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2aNS10. Sound and noise in urban parks

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The main goal of this work is to study the soundscape of city gardens and urban parks using a sample of ten sites in Oporto, Portugal to analyze their soundscape through the acoustic characterization of the park's exterior and interior noise levels (LAeq, LA10, LA50 and LA90) and by a socio-acoustic survey to the visitors to check their perception of acoustic quality. The measurements showed gardens/parks with interior noise levels from 47 to 61 dB(A) (with exterior noise levels up to 67 dB(A)). The difference between exterior and interior LAeq was between 3 and 19 dB. The gardens with lower noise levels are the largest and out of downtown. An "acoustic" classification for gardens/urban parks is proposed regarding their noise "isolation" capacity and their acoustic ambiance. Old 1990 measurements allow for the comparison of the acoustic evolution in the last 21 years. The socio-acoustic survey concludes that Oporto's city parks are visited mostly by an elderly male population that regards these places as sites of gathering and to practice some physical activity rather than as an acoustic retreat. They seem accustomed to the dominant sound sources, classifying those spaces as pleasant and quiet, even when noise is over acceptable limits.

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1 Introduction

The objectives of this work are the characterization and analysis of the sound levels in the most significant city gardens and urban parks of Oporto (the second largest town in Portugal with 238,000 inhabitants and 42 km^2) using two approaches [1]:

- *In situ* sound level measurements to acoustically characterize the gardens' interior and exterior environment;
- Questionnaires to visitors of the parks to assess their perceived acoustical quality and tranquility achieved in those places.

To understand the evolution of noise levels in the last 21 years, a comparison with measurements done in 1990 is presented.
This study also formulates an "acoustical" classification for city gardens and urban parks regarding their aptitude for "urban noise isolation" and to provide a calm and serene environment to their visitors.

2 Methodology

2.1 Parameters

The acoustic parameters used in this study were L_{Aeq}, L_{A10}, L_{A50} and L_{A90}. These statistical descriptors were used especially to allow a comparison with results measured on 1990 and to analyze the evolution in the last 21 years of the Oporto's gardens. Measurements were done in the exterior and in the interior of ten gardens/parks. The sound level variation from the outside to the inside of the parks in each of those parameters was also analyzed.
The equipment used for the *in situ* measurements was a *Brüel & Kjær* 2236 sound level meter with a B&K 4188 microphone (Figure 1).

2.2 Questionnaires

A system of personal interviews to visitors within the parks was used to obtain concrete answers to subjective matters relating to the noise exposition (Figure 2). The visitors were randomly approached during their activity in the parks and asked to be a volunteer in this study. Not to allow any bias, the visitors were not told that the main goal was to assess the soundscape in the park. Instead, they were informed that the inquiry was about the environmental quality of that park, giving a much more general idea of the objective.
The questionnaire used had ten closed questions and one open question, divided in three sections. The first section is composed by fields regarding the identification (genre and age); the second regards the sound and environmental quality of the park and the third involves the type of visitor concerning his/her park use and a final evaluation.
The second section of the questionnaire is based in a normalized methodology [2] tested by Pereira [3], with adaptations for this case, and consisted of eight closed questions (nºs 1-5 and 7-9) in a Likert scale and one open question (nº 6):

- Question 1: *Are the sounds that I hear in this park expected?*
- Question 2: *Do I like the sounds that I hear?*
- Question 3: *Does the volume of these sounds bother me?*
- Question 4: *Do I consider this garden/park agreeable?*
- Question 5: *Do I consider this garden/park tranquil?*
- Question 6: *Identify three sounds that you hear in this garden/park.*
- Question 7: *What brings you to this garden/park?*
- Question 8: *What is the aspect of this garden/park that is the most important for you?*
- Question 9: *How do you rate this garden/park?*

Question 2 wanted to identify the visitors' opinion about the aesthetic quality of the sound they heard to know if these sounds should or should not be preserved in the local soundscape. In question 6, all the main sounds identified by the visitors are registered to be listed and grouped concerning their reference aspects based on Schafer's classification [4]: a) traffic, b) human sounds, c) natural sounds, d) bird sounds, e) equipments and machinery, f) music, g) traffic lights and h) other. Question 7 wants to identify the motives that brought the visitors to the park. In question 8 the visitor was invited to classify the importance of some aspects of the garden (choosing only one) as vegetation, clean air, cleanness, safety and silence. Finally the visitor was asked in question 9 to give an overall opinion of the garden.

