niveles sonoros estaban por encima de los permitidos por las normas y podían ser perjudiciales

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para la salud auditiva si se dejaban durante largos periodos de tiempo. Se llegó a la conclusión de que la falta de materiales acústicos adecuados en los proyectos puede contribuir a elevar los niveles de presión sonora y la exposición al ruido.

PALABRAS CLAVE: confort acústico;patio de comidas;ruido ocupacional.

1 Introduction

Hearing is crucial for people's social interaction and locomotion. When hearing loss, several aspects of individual, social, and psychological behavior are affected, resulting in a reduction in quality of life due to exposure to excessive noise.

According to Bistafa (2011), noise, an unpleasant sound, has significant impacts on the quality of life, productivity, and mental health of workers. The author points out that noise is present in large industries, causing discomfort to workers during working hours. This reality also applies to shopping centers, highlighting occupational noise as little considered for human health.

Noise pollution occurs[1] when sounds exceed levels considered normal for hearing limits and is a significant threat to human health. According to the World Health Organization (WHO), noise pollution of 50 dB (decibels)[2] is already considered harmful and, from 55 dB(A)[3], can cause stress levels and other adverse effects on the individual. Upon reaching the 75 dB(A) mark, noise pollution causes more severe damage, with a risk of hearing loss, through

[1] Refers to any undesirable sound that occurs during office hours. Prolonged exposure to high levels of noise can damage health and cause hearing loss in employees.

[2] Unit of measure used to express the intensity or level of a sound.

[3] This is the softest sound a healthy human ear can hear. The A-weighting scale is used to measure environmental noise, such as traffic noise or building noise.

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prolonged and routine exposure of up to 8 hours (World Health Organization, 2021).

Generally, shopping centers focus mainly on the interior, using metallic structures and zenithal lighting to bring natural light and create pleasant environments. However, acoustic comfort is often neglected (Kusakawa, 2002), especially in areas such as food courts, where there is a lack of furniture with absorbent materials or noise barriers to control and reduce noise.

Acoustic comfort in shopping centers is often overlooked due to the prioritization of aesthetics and design over functionality. Frequently used materials such as glass, metal, and concrete reflect sound and increase reverberation, making the environment noisier and more uncomfortable. Competition between stores and entertainment venues can lead to an increased volume of music and ads, contributing to noise pollution. In addition, the lack of sound insulation between stores, corridors, and living areas also contributes to the increase in environmental noise.

In 1978, the Ministry of Labor and Employment approved a set of Regulatory Standards (NR) to improve worker safety. One of these standards is NR-15, which deals with unhealthy activities and operations. This standard specifies the tolerance limits for exposure to environmental agents, which are classified into physical, chemical, and biological categories (Brasil, 1978).

Tolerance limits for continuous and intermittent noise are established to protect the health and physical integrity of workers exposed to these harmful agents. In Brazil, for a working day of 8 hours a day, the acceptable noise level is 85 dB(A). If these limits are exceeded, the activity is considered harmful, and the worker has the right to receive an unhealthy additional, which is an additional percentage to their salary, if the risk cannot be eliminated or neutralized, following NR-15 (Brasil, 2022).

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The Acoustics Standard: sound pressure levels indoors in buildings - NBR 10.152 (Associação Brasileira de Normas Técnicas, 2017), mentioned in Regulatory Standard 17, and establishes appropriate noise limits to ensure acoustic comfort in various indoor environments. In the case of restaurants, this standard indicates that the ideal sound power should be between 40 dB(A) and 50 dB(A), as levels above these values are considered uncomfortable and can impair acoustic well-being, as defined by ABNT/NBR 10152 (2017). However, it is essential to note that this standard does not address the issue of noise in shopping centers environments.

Thus, given the lack of studies in this regard, the acoustics in three shopping centers in the city of Maceio (Alagoas, Brazil) was evaluated. Sound Pressure Levels – SPL, and Speech Intelligibility Levels - SIL were analyzed in different areas of the malls to better understand the noise present in these environments and highlight the importance of the concern with sound quality since there are no established standards to guide these data.

