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Urban Noise as an Environmental Impact Factor in the Urban Planning Process

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Abstract

This research focuses on an analysis of the perception of urban noise in the daily lives of the residents of two different areas: (1) a residential neighborhood and (2) a city center, respectively, considering (1) an acoustically ideal urban environment and (2) an acoustically polluted urban environment. To this end, a random sample of individuals from both areas was asked to fill out a questionnaire. Sound pressure levels were also measured in each of the evaluated areas. The World Health Organization (WHO) considers a quiet area as one in which the measured sound pressure level is up to 55 dB(A). The average measured sound pressure levels were 53.5 and 72.9 dB(A), respectively, in the quiet area and in the area considered acoustically polluted. Data were subjected to a multivariate factor analysis. The main complaints reported by the interviewees were as follows: headache, irritability, poor concentration and insomnia. Interviewees in the city center stated that street traffic noise was the main source of annoyance, while the residents of the residential area stated that the main source of discomfort was air traffic noise.

Keywords: noise pollution, urban environment, environmental noise, sound pressure level, noise annoyance

1. Introduction

Research has revealed a significant association between environmental noise and deleterious effects on humans [1, 2]. According to Babisch et al. [3]: "66–70 dB(A) is to be regarded as the threshold of health impairments which can be verified by epidemiological methods at population level." Based on the abovementioned data, Maschke [4] states that: "from the point of view of preventive medicine, an equivalent sound pressure level of Leq = 65 dB(A) should be

maintained as the limiting value of exposure to traffic noise during the day. For residential areas, the World Health Organization recommends a maximum equivalent continuous sound level, Leq, of 55 dB(A) [5].

A comparative analysis of subjective evaluations (population responses) by inhabitants of areas of high and low noise incidence, such as a residential area and the downtown area of a city, with noise levels lower and higher than 65 dB(A), respectively, may provide information indicating that there are potential negative effects on the inhabitants' health [3]. This is a research strategy that allows one to correlate perceived organic effects and individual sensitivity to noise in urban regions, and it can be corroborated by objective evaluations, that is, sound-level measurements [6].

Some studies have been conducted in Brazil, whose findings were obtained by using questionnaires and through measurements of sound levels [7, 8]. This chapter includes all the statistical development necessary to explain the reaction of the interviewees in relation to noise, which was not presented in Paz et al. [8]. In this context, the purpose here is to make a comparative analysis not only of the results obtained with the values established by Curitiba Municipal Law No. 10,625 and those recommended by the WHO, but also of the perception of urban noise in the daily lives of the residents of a residential area and a downtown area of mixed occupation in the city of Curitiba, Brazil [5, 9]. The idea is to characterize two distinct situations: (1) an acoustically ideal urban environment and (2) an acoustically polluted urban environment.

Evaluations were performed based on the responses to a questionnaire that was presented to a random sample of residents from each area. The data were classified and treated statistically by means of multivariate factor analysis. Equivalent continuous sound levels, Leq, were also measured in each area and expressed in dB(A).

2. Materials and methods

This study analyzes the quality of environmental noise in Curitiba, Brazil, based on questionnaires and measurements, comparing two distinct urban areas—a residential one and the city's downtown area.

Initially, a representative portion of each area was selected for the application of the questionnaire. The questionnaire was filled out by the residents of each area between 7 a.m. and 7 p.m., in the presence of the researcher. The quantitative perception of noise was determined using the Likert Scale, ranging from 0 to 6, with the following criteria: (0) no increase, (1) very little, (2) a little, (3) average, (4) a lot, (5) intense and (6) extreme. Multiple choice questions were used to determine the interviewees' qualitative perception of noise, such as awareness of the population about the issue of urban noise, identification of the occurrence of psychophysiological disorders and determination of which types of sources cause the greatest annoyance. The questionnaire included information about the interviewees' identification and registration.

The survey sample was selected randomly and comprised 105 interviewees, 63% men and 37% women, in the residential neighborhood of Jardim das Américas and 130 interviewees, 52% men and 48% women, in the downtown area – Centro. The criterion for selection was individuals over 16 and less than 70 years of age.

The data on noise perception were treated statistically using the STATISTICA 5.0 software, and multivariate factor analysis of the data was chosen in view of the characteristics of the samples of the two populations. The extraction method used here was the Principal Components method, and the criterion to determine the number of factors was the "Kaiser criterion," that is, the number of factors equal to the number of eigenvalues greater than or equal to 1 (**Figures 1** and **2**).