2.3 Procedures for *in situ* measurements

The following procedures were followed for the *in situ* measurements:

- Meteorological conditions were taken into account not using rainy days or when the wind speed was above 5 m/s;
- To compare with *in situ* measurements done in 1990 (in six gardens) a similar time schedule was used in this study (between 15 h and 18 h);
- To chose the measuring positions within the parks two perpendicular axes were traced, if possible, oriented by the North-South lines, getting four points in the limits of the garden/park and two in the interior;
- Measuring intervals of about 10 to 20 minutes were used to get representative values of the chosen parameters;
- Each measurement position was chosen not to interfere with the visitors and at least 3.5 m from any reflective surface;
- The sound level meter was placed in each position with a tripod at a height of 1.2 to 1.5 m (Figure 1).

3 Sample

The selection of gardens/urban parks used in this study followed a criterion of being representative in size and in use by the public (Table 1 and Figures 1 to 4). They were chosen based on their placement and significance within the town including the desire to include, in the sample, places with small and large areas, within and outside the downtown zone, that is, where diverse parameters could be studied as urban density, proximity with large road highways and the multiplicity of uses that those spaces bring to the city.

Table 1 - City gardens and urban parks studied
(*Jardim* = Garden; *Praça* = Square, *Quinta* = Farm; *Parque* = Park).

City garden/urban park full name (short name)		Area (ha)	Parish (within Porto county)	Type of perimeter
1	Jardim Teófilo Braga (*República*)	1.3	Cedofeita	free (no fence or other limit)
2	Praça do Marquês de Pombal (*Marquês*)	0.8	Santo Ildefonso	free (no fence or other limit)
3	Praça Mouzinho de Albuquerque (*Boavista*)	3.1	Cedofeita	free (no fence or other limit)
4	Jardim de João Chagas (*Cordoaria*)	1.6	Vitória	free (no fence or other limit)
5	Jardim de São Lázaro (*S. Lázaro*)	0.7	Bonfim	totally fenced
6	Jardim da Casa de Serralves (*Serralves*)	18.0	Lordelo do Ouro	totally walled
7	Parque Ocidental da Cidade (*Ocidental*)	83.0	Aldoar	partially walled
8	Quinta do Covelo (*Covelo*)	8.0	Paranhos	with wall and metallic fence
9	Parque de São Roque (*S. Roque*)	4.5	Bonfim	totally walled
10	Praça Francisco Sá Carneiro (*Velásquez*)	3.0	Bonfim	free (no fence or other limit)

Figure 1 (left): Measurement in Garden 1 (*República*, East side).
Figure 2 (right): Visitors in Garden 1 (*República*) answering the questionnaire.

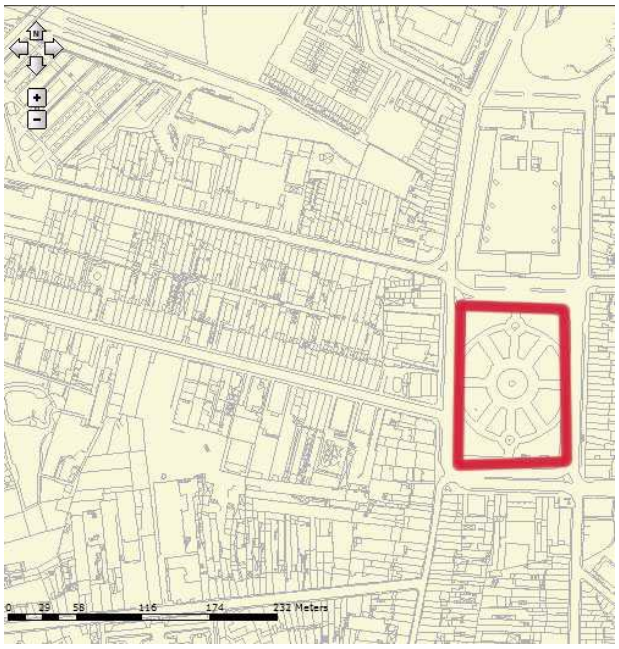


Figure 3 (left): Urban area of the Municipal Plan with Garden 1 in red [adapted from 5]
Figure 4 (right): Aerial photo of Garden 1 (*República*) [6].

4 Results and analyses

4.1 *In situ* measurements

4.1.1 Measured values

Using the L_{Aeq} values measured in the exterior and interior of the gardens studied it is possible to find an effective reduction in the interior L_{Aeq} compared with the gardens' exterior, in all cases studied (Figures 5 and 6). This can be justified by the fact that the involved sound sources are in the gardens' periphery making possible a decrease of sound pressure level (even if small) with the progressive increase in distance from the noise source.
In Figure 5, concerning the surrounding noise levels (exterior of the gardens/urban parks), it is possible to see that the most noisy environment was measured around Garden 3 (*Boavista*), followed by the exterior of Park 7 (*Ocidental*), with the highest L_{Aeq} value (67 dB). The quietest was the exterior of Garden 9 (*S. Roque*) with the lowest L_{Aeq} (54 dB).
Having the noisiest environment around Garden 3 (*Boavista*) can be justified by the urban net in that place because it is a major round square (with a circular turnaround) with main streets getting to and out of that square (an important commercial area that canalizes a large amount of compact traffic in and out of it).
For Park 9 (*S. Roque*), its urban environment is characterized as a residential area with low traffic, which justifies the differences found in noise levels.