2 Material and Methods

A case study was conducted to identify the factors influencing the acoustic scenarios of commercial environments. The explanatory quantitative evaluation method was adopted to provide a more comprehensive and in-depth view of the evaluated phenomenon, allowing a more complete and reasoned analysis.

The case study is a research modality widely adopted in the social sciences (Gil, 2002), whose purpose is to describe the situation of the context in which the investigation occurs and to explain the causal variables of a given phenomenon in complex situations.

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The research was divided into two main stages: the first consisted of characterizing the three selected shopping centers, while the second involved performing on-site sound measurements. These steps were essential for the presentation and analysis of the data described in the results and discussion.

The survey was conducted in the internal spaces of the three largest shopping centers in the city of Maceio (Alagoas, Brazil) during the month of July, a period that coincides with the school holidays in the city.

2.1 Characterization of the object of study

The shopping centers with the largest number of stores and a relevant extension of implementation were selected as the object of study. These developments were named Shopping A, Shopping B, and Shopping C.

Establishment A and B are classified as Traditional Regional, from 30,000 to 59,999 m^2 of Gross Leasable Area (GLA), and Establishment C, as Traditional Mega, above 60,000 m^2 of GLA, according to the classification standard of the Brazilian Association of Shopping Centers (ABRASCE) (Chart 1).

CHART 1 – Characterization of establishments.

Establishments	Area	Average flow of people	Stores
Shopping A	57,000m^2	>1 million/month	300
Shopping B	>47,000m^2	750 thousand/month	130
Shopping C	100,000m^2	1 million/month	200

Source: the authors (2023).

Establishments A and C are in different neighborhoods, but the avenue is in the lower part of the city of Maceio. Shopping B is in the highest part of the city, in the largest neighborhood in terms of territory and population. This means there is a greater visual concentration in Shopping B at certain times.

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In each of the three establishments, physical and sound surveys were carried out in three specific locations, as follows:

a) food court: chosen because it has a large flow of users.

b)children's play space: where there are machines with sounds attractive to children, and the environment is normally closed, ensuring internal sound levels without external interference.

c)circulation area: located near shops and kiosks, where people are subject to travel throughout the day.

These three environments were selected for analysis due to the large circulation of people and the problematic noise control. Sound measurements were made at three points in these three selected environments (Figure 1).

The measurement points in the food court of Shopping A are indicated in the schematic (Figure 1A), and it is also possible to observe the sketch of the volume of the space. The general floor plan of Shopping center B is shown in Figure 1B. The third floor of Shopping center C, where the measurements were made, is shown in Figure 1C.

This study was conducted on certain days of the week (Monday and Tuesday), as well as on weekends (Saturday). Measurements were taken at lunchtime (12:00 pm to 2:00 pm) and at dinner/leisure time (6:00 pm to 8:00 pm).

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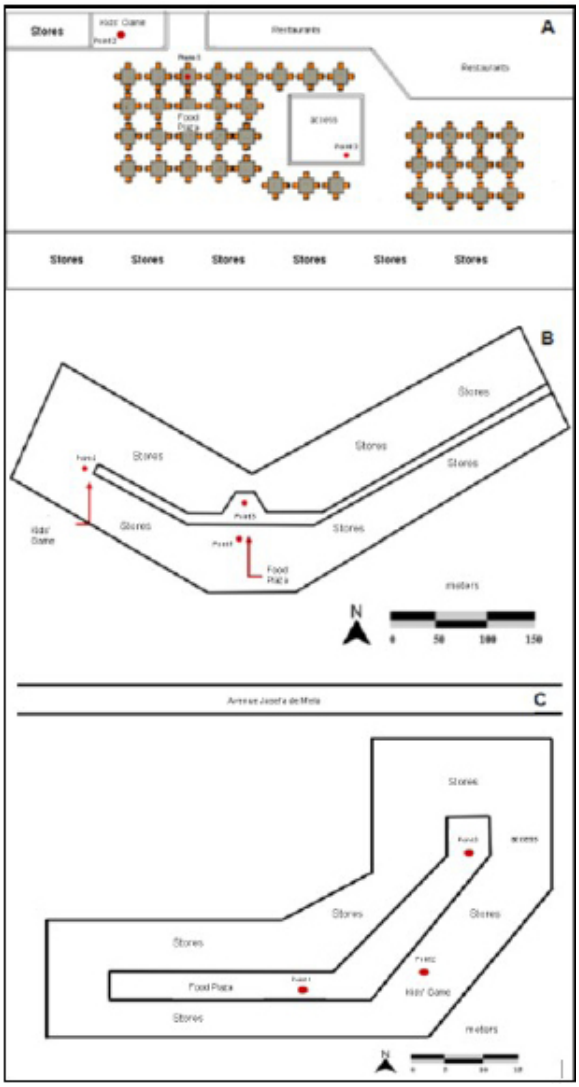
FIGURE 1 – Implementation of the establishments, showing the sound measurement points. A) Scheme of the food court of Shopping A - upper floor; B) Implementation of Shopping B - ground floor and C) Scheme of the third floor of Shopping C.