The first step consisted in ascertaining the level of awareness of the population regarding the problem of urban noise. The next step involved classifying the degree of annoyance generated
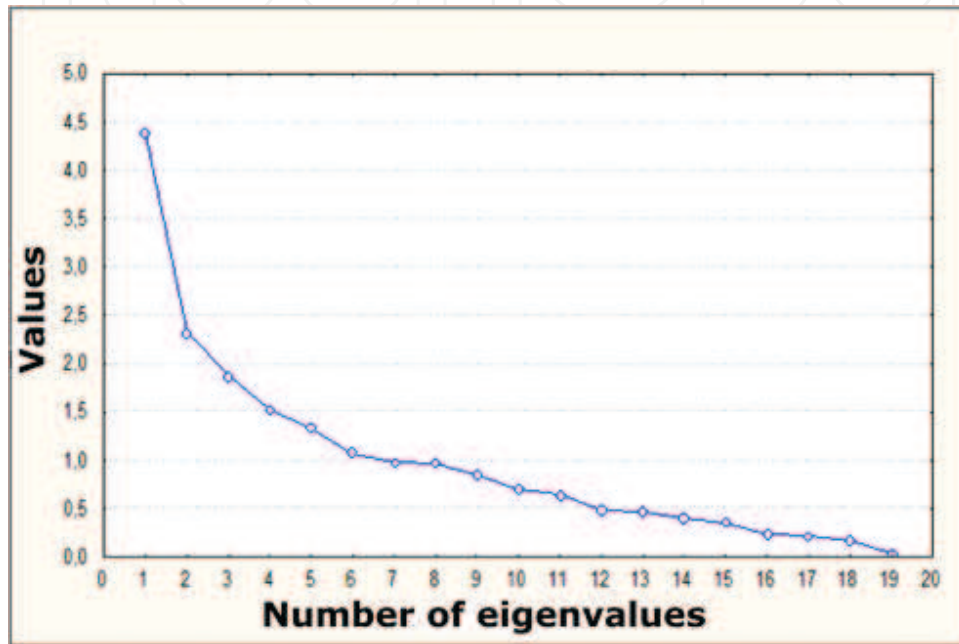

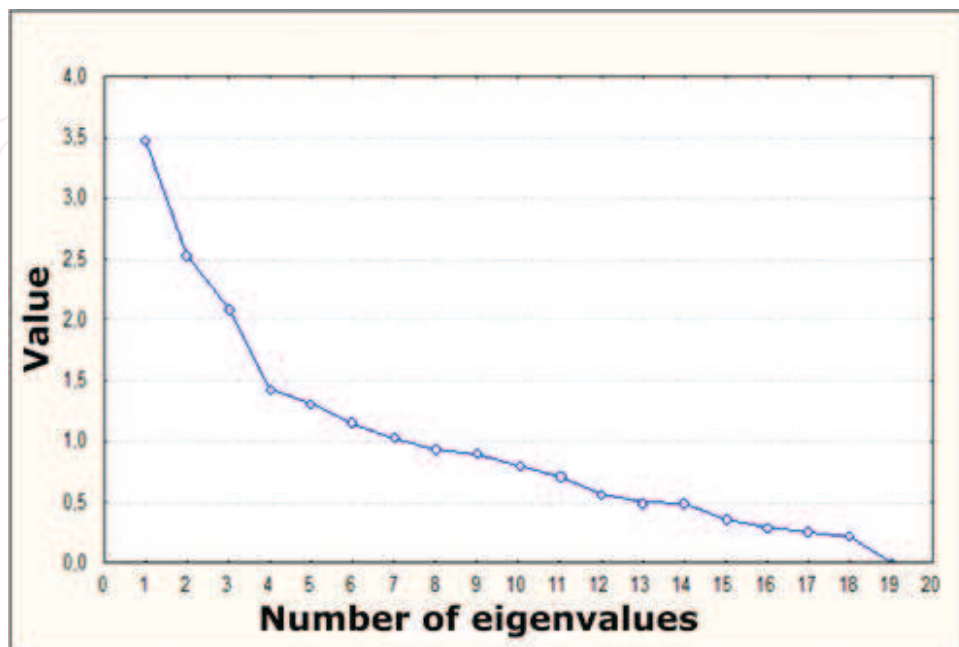**Figure 1.** Eigenvalues for the residential neighborhood.

Figure 2. Eigenvalues for the downtown area.

by urban noise. Note that this step involved only two variables, so each variable was subjected to a descriptive univariate statistical analysis.

The following step consisted in a multivariate factor analysis of the observations obtained by the Principal Components method, using varimax normalized rotation to rotate the axes.