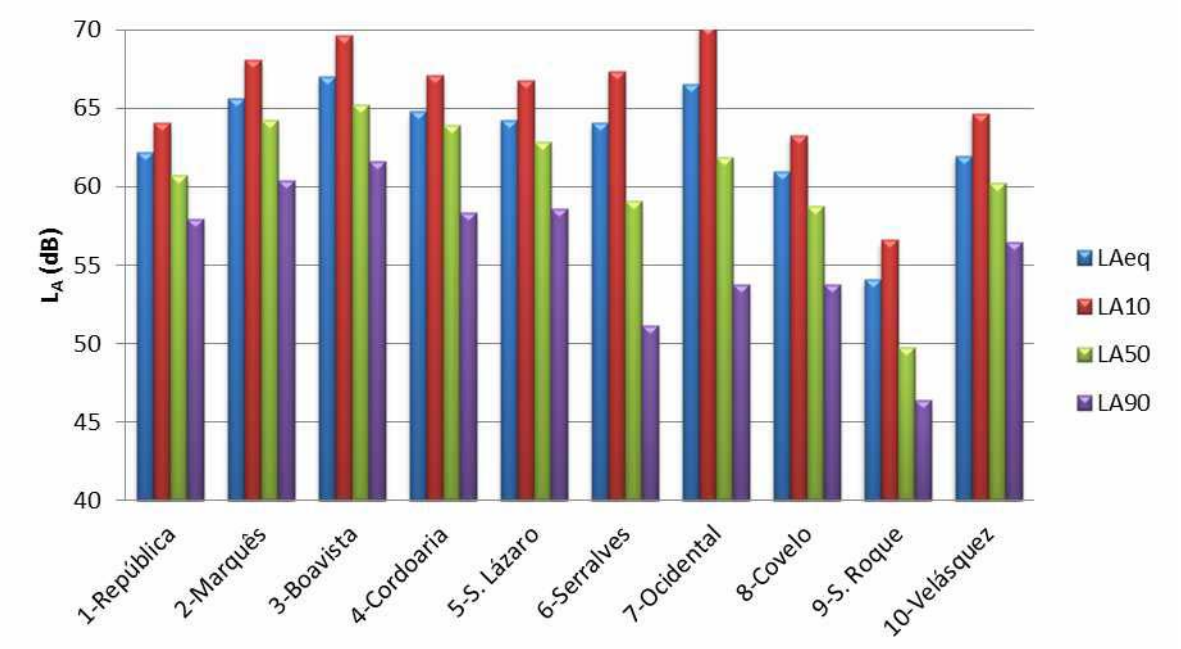


Figure 5 - Average sound levels values (L_{Aeq}, L_{A10}, L_{A50} and L_{A90}) measured in the exterior of ten gardens/urban parks of Oporto, Portugal.