Source: the authors (2023).

2.2 Sound measurements

The measurements were conducted following the recommendations of NBR 10151 (Associação Brasileira de Normas Técnicas, 2019). Measurements were made using the sonometer (Brüel & Kjær, class 1, Type 2207), properly calibrated. The sonometer was positioned at a height of 1.20 m from the floor

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and at a minimum distance of 2 m from any vertical barrier. Measurements were performed considering peak times, from 12:00 to 2:00 p.m. (daytime measurements) and 6:00 to 8:00 p.m. (nighttime).

From the measurements (in dBA), the Equivalent Sound Pressure Levels (LAeq), maximum (L90), minimum (L10), as well as the sound pressure levels in the frequency ranges of 125, 250, 500, 1000, 2000, 4000 and 8000 Hz were obtained. The Speech Interference Level - SIL was performed using the SIL calculation (Speech Interference Level) according to the methodology proposed by Mehta *et al*. (1999).

Each measurement point (Figure 1) was considered a repetition in each environment. The data obtained in LAeq were analyzed using the arithmetic mean of three replicates.

3 Results and Discussion

Currently, no regulations deal with the acoustic comfort of shopping centers spaces. Thus, the results obtained in the present study were compared with those recommended by NR-01 (Brasil, 2020), which determines that all companies must follow the other NRs when dealing with occupational health and safety. This implies the implementation of sound control measures so that sound levels do not exceed the sound pressure limits - LAeq above 80 dB(A) in these environments.

Data were collected on site and include information such as the LAeq, which indicates the average sound pressure level throughout the measurement, the L10, which represents the level exceeded during 10% of the measurement time, and the L90 which corresponds to the level exceeded during 90% of the measurement time.

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The tables present the sound pressure levels at different audible frequencies (125, 250, 500, 1000, 2000, 4000 and 8000 Hz). The results of the sound measurements conducted at Shopping A are presented in Tables 1 to 6. In addition, the SIL was calculated [4], and these values are in the following tables.

3.1 General analysis of the Sound Pressure Levels obtained

Table 1 displays the sound data of lunch time (12:00 to 2:00 p.m.) on weekdays and dinnertime (6:00 to 8:00 p.m.). Table 2 shows the sound data of the weekend, at the same times mentioned above, representing the scenarios found in Shopping A.

TABLE 1 – Sound Pressure Levels – SPL (dBA), at lunch and dinner times, on a weekday, at Shopping A.

SPL weekday (12:00 to 2 p.m.)				NPS weekday (6:00 to 8:00 p.m.)		
Frequency (Hz)	Game Room	Circulation	Food Court	Game Room	Circulation	Food Court
125	64.6	62.2	63.4	64.6	63.1	66.3
250	64.2	62.1	64.5	64.9	67.1	66.1
500	63.7	63.9	66.7	65.9	66.7	69.7
1000	61,8	59.6	63.8	67.5	62.8	66.1
2000	55.3	54.1	59.8	61.1	59.9	60.5
4000	50.7	47.7	54,3	57.0	52.1	55.5
8000	43.8	40.4	46.4	51.3	44.7	48.1
Mean Sound Pressure Levels (LAeq), maximum (L90), minimum (L10) and SIL						
LAeq	70.2	69.4	73,3	78.0	72.8	75.3
L10	63.7	65.8	68.6	67.4	66.8	70.7
L90	82.1	77.0	86.8	88.5	83.1	84.5
SIL	57,9	56.3	61.1	62.9	60.4	62.9

Source: the authors (2023).