The subjective evaluation began with 19 variables for the two populations. The first step was to identify the interdependence of the variables for each population based on the statistical tests for the F-Normal distribution (**Figures 3** and **4**). This procedure revealed that the variables showed a normal distribution at a 5% level of significance, that is, the observations were well grouped. After checking the normality conditions of the two populations, a factor analysis was performed to identify the factors, that is, unobservable variables with low linear correlation, which would group the highly observable variables correlated into groups (factors).
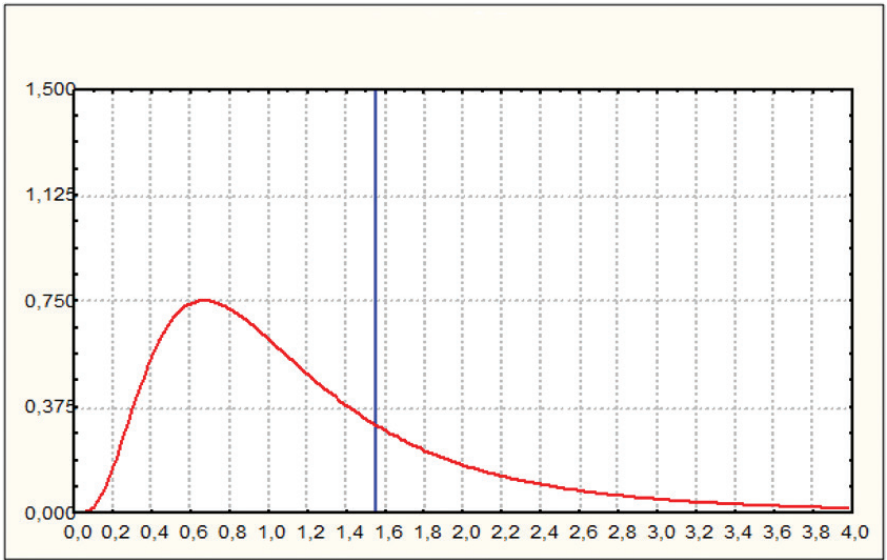
Figure 3. F-normal distribution for the downtown area.
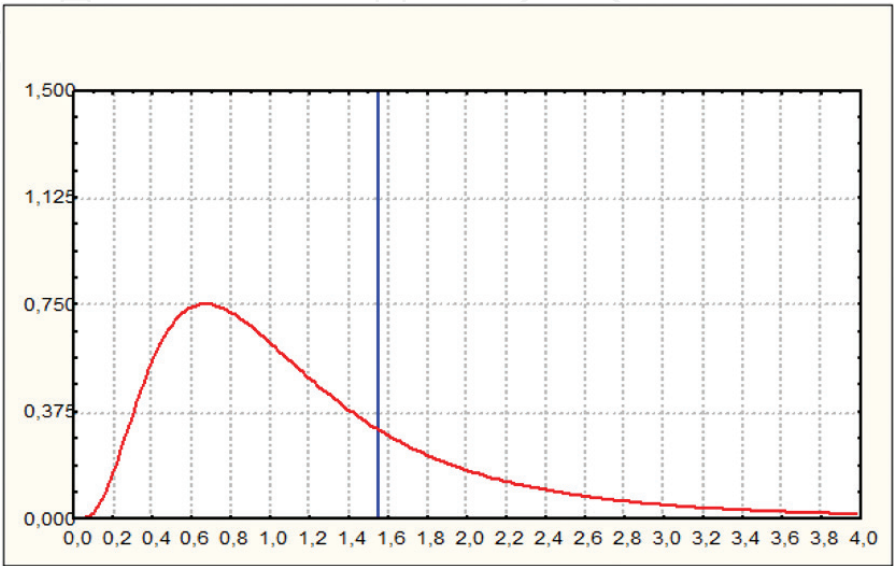
Figure 4. F-normal distribution for the residential neighborhood.

It should be noted that the variables were given the literal algebraic designation (X1, X2, …, X19) as a function of the input conditioning of the observations in the analysis software.

This factor analysis involved the following steps:

• Descriptive statistical calculations of the variables (mean, standard deviation, mode frequency, minima and maxima, median, mode and variance) (**Tables 1** and **2**).

• Calculation of Correlation Matrices

• Calculation of Covariance Matrices

• Calculation of Eigenvalues (**Table 3**)

• Calculation of factorial weights, commonalities and specific variance, first without rotation of the axes, and then with varimax normalized rotation. **Tables 4** and **5** list the results of the first two parameters, with rotated axes. **Table 6** presents the commonalities of the residential and downtown areas.

• Calculation of the residual matrix and of the factor score coefficients, with and without rotation of the axes;

• Calculation of the factor scores;

• Classification and Analysis of the factors.

Var.	Note	Mean	Min.	Max.	Var.	Std. Dev.	Median	Mode	Mode freq.
Residential area									
X1	104	1.98	0	6	1.49	1.22	2	2	30
X2	104	2.30	0	5	1.86	1.36	2	2	29
X3	104	1.44	0	5	1.71	1.31	1	0	31
X4	104	2.49	0	6	1.65	1.28	2	2	32
X5	104	1.93	0	6	2.04	1.43	2	Multiple	—
X6	104	0.11	0	1	0.10	0.31	0	0	93
X7	104	0.54	0	1	0.25	0.50	1	1	56
X8	104	0.61	0	1	0.24	0.49	1	1	63
X9	104	0.12	0	1	0.10	0.32	0	0	92
X10	104	0.21	0	1	0.17	0.41	0	0	82
X11	104	0.12	0	1	0.10	0.32	0	0	92
X12	104	3.51	0	6	3.73	1.93	4	6	21
X13	104	1.84	0	6	4.16	2.04	1	0	43
X14	104	2.74	0	6	3.24	1.80	3	3	28
X15	104	3.00	0	6	3.46	1.86	3	4	24
X16	104	1.66	0	6	2.42	1.56	1	0	31
X17	104	1.83	0	5	2.09	1.44	2	0	27
X18	104	0.31	0	1	0.22	0.46	0	0	72
X19	104	0.67	0	1	0.22	0.47	1	1	70

Table 1. Results of descriptive statistical analysis of residential areas.