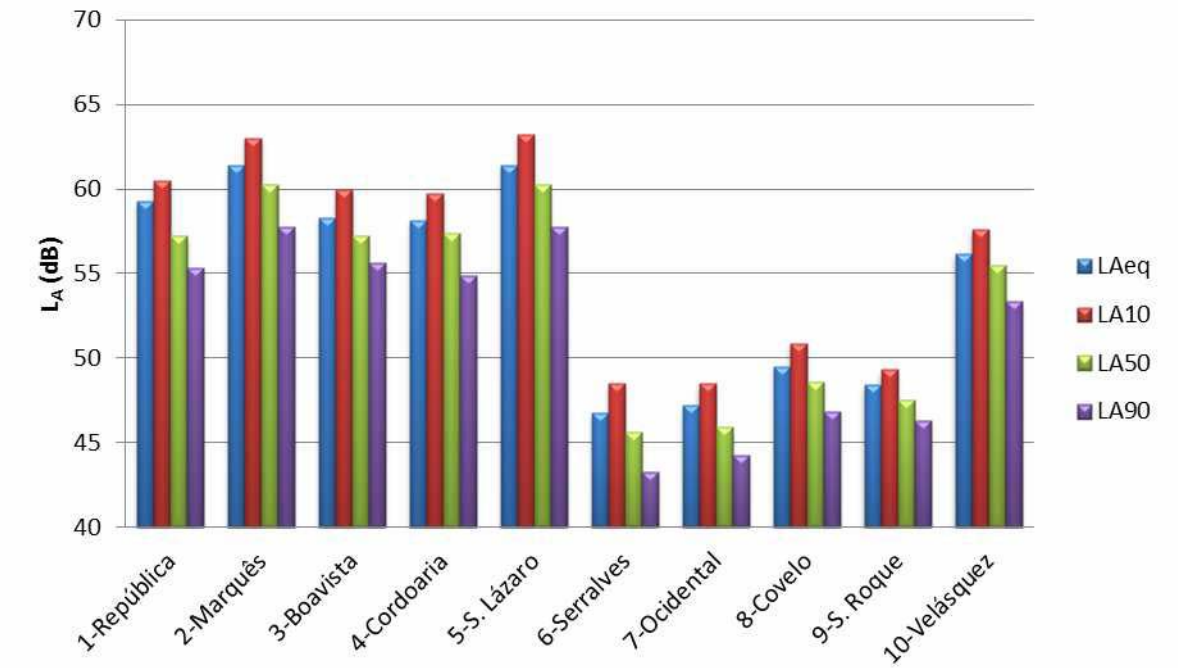


Figure 6 - Average sound levels values (L_{Aeq}, L_{A10}, L_{A50} and L_{A90}) measured in the interior of ten gardens/urban parks of Oporto, Portugal.

The most noisy interior in the tested gardens (Figure 6) were numbers 2 and 5 with L_{Aeq} of 61 dB (*Marquês* and *S. Lázaro*) that can be justified by their reduced garden size and by the heavy concentration of visitors that intensely use those places. The quietest garden was number 6

(*Serralves*) with L_{Aeq} of 47 dB. This value can be justified by the extensive garden area (18 ha) and its insertion within a residential area distant from large traffic roads.
It is possible to observe a maximum variation, on average, of about 15 dB(A) in the various parameters, between the most and the least noisy parks.

4.1.2 Difference values

To analyze how gardens/parks can decrease noise, regarding the emergence of extreme noise levels (L_{A10}) to the background levels (L_{A90}), the comparison of their measured exterior and interior values was done.
Regarding exterior values (Figure 5) a difference between those two parameters' values (L_{A10} - L_{A90}) of about 10 dB was found on average. The largest difference (17 dB) was registered in Park 7 (*Ocidental*) and the smallest (6 dB) in Garden 1 (*República*). These differences, measured outside the gardens, can be explained, when high, by the road traffic having a small number of vehicles that makes the background noise relevant; when those differences are small they indicate that the road traffic is more intense, masking the background noise.
In the gardens' interior (Figure 6) the difference between the extreme noise levels (L_{A10}) and the background levels (L_{A90}), is about 5 dB on average. The largest difference (6 dB) was measured in Garden 5 (*S. Lázaro*) and the smallest (3 dB) in Park 9 (*S. Roque*). These differences are small; however, the difference in Garden 5 (*S. Lázaro*) is higher due to the concentrated presence of visitors. The smallest can be justified by the stability and regularity in the measured values because the garden has less visitor use and is placed within a residential area without heavy traffic roads. The values in other gardens are close to the average (5 dBA). It can be expected that without major noisy sound sources in a garden's interior, this will also be the average difference between its extreme levels (L_{A10}) and background noise levels (L_{A90}).
In three urban parks a great reduction capacity was verified by a difference larger than 9 dB between exterior and interior L_{Aeq} values: Park 7 (*Ocidental*) (19 dB), Park 6 (*Serralves*) (17 dB) and Park 8 (*Covelo*) (11 dB). The gardens with smaller areas show a smaller variation between the exterior L_{Aeq} and the interior L_{Aeq}, such as Garden 1 (*República*) (3 dB), Garden 2 (*Marquês*) (4 dB), Garden 4 (*Cordoaria*) (7 dB), Garden 5 (*S. Lázaro*) (3 dB) and Garden 10 (*Velásquez*) (6 dB).
Two gardens must be distinguished: numbers 1 and 5 (*República* and *S. Lázaro*) show the smallest noise level variation between the exterior and the interior (ΔL_A = 3 dB). This can perhaps be explained for garden 5 (*S. Lázaro*) by its elevated terrain level relative to the surrounding street with the largest traffic (on average about 1 m), and by the large traffic volume that the surrounding streets have. The fact that within the gardens several groups of retired persons are playing cards together is also a factor that can increase the overall L_{Aeq} value in the interior of those gardens.