[4] Speech Interference Level - SIL refers to the amount of interference or noise present in an audio signal during communication. It is typically measured in decibels (dB) and represents unwanted sounds or disturbances that affect speech clarity.

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TABLE 2 – Sound Pressure Levels – SPL (dBA), at lunch and dinner times, on weekends, at Shopping A.

SPL weekend (12:00 to 2 p.m.)				SPL weekend (6:00 to 8:00 p.m.)		
Frequency (Hz)	Game Room	Circulation	Food Court	Game Room	Circulation	Food Court
125	71.5	62.3	62.6	72,0	61,8	65.3
250	70.3	68.2	68.5	71.5	67.3	66.7
500	66.6	67.2	72.1	71.2	66.4	72.1
1000	67.6	64.2	68.6	73.0	65.0	70.1
2000	58.5	59.6	62.9	68.5	60.7	65.3
4000	55.6	52.7	53.8	63.7	53.1	59.4
8000	48.4	43.6	46.2	57.2	44.1	49,0
Mean Sound Pressure Levels (LAeq), maximum (L90), minimum (L10) and SIL						
LAeq	75.0	73.6	77.7	80.6	73.7	78.6
L10	69.7	68.7	73,3	73.2	69.0	74.8
L90	85.5	80.6	84.4	89.7	83.6	84.9
SIL	62.1	60.9	64.3	69.1	61.3	66.7

Source: the authors (2023).

The data collected show that the food court of Shopping A has a noisier environment on weekends, which can be explained by the greater demand of the population for this space on days off from work. Compared to the level allowed in restaurants, up to 50 dB(A), following NBR 10152 (Associação Brasileira de Normas Técnicas, 2017), the excess noise during the week is more than 25 dB(A) and, on weekends, it reaches about 28 dB(A). The results become worrisome when observing the L90, with sound pressure levels reaching almost 37 dB(A) more than recommended on weekdays.

Tables 1 and 2 reveal that the food court is the noisiest environment. In fact, in this environment there is a great flow of people talking and circulating. In addition, the absence of suitable acoustic materials such as partitions or absorbent elements favors the presence of noise. Gaming environments, on the other hand, are the second noisiest, with sound pressure levels above 70 dB(A), especially at night. In

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this place, in addition to the noise from children and toys, there is also the noise contamination of the food court.

Gaming environments stand out as the second noisiest, with sound pressure levels above 70 dB(A) in all four measurements performed. The highest noise indices were recorded at night, with 78 dB(A) on weekdays and 80 dB(A) on weekends. This data is attributed not only to children's noises, but also to the sounds produced by toys. In addition, the noise contamination of the food court also contributes to the high noise levels in this environment.

The circulation areas also presented noise levels above that recommended by NBR 10152 (Associação Brasileira de Normas Técnicas, 2017) (Tables 1 and 2). This is due to the conversations and ambient sound of the speakers on the ceiling. These areas are less noisy during the week, with a surplus of about 20 to 23 dB(A) compared to weekends, where the volume increase is not significant on different days and times.

Tables 3 and 4 present the acoustic scenarios obtained in Shopping B. The results obtained in Shopping B revealed that the gaming environment has the worst acoustic scenario, due to its proximity to the store aisle and the agglomeration of machines. In this environment, noise levels reached 76 dB(A) during the day (Table 3) and above 85 dB(A) at night on weekends (Table 4). This increase is due to the greater public demand these days. However, sound pressure levels reached 96 dB(A) overnight, which is concerning compared to L90 levels.

In the circulation area, the noise levels recorded in Shopping B were like those in Shopping A, with higher peaks at night on weekends, with a constancy between 69 and 75 dB(A) (Table 4).

As shown in Tables 3 and 4, a significant improvement was observed in the acoustic scenario of the food court. This result is possibly due to a renovation

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carried out in this environment, where acoustic barriers were used in wood, which is a sound-absorbing material.