Var.	Note	Mean	Min.	Max.	Var.	Std. Dev.	Median	Mode	Mode freq.
Downtown area									
X1	130	**3.**32	6	6	1.86	1.36	3	3	45
X2	130	4.02	0	6	1.58	1.26	4	4	51
X3	130	2.87	0	6	2.69	1.64	3	3	37
X4	130	4.16	0	6	1.76	1.33	4	4	47
X5	130	2.81	0	6	1.80	1.34	3	3	43
X6	130	0.19	0	1	0.16	0.40	0	0	105
X7	130	0.43	0	1	0.25	0.50	0	0	74
X8	130	0.63	0	1	0.23	0.48	1	1	82
X9	130	0.12	0	1	0.10	0.32	0	0	115
X10	130	0.26	0	1	0.19	0.44	0	0	96
X11	130	0.12	0	1	0.10	0.32	0	0	115
X12	130	4.22	0	6	1.91	1.38	4	5	41
X13	130	1.27	0	6	3.52	1.88	0	0	77
X14	130	1.53	0	6	3.13	1.77	1	0	57
X15	130	3.42	0	6	2.59	1.61	4	4	47
X16	130	2.01	0	6	2.29	1.51	2	Multiple	—
X17	130	1.55	0	6	2.19	1.48	1	0	41
X18	130	0.30	0	1	0.21	0.46	0	0	91
X19	130	0.70	0	1	0.21	0.46	1	1	91

Table 2. Results of descriptive statistical analysis of downtown areas.

Factor	Eigenvalue	Total variance%	Accumulated eigenvalue	Accumulated%
Residential area				
1	4.38	23.06	4.38	23.06
2	2.32	12.20	6.70	35.26
3	1.87	9.86	8.57	45.12
4	1.53	8.05	10.10	53.17
5	1.33	7.01	11.43	60.18
6	1.07	5.64	12.51	65.82
Downtown area				
1	3.47	18.28	3.47	18.28
2	2.52	13.26	5.99	31.55
3	2.09	11.01	8.08	42.55
4	1.43	7.52	9.51	50.07
5	1.30	6.87	10.82	56.94
6	1.15	6.03	11.96	62.97
7	1.03	5.41	12.99	68.39

Table 3. Eigenvalues for the residential and downtown areas.

Residential area						
Var.	F1	F2	F3 to F6			
	Temporal perception	Atypical noise	Sources and complaints			
X1	0.81	0.10	0.03	−0.09	0.10	−0.04
X2	0.80	0.07	0.09	0.01	0.18	−0.01
X3	0.61	−0.25	0.19	0.07	−0.28	0.28
X4	0.88	0.03	0.12	0.05	0.04	−0.06
X5	0.59	−0.13	0.31	0.37	−0.22	0.18
X6	0.10	0.01	−0.14	0.15	0.14	0.71
X7	0.00	−0.05	−0.02	0.03	0.74	0.04
X8	−0.05	−0.22	0.26	−0.12	0.37	0.45
X9	−0.09	0.07	0.11	0.82	0.00	0.28
X10	0.25	0.06	−0.03	0.47	0.21	−0.29
X11	−0.15	0.16	−0.30	−0.13	−0.71	−0.18
X12	0.24	0.12	0.56	0.18	0.29	−0.34
X13	−0.05	0.06	0.83	0.05	0.06	−0.02
X14	0.29	0.18	0.54	−0.31	−0.12	0.15
X15	0.14	−0.12	0.80	0.10	0.08	−0.14
X16	0.29	−0.03	0.54	0.00	0.11	0.35
X17	0.37	−0.19	0.36	−0.19	0.30	−0.37
X18	−0.02	−0.96	0.00	−0.03	0.11	0.01
X19	0.02	0.96	0.05	0.04	−0.09	−0.04
% Expl.	0.35	0.18	0.45			

Table 4. Factorial weights for the residential neighborhood.

As shown in **Tables 4** and **5**, seven main factors were identified for the downtown area and six main factors for the residential neighborhood as a function of the linear correlation between the observable variables. The factors were grouped into three main statistical indicators, called "Temporal Perception," "Perception of Atypical Noise" and "Sources and Complaints."

The indicators explain about 98% of the phenomenon of urban noise pollution for the residential neighborhood and about 81% of the phenomenon for the downtown area, demonstrating that the model created here is a close simulation of reality. This is confirmed by the analysis of the commonalities, as well as by the analysis of the other parameters such as residual matrix and specific variance. Sound levels were measured during the daytime (7 a.m. to 7 p.m.) at