4.1.3 Gardens behaving as noise barriers

Analyzing the noise stability in the gardens' interiors, with intrusions of emerging noise (from the background noise level) that can have a perturbing effect in its calm soundscape it is possible to check that gardens 6, 7 and 8 (*Serralves*, *Ocidental* and *Covelo*) are the ones that show the largest noise level variations (Table 2). This indicates that these spaces have the potential of reducing those higher intensity and short duration noises. Although the three parks are surrounded by high traffic roads, their land extension seems to allow the reducing of those

noises. It is not possible to disregard also the existence of walls in the perimeter of these urban parks functioning, even if partially, as noise barriers.
In the opposite extreme are gardens 1, 2 and 5 (*República*, *Marquês* and *S. Lázaro*) which reveal an incapacity of significantly reducing the peak noise levels due to their reduced land extension (less than 1.4 ha), proximity to traffic roads and the inexistence of walled perimeters that could attenuate the outside noise. Note the zero value achieved in the variation regarding the background noise (L_{A90}) in park 9 (*S. Roque*) justified by the relatively constant acoustic environment in its exterior and interior, caused by its insertion in a residential area with low traffic volume.

Table 2 - Variations in the average values of: L_{Aeq}, L_{A10} (extreme values), L_{A50} (median) and L_{A90} (background), in the exterior and interior of gardens/urban parks in Oporto, Portugal.

Gardens/Parks		**ΔL_{Aeq} (dB) ($=L_{ext.} - L_{int.}$)**	**ΔL_{A10} (dB) ($=L_{ext.} - L_{int.}$)**	**ΔL_{A50} (dB) ($=L_{ext.} - L_{int.}$)**	**ΔL_{A90} (dB) ($=L_{ext.} - L_{int.}$)**
1	*República*	2.9	3.6	3.5	2.6
2	*Marquês*	4.3	5.1	4.0	2.6
3	*Boavista*	8.7	9.6	7.9	6.0
4	*Cordoaria*	6.6	7.4	6.5	3.5
5	*S. Lázaro*	2.9	3.5	2.6	0.9
6	*Serralves*	17.3	18.8	13.5	7.9
7	*Ocidental*	19.3	21.8	16.0	9.5
8	*Covelo*	11.4	12.4	10.1	6.9
9	*S. Roque*	5.6	7.3	2.3	0.0
10	*Velásquez*	5.8	7.0	4.8	3.1
Arithmetic average		*8.5*	*9.7*	*7.1*	*4.3*

4.2 Questionnaires

4.2.1 Results

The sample has 85 inquiries done to visitors of the gardens (66% male) with 26% between 46 and 65 years old and 36% older than 65 years old. This reveals that the common user of the gardens/parks in Oporto is usually adult (only 14% were younger than 18 years old).
When questioned if the sounds that they heard were expected (question 1) the majority (66%) answered that they agreed largely or totally, and only 2% said they were indifferent. 13% disagreed (Figure 7).
When asked if they liked the sound that they heard (question 2), the majority answered that they agreed (49%), while others showed some indifference (13%) or even some form of annoyance (21%) (Figure 8).
When questioned if the "volume" of these sounds caused annoyance (question 3), the majority disagreed strongly (32%) or totally (21%), 16% showed indifference and the remaining 25% were annoyed in some degree by those sounds (Figure 9).
When questioned about the tranquility given by the park (question 5), the visitors agreed mildly (19%) or a lot (52%), and 14% disagreed in some form (Figure 10).

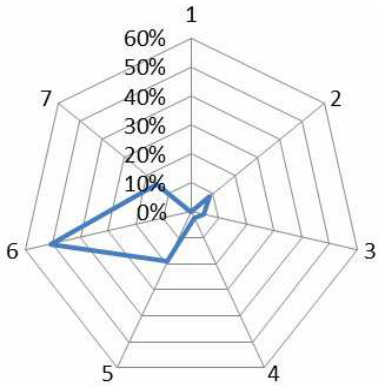


Figure 7 - Answers to: *The sounds that I hear in this park are expected.*
(1: *Disagreement*, 7: *Agreement*)

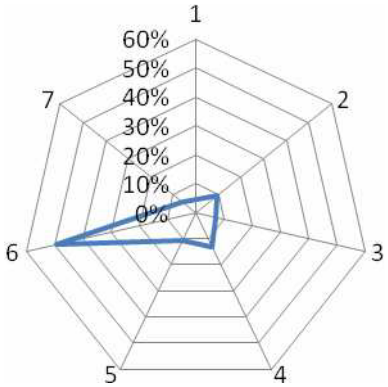


Figure 8 - Answers to: *I like the sounds I hear.*
(1: *Disagreement*, 7: *Agreement*)