In addition, acoustic barriers also promote greater privacy and contribute to a more pleasant listening experience, even if in a reduced way. This can be observed through sound pressure levels (LAeq) between 71 dB(A) during the day and 77 dB(A) at night (Tables 3 and 4).

TABLE 3 – Sound Pressure Levels – SPL (dBA), at lunch and dinner times, on weekday, at Shopping B.

SPL weekday (12:00 to 2 p.m.)				SPL weekday (6:00 to 8:00p.m.)		
Frequency (Hz)	Games	Circulation	Food Court	Games	Circulation	Food Court
125	*66.5*	*57,9*	64.5	67.7	59.5	65.1
250	*66.0*	*60.7*	64.7	66.7	62.8	66.0
500	*65.9*	*62.6*	64.4	68.9	64.2	68.7
1000	*65.3*	*60.9*	62.5	69,3	61.4	66.2
2000	*64.3*	*56.1*	58,8	68.3	56.1	61.7
4000	*60.5*	*48.0*	53,5	61.4	49.8	52.5
8000	*55.0*	*40.5*	43.1	51.5	42.5	41,4
Mean Sound Pressure Levels (LAeq), maximum (L90), minimum (L10) and SIL						
LAeq	75.8	69,3	71.4	78.9	70.4	74.9
L10	67.7	64.1	67.0	70.4	66.0	67.8
L90	87.6	78.0	78.5	92.1	78.6	85.9
SIL	64.0	56,9	59.8	67.0	57,9	62.3

Source: the authors (2023).

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TABLE 4 – Sound Pressure Levels – SPL (dBA), at lunch and dinner times, on weekends, at Shopping B.

SPL weekend (12:00 to 2 p.m.)				SPL weekend (6:00 to 8:00p.m.)		
Frequency (Hz)	Games	Circulation	Food Court	Games	Circulation	Food Court
125	*79.2*	*60.6*	65.6	84.7	60.6	62.9
250	*73.0*	*73.7*	66.6	70.6	64.2	63.6
500	*73.8*	*64.6*	70.7	75.4	68.3	70.5
1000	*67.9*	*61.0*	66.0	76.6	66.0	68.3
2000	*64.7*	*56.4*	62.4	74.3	63.4	63.6
4000	*58.0*	*50.0*	55.6	67.2	54.4	57.0
8000	*51.4*	*43.5*	43.8	55.4	45.6	48.2
Mean Sound Pressure Levels (LAeq), maximum (L90), minimum (L10) and SIL						
LAeq	80,2	70.8	76.6	85.4	75.2	76.8
L10	72,0	66.1	71,1	77.4	69.8	71.3
L90	87.4	81.2	85.3	96.0	92.5	86.7
SIL	66.1	58.0	63.7	73.4	63.0	64.9

Source: the authors (2023).

Tables 5 and 6 present the acoustic scenarios obtained at Shopping C. Table 5 shows the sound data at lunchtime (12:00 to 2 p.m.) on a business day and dinnertime (6:00 to 8:00 p.m.). In the daytime, it was observed that there was a greater variation in relation to the nocturnal acoustic scenario (Table 5).

In the gaming environment, sound pressure levels ranged from 72 to 75 dB(A) during the day (Table 5), reaching approximately 87 dB(A) at night (Table 6). L90 levels exceed 100 dB(A) in night periods on weekdays (Table 5).

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TABLE 5 – Sound Pressure Levels – SPL (dBA), at lunch and dinner, on weekdays, at Shopping C.