Downtown area						
Var.	F1	F3	F4 to F7			
	Temporal perception	Atypical noise	Sources and complaints			
X1	0.73	−0.09	−0.01	0.13	0.00	−0.15
X2	0.77	0.15	−0.17	−0.02	−0.09	0.02
X3	0.52	−0.07	0.13	0.09	0.43	0.11
X4	0.81	0.09	−0.03	0.01	0.14	−0.06
X5	0.51	0.09	0.32	−0.13	0.27	0.37
X6	0.10	0.03	0.14	−0.08	0.71	−0.16
X7	−0.07	0.03	0.11	0.18	0.19	0.19
X8	0.08	0.06	0.19	0.82	−0.04	0.13
X9	0.04	0.08	−0.20	0.15	0.67	0.07
X10	0.10	0.10	−0.02	0.03	0.06	−0.88
X11	0.05	−0.15	−0.01	−0.65	−0.19	0.19
X12	0.45	−0.12	0.02	0.50	0.05	−0.15
X13	−0.05	−0.02	0.88	0.09	−0.16	0.05
X14	−0.01	0.11	0.84	0.14	0.14	0.00
X15	0.37	0.15	0.01	0.21	−0.12	0.13
X16	0.08	−0.18	0.21	−0.05	0.16	−0.17
X17	−0.05	−0.10	0.11	−0.02	0.00	−0.13
X18	0.04	0.98	0.04	0.05	0.05	−0.05
X19	−0.04	−0.98	−0.04	−0.05	−0.05	0.05
% Expl.	0.27	0.16	0.38			

Table 5. Factorial weights for the downtown area.

different points in each area (downtown and residential neighborhood), making a total of 60 measurements (**Figures 5** and **6**), using Brüel & Kjaer 2238 sound-level meter. Evaluator 7820 software was used to obtain an average value of the equivalent sound level of each area, based on the histograms of the mean equivalent levels as a function of time (**Figures 11** and **12**). The measurements were taken following the guidelines of the Brazilian Standard NBR 10151 [10], which assesses community and neighborhood noise levels.

Var.	For six factors (Residential area)	For six factors (Downtown area)
X1	0.68	0.60
X2	0.69	0.72
X3	0.64	0.51
X4	0.81	0.70
X5	0.68	0.60
X6	0.58	0.58
X7	0.56	0.56
X8	0.47	0.75
X9	0.77	0.52
X10	0.41	0.80
X11	0.69	0.64
X12	0.61	0.51
X13	0.71	0.83
X14	0.54	0.80
X15	0.71	0.58
X16	0.51	0.66
X17	0.57	0.70
X18	0.93	0.97
X19	0.93	0.97

Table 6. Commonalities.

Figure 5. Measurement points in the downtown area (Centro).

Figure 6. Measurement points in the residential neighborhood (Jardim das Américas).

3. Results and discussion

The analysis of the questionnaires clearly revealed the interviewees' opinions about the presence of urban noise. Of the total sample of interviewees, 95.5% in the downtown area and 98% in the residential neighborhood believe that noise can be harmful to health. Sensitivity to increasing noise levels was expressed by 78.25% of the interviewees as "increased" and "greatly increased" in the downtown area, and 71.7% between "increased a little" and "increased" in the residential neighborhood, as indicated in **Figure 7**.

Three statistical indicators were identified in the multivariate factor analysis of the data, namely: "Temporal Perception," "Perception of Atypical Noise" and "Sources and Complaints."