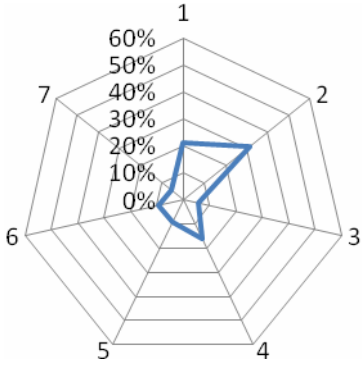


Figure 9 - Answers to: *The volume of these sounds bothers me.*
(1: *Disagreement*, 7: *Agreement*)

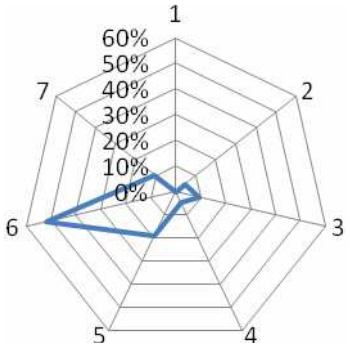


Figure 10 - Answers to: *I consider this garden/park tranquil.*
(1: *Disagreement*, 7: *Agreement*)

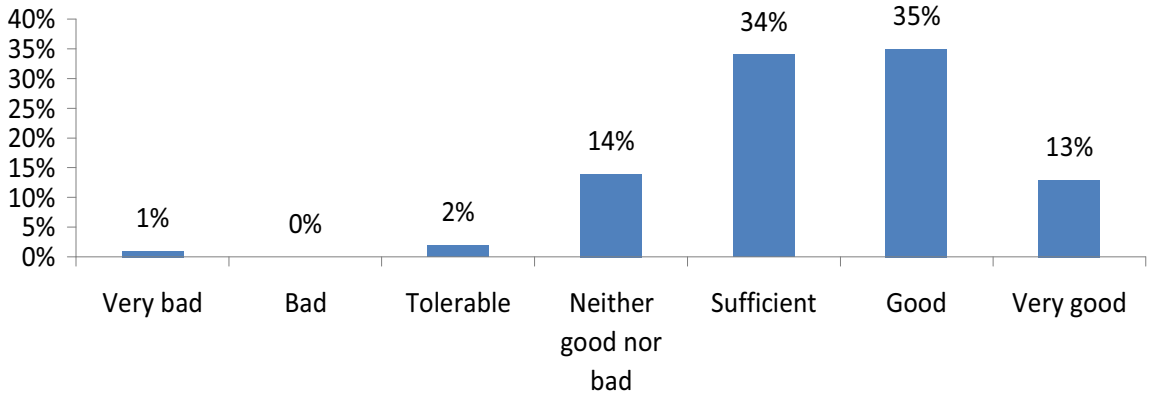


Figure 11 - Distribution of the visitors' global evaluations of the gardens/parks.

Visitors were asked to identify three sounds in the garden. Using Schafer classification [3] those sounds are grouped as: *traffic* (34%), *human sounds* (28%), *natural sounds* (10%), *birds* (24%), *machinery* (2%), *music* (0%), *signals* (2%) and *others* (1%).

When questioned about the reason of his/her visit to that garden/park, they answered whether it was for *recreational purposes* (53%), for *sport* (17%) or for the *vegetation* (17%).
Questioned about which aspect of the garden/park they consider is the most important, *clean air* appears in front (32%), followed by *vegetation* (28%) and the *neatness* of the garden (24%). Only 2% of the visitors remarked that they were looking for *silence* when visiting the garden/park.
Finally a global evaluation of the park was asked from *Very bad* to *Very good*. Almost half (48%) think the garden/park is *Good* or *Very good* and only 1% answered *Very bad* (Figure 11).