	SPL weekday (12:00 to 2 p.m.)			SPL weekday (6:00 to 8:00p.m.)		
Frequency (Hz)	Games	Circulation	Food Court	Games	Circulation	Food Court
125	*64.6*	*65.0*	63.4	75.3	67.4	64.9
250	*67.1*	*60.7*	60.5	68.1	65.1	65.5
500	*63.8*	*62.1*	61.7	71.6	67.1	68.1
1000	*64.3*	*61.0*	59.2	78.9	66.3	67.3
2000	*57.5*	*57.7*	53.8	75.5	62.5	31.4
4000	*50,4*	*51.8*	45.9	65.8	54.2	51.0
8000	*40.6*	*45.0*	36.7	64.0	47,1	40.9
Mean Sound Pressure Levels (LAeq), maximum (L90), minimum (L10) and SIL						
LAeq	72.2	70.4	68.7	86.7	74.8	75.5
L10	65.1	66.3	63.7	71.8	70.4	73.2
L90	78.8	78.8	83.8	101.8	80.5	82.3
SIL	59.0	58.2	55.2	72.9	62.5	54.5

Source: the authors (2023).

TABLE 6 – Sound Pressure Levels – SPL (dBA), at lunch and dinner times, on weekends, at Shopping C.

	SPL weekend (12:00 to 2 p.m.)			SPL weekend (6:00 to 8:00p.m.)		
Frequency (Hz)	Games	Circulation	Food Court	Games	Circulation	Food Court
125	*65.3*	*97.2*	62.1	72.3	68.8	67.4
250	*67.9*	*64.0*	65.4	72.1	68.3	70.9
500	*66.6*	*66.8*	68.5	72.1	73.5	76.5
1000	*67.0*	*62.8*	63.8	74.1	71,1	73.8
2000	*62.7*	*59.9*	59.4	70.7	65.4	67.2
4000	*57.6*	*53,5*	50.2	64.1	57.8	58.5
8000	*53.4*	*48.9*	40.1	57.8	51.9	45.6
Mean Sound Pressure Levels (LAeq), maximum (L90), minimum (L10) and SIL						
LAeq	75.9	73.5	73.7	82.4	80.0	82.2
L10	72,0	72,0	68.3	72.3	75.7	78.4
L90	85.1	78.8	83.7	89.9	87.8	93.2
SIL	63.5	60.8	60.5	70.2	66.9	69.0

Source: the authors (2023).

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In the Shopping's circulation area, sound pressure levels ranged from 70 to 80 dB(A) and were also higher at night (Tables 5 and 6).

In the food court, sound pressure levels were 68 to 82 dB(A) (Tables 5 and 6), standing out for having the lowest levels of L90, between 82 and 93 dB(A) (Tables 5 and 6). Despite being above the recommendations of NBR 10152 (Associação Brasileira de Normas Técnicas, 2017) for restaurants, the environment has a good spatial configuration and uses adequate acoustic materials to absorb sound and control noise sources. Shopping C also has acoustic barriers and niches with vegetation between the eating environments, creating a sense of welcome and acoustic privacy.

Shopping C stands out for having more varied environments and efficient use of acoustic materials to control noise. However, compared to other acoustic scenarios, the data are not as favorable due to the high sound power of passers-by since it is the busiest shopping due to its privileged location near the seafront of Maceio, Alagoas.

3.2 Analysis by environments Sound Pressure Levels obtained

A dissociated comparative analysis was carried out between the measured environments since the uses, occupations, and architectural compositions are distinct from each other. Figure 2A shows the LAeq Levels obtained in the game rooms. Regardless of the establishment, high sound pressure levels were observed in this environment (Figure 2A). It is important to highlight that noise exposure is not restricted only to children who remain in the game rooms being of concern the risks related to the hearing health of the employees of these places, who are exposed to this scenario for at least 8 hours.

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Despite the differences in the composition of the environments studied, it was found that the noise sources are similar in these spaces, namely: people talking/shouting and driving, the sound of toys, ambient music, and residual noise [5] from the outside of the environments.

Figure 2B shows data on noise levels recorded at strategic circulation points in Shopping centers. In Shopping A, the flow of people occurred near the food kiosks, which have space to accommodate users. In Shopping B and C, circulation occurred in areas close to the escalators, with many customers and employees. In addition, in these areas, several stores use speakers inside, in addition to playing music or information throughout the day. Despite the different architectural forms, there is a standardization of the materials used in these environments, namely porcelain, ceramics, concrete, and plaster. From the measured data, it should be noted that there was a constancy between 69 and 75 dB(A) (Figure 2B) in Shopping B.