The indicators explain about 98% of the phenomenon of urban noise pollution for the residential neighborhood and about 81% of the phenomenon for the downtown area, demonstrating that the model created here closely represents reality. An analysis of the statistical indicator of Temporal Perception revealed that 61.5% of the interviewees from the downtown area and 57.15% from the residential neighborhood perceived an increase in noise levels, particularly during the week in the morning and afternoon, and during weekend nights (**Figures 8** and **9**).
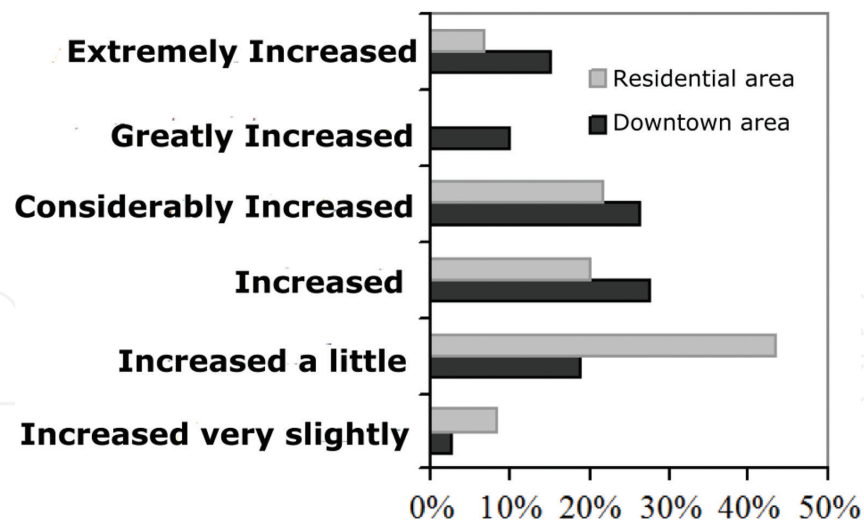
Figure 7. Perception of increasing noise.
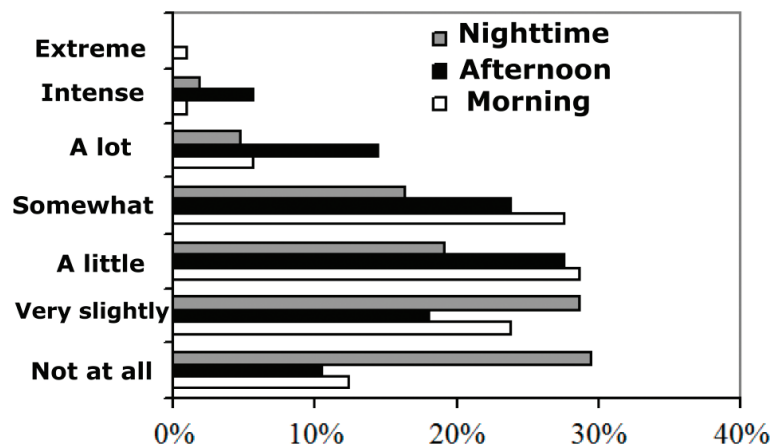
Figure 8. Temporal perception of noise in the residential neighborhood.
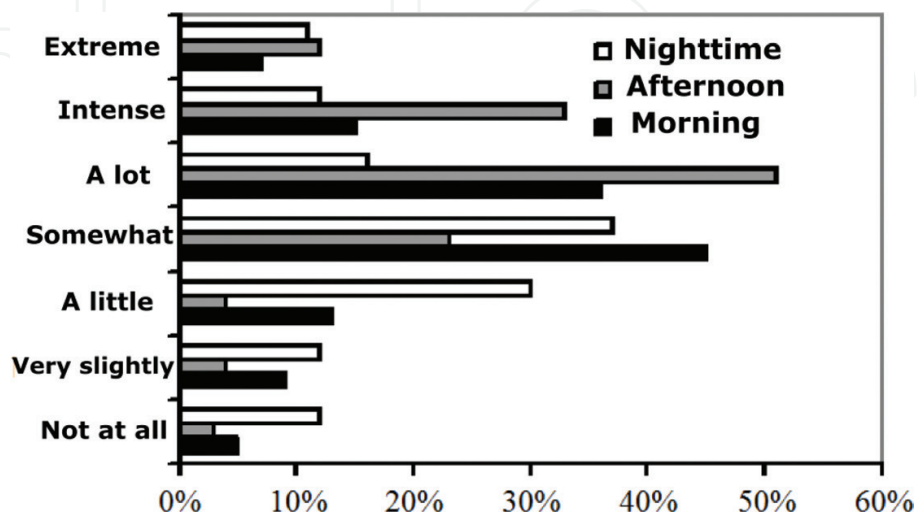

Figure 9. Temporal perception of noise in the downtown area.

An analysis of the statistical indicator of Perception of Atypical Noise (sources of annoyance in other buildings; perception of sporadic noise sources) revealed that 70% of the interviewees downtown and 30% of interviewees in the residential area feel disturbed by noise from atypical sources.

The indicator Sources and Complaints, which comprised the largest number of correlated variables in the study, pertained to information about existing and/or perceived types of noise sources in the urban environment, and about the occurrence of the main psychophysiological complaints described by the interviewees. In the two areas under study, the most frequent complaints about the effects of urban noise were irritability and poor concentration (**Figure 10**). These results are comparable to those found by Paneto et al. [11], which addressed the theme "*Relationship between urban noise and the health of users of public spaces….*" Paneto et al. [11] applied a questionnaire to 375 people, and the main reactions to noise exposure were as follows: irritability (58%), difficulty to concentrate (42%), sleeping disorders (20%) and headaches (20%). In addition, traffic noise was considered the most annoying type of noise (**Figure 11**). Also for Paneto et al. [11] the main source of noise is traffic noise. According to Paneto et al. [11], "*possible measures to mitigate urban noise including planning vehicle flows, reducing vehicle traffic speed, improving street pavement conditions, inspecting vehicles to determine their noise emissions, and establishing permits for heavy vehicles to*
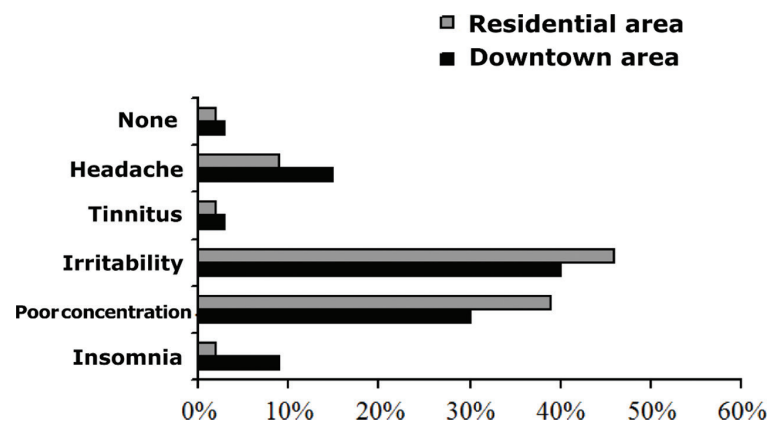