4.2.2 Analysis

The answers of the 85 visitors in this study reveal a greater rate of agreement with the pleasant aspects of the soundscape than with those that are not enjoyable. Usually visitors are more concerned with the social aspects than with those regarding the soundscape. It can be understood that traffic noise (the most remarked in question 6) is identified as an integral part of the sonorous landscape of the Oporto gardens by a minority that feels annoyed, and by a majority that expect to find that noise when visiting the parks.
In regard to the composition of the soundscape, in all the gardens the noise from traffic was identified as being the one with most answers (34%). Nevertheless a large part of the visitors (53%) were not annoyed by that interference in the soundscape. In particular a few elderly persons informally confessed that they go to the gardens to see people and hear "noise".
Question 3 asked for opinions about the annoyance of the sound level in the park. The majority (59%) disagreed with the statement that the soundscape volume was a nuisance, while 25% stated that they were annoyed by it. However 60% of the gardens showed average interior L_{Aeq} values higher than the WHO proposed limit of 55 dB [7].
A comparison of the questionnaire data and the measurement results show that park visitors have a certain tolerance to high sound levels. Only 25% of the inquired stated that the sound "volume" was, in any way, a nuisance (*a little*, *too much* or *totally*), while 59% disagreed with the nuisance statement. Another point that reinforces this idea and justifies the lack of nuisance is the evaluation that the visitors did of the soundscape regarding agreeability and tranquility: 84% agreed that the garden/park was agreeable and 81% established that the garden/park was tranquil. These results confirm that, in the presence of an agreeable sound, like birds singing for instance, the level of annoyance with the sound level in the soundscape is relatively low. So, the presence of agreeable sounds like natural sounds can considerably enhance the acoustic comfort even when the sound level is rather high [3, 8]. Another factor that could have influenced perception of the soundscape volume is the visual landscape, especially the vegetation, noted by 28% as one of the main reasons to visit the park. Earlier studies showed that the presence of vegetation provokes a more pleasant condition [4, 8] acting as an element capable of reducing the feeling of tiredness caused by high sound levels.
With the answers to question 6 it is evident that even in areas like public gardens, traffic noise is clearly heard and accounts for 34% of all stated noises in the parks. However it was verified that these noises do not dominate the soundscape as they do in the majority of urban environments because the inquired were capable of identifying other sounds. This demonstrates the diversity of sounds that are part of the soundscape and the intelligibility of those environments where sounds can be clearly heard. In other words, the surrounding traffic noise does not mask other

sounds present in those parks especially birds singing, human sounds and other natural sounds (wind, water, leaves moving and other animals).
Finally, the majority of Oporto gardens' visitors globally evaluates these places as *Good/Very good* (48%) against only 1% with *Bad/Very bad*. The majority felt satisfied with the environment they found in the gardens and urban parks in Oporto.

5 Acoustical classification for city gardens and urban parks

There is no universally accepted criterion for a sound level limit in public city gardens and urban parks. However the WHO recommends a maximum L_{Aeq} value of 55 dB for exterior recreational areas [7].
Dialogue among park visitors is one of the most used activities there. The bibliography refers that speech interference begins about 50 dB(A). It is known that speech in a 45 dB(A) environment is intelligible and also slight intelligible under 55 dB(A).
It is a goal of this classification to reveal the grade of noise isolation that the park has against outside noise. The one with larger noise isolation will have a better sound environment and an overall better acoustic environment if the surroundings are not very noisy.
Combining the two aspects, speech intelligibility and outside noise isolation, the following Garden Classification (*GC*) is proposed to acoustically rate public city gardens and urban parks:

$$GC = \frac{L_{Aeq\,\mathrm{int}} - L_{Aref}}{0.5*\Delta L_{A10} + 0.3*\Delta L_{A50} + 0.2*\Delta L_{A90}} = \frac{L_{Aeq\,\mathrm{int.}} - 45}{0.5*\Delta L_{A10} + 0.3*\Delta L_{A50} + 0.2*\Delta L_{A90}} \qquad (1)$$

where *GC* is the Garden Classification, $L_{Aeq\ int.}$ is the continuous equivalent noise level measured in the garden's interior; L_{Aref} is the reference noise level where speech is totally intelligible (45 dB); ΔL_{A10}, ΔL_{A50} and ΔL_{A90} are respectively the variation in each parameter of the values measured in the exterior and in the interior of the garden ($\Delta L_{An} = L_{An\ exterior} - L_{An\ interior}$). The expression (1) states in the numerator the importance given to speech intelligibility (emergence of interior noise from speech), so the 45 dB value for L_{Aref} is subtracted from the interior L_{Aeq}. The garden will have better speech intelligibility the lower the value of that numerator. The denominator considers the garden's behavior regarding noise isolation from the outside using a weighted average of three noise statistical descriptors (L_{A10}, L_{A50} and L_{A90}). The garden/park will have a better noise isolation the higher that weighted average is.
Table 3 presents the Garden Classification using a subjective rating scale. The garden with a higher GC will have lower speech intelligibility within, and bad noise isolation from outside noises. Using this classification it was possible to form Tables 4 and 5 with the GC for all the ten parks tested.

Table 3 - Garden Classification (*GC*)
Proposed scale for a subjective acoustic evaluation regarding gardens and urban parks.

GC	**≤ 0.2**	**]0.2 - 1]**	**]1 - 2]**	**]2 - 3]**	**> 3**
Classification	*Excellent*	*Very good*	*Fair*	*Bad*	*Very Bad*

Table 4 - Values of the GC parameter's numerator ($\Delta L_{A(int-ref)}$) and denominator ($\Delta L_{A\ weighted\ average} = 0.5*L_{A10} + 0.3*\Delta L_{A50} + 0.2*\Delta L_{A90}$) to calculate the urban Garden Classification *GC*.