Figure 2C shows the sound pressure levels obtained in the food courts. Shopping A has a simpler structure in relation to the other environments studied. This is due to the proximity of the tables and chairs and the fact that the chairs are made of polypropylene, a material suitable for sound insulation. However, the hollow structure of these chairs is not efficient enough to generate significant effects globally. Unlike the others studied, this environment is the only one with a single ceiling height, which makes the environment noisier since the sounds do not have as much space to propagate, thus remaining with sound intensity for a longer time in proximity to the users of the space.

[5] Remaining sound of the total sound in a given location and a given situation when the specific sound is supplied.

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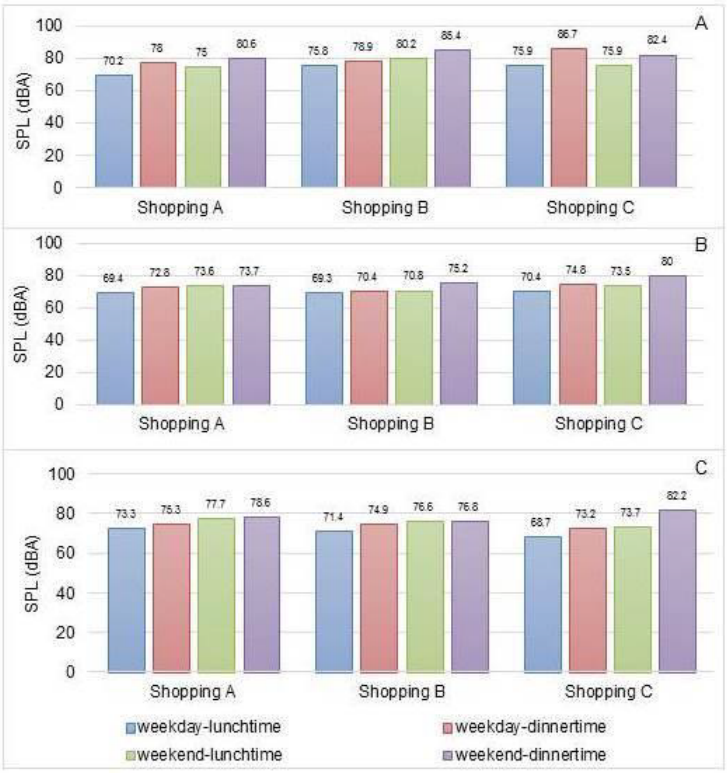
FIGURE 2 – Sound Pressure Levels – SPL (dBA) found in the three shopping centers. A)Gameroom; B) Circulation and; C) Food court.



Source: the authors (2023).

Recently, Shopping B was renovated in its structure, intending to promote greater sound absorption in the environment. One of the changes made was replacing the floor with a more porous concrete. In addition, the polypropylene chairs were replaced by wooden chairs, maintaining the tables with a granite top. Stations were also added between the tables, where it is possible to use high stools made of wood. These changes contributed to sound absorption, acting as acoustic barriers.

Despite this, the results obtained in this study show that structural reforms have not yet been sufficient to maintain good acoustic quality. The food court of Shopping B, despite maintaining sound levels close to and/or even less intense than in other scenarios, being between 71 and 77 dB(A) (Figure 2C), presents itself as the most reverberant environment, since in its double height and ceiling there is the application of glass without proper acoustic treatment.

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The perception in this environment is that an "island of noise" effect propagates toward the tables, making this the most unpleasant permanence among the studied environments.

Sound pressure levels in the food courts of Shopping C remained stable, although they increased on weekends during dinnertime (Figure 2C). It should be noted that the materials used in the food court in shopping mall C help in sound absorption due to the use of tables and chairs with wood finishes, as it is a porous material. In addition to the use of this material in furniture, there is also wood applied on fixed barriers that build islands between this furniture as well as on islands with padded seats, which helps in absorption and thus reduces reverberation in the environment.

On weekends, especially at night, noise levels were higher (Figure 2A, 2B and 2C), which is due to the population's greater demand for leisure environments. This results in different noise levels depending on the day and time these locations are frequented.