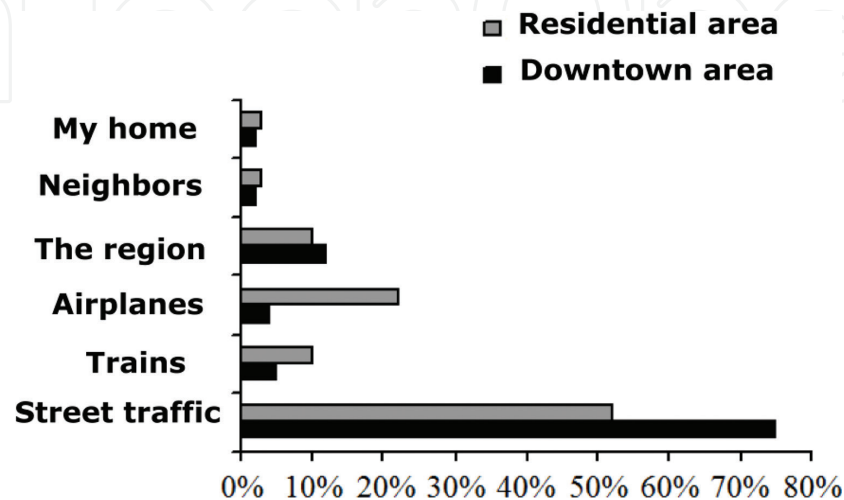**Figure 10.** Main complaints described by the interviewees.

Figure 11. Perception of noise source that causes the greatest annoyance.

circulate in the vicinity of preset areas times." Paneto et al. [11] also stated "*suggest that interventions could be carried out to favor pedestrians, such as the construction of acoustic barriers at strategic locations, and the zoning of squares and parks, to render these public environments healthier*".

It should be noted that the second most annoying type of noise reported in the residential neighborhood was airplanes. This is explained by the fact that the residential neighborhood of this study lies in an aircraft landing flight path.

The mean measured equivalent sound levels, Leq, were 72.9 dB(A) in the downtown area and 53.3 dB(A) in the residential neighborhood, indicating a significant difference between the two areas in question, as illustrated in **Figures 12–14**.
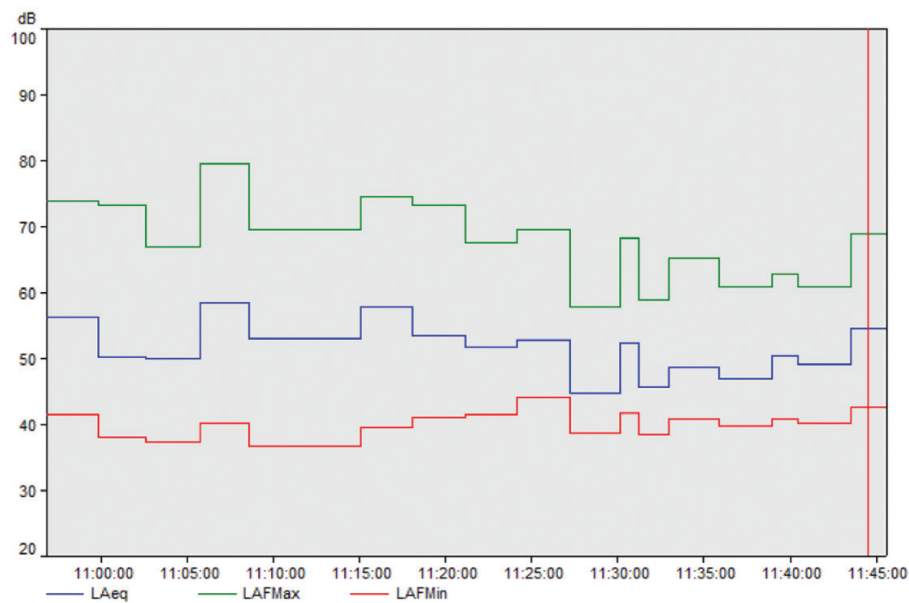
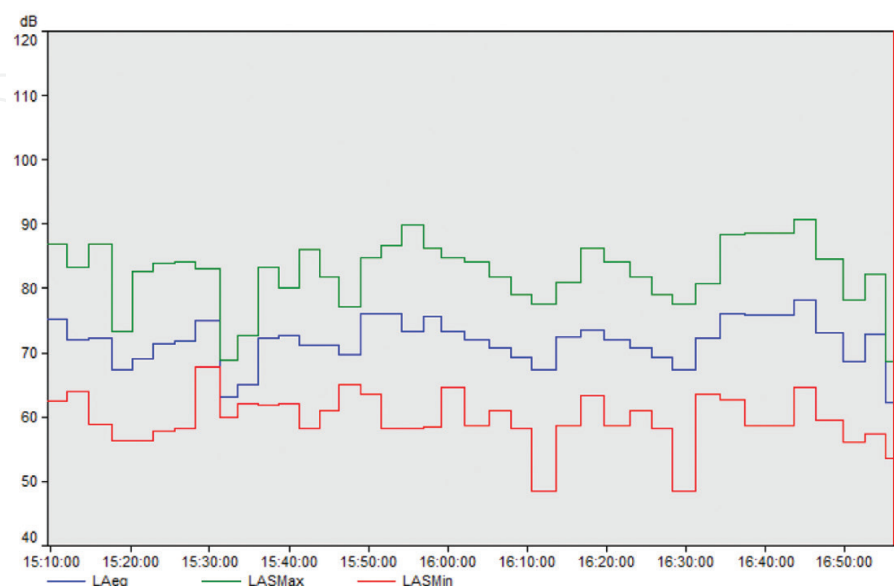**Figure 12.** Histogram of measurements taken in the residential neighborhood.

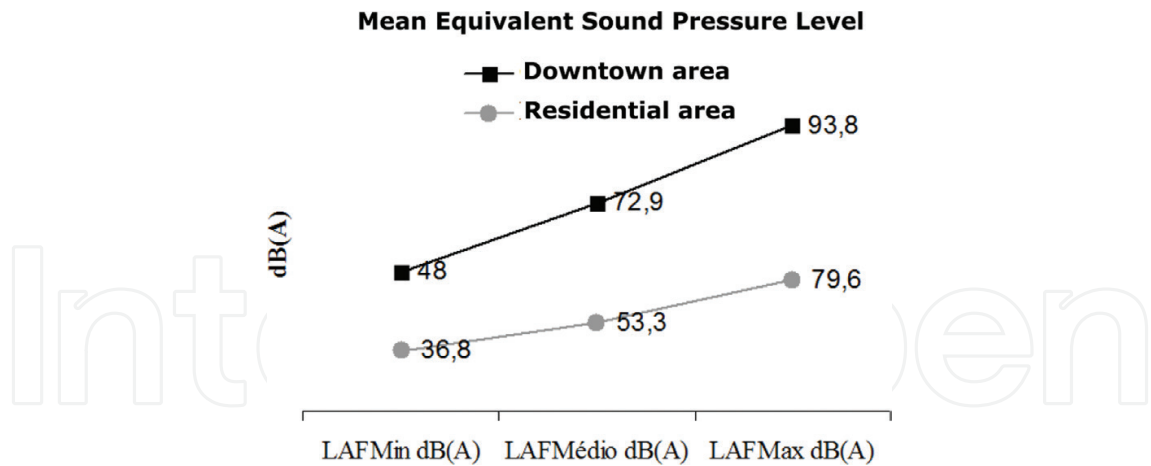**Figure 13.** Histogram of measurements taken in the downtown area.

Figure 14. Mean equivalent sound pressure levels (minimum level L_{AFMin}, mean level L_{AFMean} and maximum level L_{AFMax}).

Urban noise pollution is present in virtually every country in the world. Noise pollution studies are therefore needed to find solutions to improve the quality of life in cities.

Urban noise has often been cited as an environmental impact that affects society negatively, which is why it has been analyzed with greater care in reports submitted to government environmental agencies. The results presented in this chapter showed a detailed explanation of how to characterize noise in a community. This characterization can assist in decision-making for urban planning, environmental control and environmental licensing [12].

The problem of noise pollution should be considered a priority in environmental planning, in order to improve urban soundscapes and education on environmental health so as to increase people's well-being and quality of life in cities. Any intervention in an urban environment that leads to variations in a determinant parameter or variable of the noise emission process should be assessed predictively and proactively in the medium and long-term, in view of its possible effects on the environment where it is implemented. Hence, scientific tools must be developed to measure the impact of noise pollution in urban areas [12].

4. Conclusion

The answers to the questionnaires indicated that most of the population of this study is aware of the harmful effects of noise exposure, and this level of awareness in the two areas is considered high, that is, 95.5% in the downtown area and 98% in the residential neighborhood.

The responses to the questionnaires revealed that 78.25% of the interviewees in the downtown area and 28.3% of those interviewed in the residential neighborhood believed that the level of urban noise was increasing. This belief was corroborated by the measured mean sound pressure levels, which were 53.5 dB(A) in the residential neighborhood and 72.9 dB(A) in the downtown area, respectively.

In the two urban areas of this study, the most commonly reported effects of noise exposure were irritability and poor concentration. In addition, street traffic noise was cited as the most annoying type of noise.

A comparison was made between the parameters adopted for reference, that is, 55 and 65 dB(A), respectively, established for the areas of this study by Curitiba Municipal Law No. 10.625, and the level recommended by the World Health Organization of 55 dB(A) for residential areas. This comparison revealed that the urban noise levels in the residential neighborhood were acceptable, while those in the downtown area were unacceptable, in terms of acoustic comfort.

The sound levels measured in the residential and downtown areas indicated that the former can be classified as an acoustically controlled zone in relation to the mixed zone—the downtown area. Hence, it was concluded that the residential neighborhood can be classified as an ideal zone and the downtown area as an acoustically polluted zone. These distinct areas, with their specificities, can therefore be used as factors of reference for other evaluations.

The methodology and the results obtained and presented in this chapter are of interest to professionals working in the areas of environmental management of cities, in architecture, urban design, in environmental noise control, and so on. Finally, it is of great importance for urban managers in their decision-making, seeking to find solutions to the problems of urban planning, in what concerns the control of environmental noise pollution.

Acknowledgements

Conflict of interest

The authors declare that they have no conflict of interest.

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