3.3 Speech Interference Level - SIL

During the sound measurements, the sound pressure levels were collected at the various frequencies audible by the human being. From this collection, the SIL calculation of the measured points was performed. These are expressed in Table 7

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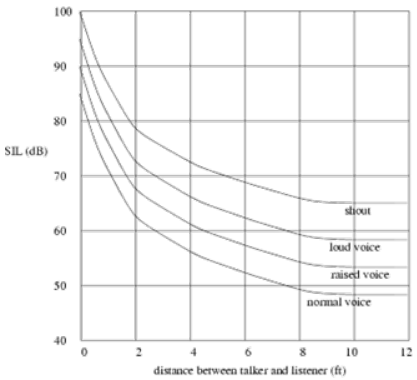
TABLE 7 – Levels of Interference in Speech – SIL of the measured points, in dB(A), in three Shopping centers in Maceio, AL.

Measured points	Weekday - lunch	Weekday - dinner/ leisure	Weekend – lunch	Weekend - dinner/leisure
		Shopping A		
Games	57.8	62.8	62	69.1
Circulation	56.3	60.3	60.9	61.3
Square	61.1	63	64.3	66.7
		Shopping B		
Games	64	67	66.1	73.4
Circulation	56.9	57.8	58	64.8
Square	59.8	62.2	63.7	63
		Shopping C		
Games	59	59	63.5	70.3
Circulation	58.2	58.2	60.8	67
Square	55.2	55.2	60.5	69

Source: the authors (2023).

In addition, from the calculation of the SIL level, it can be seen that, comparing the 36 measurements performed, 23 of these exceed 60 dB(A), while three of these presented sound pressure levels above 70 dB(A), thus being in disagreement with the recommendations of the level considered normal for conversation (Figure 3) (Mehta *et al*., 1999).

FIGURE 3 – Levels of Interference in Speech - SIL as a function of source-receptor distance.



Source: adapted of Mehta *et al*. (1999).

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The current study highlights the lack of data and reference standards for sound pressure analysis in commercial locations, such as the various spaces found in a shopping center. It would be beneficial to include recommendations of this type in standards such as NBR 10152 (Associação Brasileira de Normas Técnicas, 2017), which deals with indoor noise levels.

According to the Ministry of Labor rules, it is necessary to act when the sound pressure level exceeds 80 dB, as established in NR-01 (Brasil, 2020). This includes the management of occupational risks, administrative measures, the use of Individual Protection Equipment (IPE) and the performance of occupational examinations related to noise. The nocturnal scenarios on weekends in the three locations studied are the noisiest due to the high demand of the population for these environments for leisure and food on these days and times.

4 Final Considerations

Based on the results obtained, especially in the levels of LAeq, it is possible to verify that the main source of noise in the measured environments is the sound produced by the people present, influenced by the variety of sounds such as store calls and game machines. In addition, the presence of speakers in each case contributed to the creation of a disharmonious environment, resulting in an overload of sound sources.

Although all LAeq level measurements are within the tolerance limit of 85 dB(A) established by NR-15, they exceed the values recommended by NBR 10152 for restaurants, which is 40 to 50 dB(A). In the food courts, the values were from 68 to 82 dB(A), while in the circulation areas they were between 69 and 80 dB(A). In gaming environments, the variation ranges from 70 to 87 dB(A), exceeding the limit of NR-15.

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In the face of sound pressure levels greater than 85 dB, the use of IPE becomes mandatory in these locations, regardless of technical actions aimed at reducing these noisy levels, or other engineering actions to enclose, minimize or attenuate this physical agent.

After the analyzes, it is concluded that it is necessary to adopt more effective measures to mitigate noise in all the environments studied. The precariousness observed in the studied environments is mainly due to the materials found and the absence of elements that absorb and diffuse sound in the environment.

For proper acoustic treatment, it is recommended to use features such as acoustic clouds, tensioned ceilings, acoustic walls and partitions, baffles and absorbent floors. The presence of absorbent materials found in Shopping B and C are still not enough to ensure an acoustically healthy environment.

In addition, it is possible to observe the lack of research and regulatory standards in relation to noise present in work environments, in commercial areas, where employees are exposed to a workload of 8 hours per day.

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