Gardens /Parks		$L_{Aeq\ interior}$ (dB)	ΔL_{A10} (ext. - int.) (dB)	ΔL_{A50} (ext. - int.) (dB)	ΔL_{A90} (ext. - int.) (dB)	L_{Aref} (dB)	$\Delta L_{A(int.-ref.)}$ (dB)	$\Delta L_{A\ avg}$ (dB)
1	*República*	59.3	3.6	3.5	2.6	45	14.3	3.3
2	*Marquês*	61.4	5.1	4.0	2.6		16.4	4.3
3	*Boavista*	58.3	9.6	7.9	6.0		13.3	8.4
4	*Cordoaria*	58.2	7.4	6.5	3.5		13.2	6.3
5	*S. Lázaro*	61.4	3.5	2.6	0.9		16.4	2.7
6	*Serralves*	46.7	18.8	13.5	7.9		1.7	15.0
7	*Ocidental*	47.2	21.8	16.0	9.5		2.2	17.6
8	*Covelo*	49.5	12.4	10.1	6.9		4.5	10.6
9	*S. Roque*	48.4	7.3	2.3	0.0		3.4	4.3
10	*Velásquez*	56.2	7.0	4.8	3.1		11.2	5.6

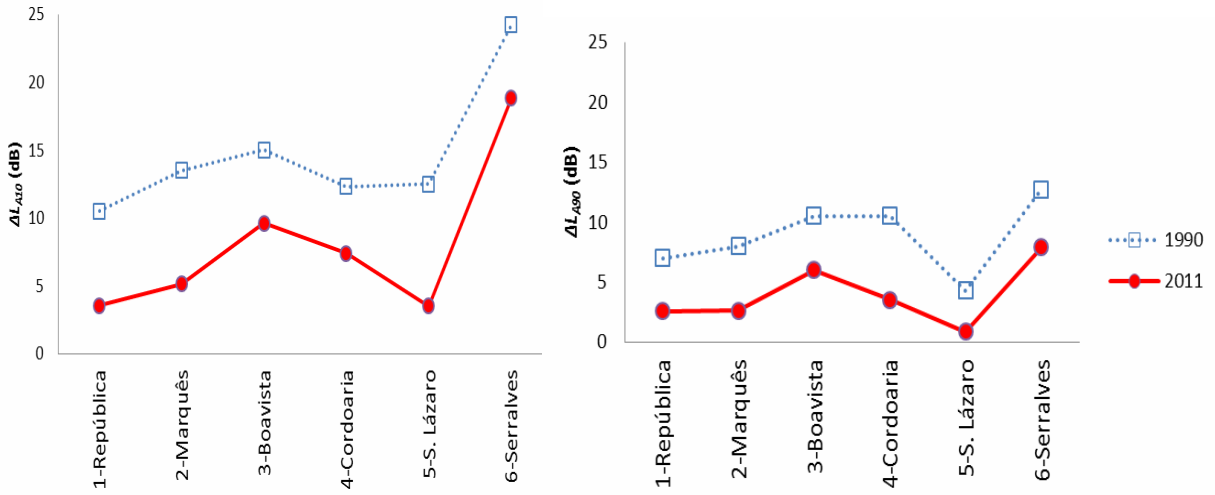
Table 5 - Acoustic Garden Classification (*GC*) for the ten tested Oporto gardens/parks.

Gardens/Parks		*GC*	Acoustic Classification
1	*República*	4.3	*Very bad*
2	*Marquês*	3.8	*Very bad*
3	*Boavista*	1.6	*Fair*
4	*Cordoaria*	2.1	*Bad*
5	*S. Lázaro*	6.1	*Very bad*
6	*Serralves*	0.1	*Excellent*
7	*Ocidental*	0.1	*Excellent*
8	*Covelo*	0.4	*Very good*
9	*S. Roque*	0.8	*Very good*
10	*Velásquez*	2.0	*Fair*

6 Two decades of evolution in the noise levels in Oporto's gardens/parks

A 1990 study analyzed six gardens [9]. To carry out a comparative analysis for 1990 and 2001 data, analogous parameters were measured in 2011, of the outside and inside noise of the gardens, as well as the values of the differences between inside and outside noise L_{A10} and L_{A90} levels ($\Delta L_{A\ n} = L_{A\ n\ exterior} - L_{A\ n\ interior}$) (Figures 12 and 13).

It is possible to observe a decrease in all parameters' differences from 1990 to 2011. On average, decreases of 7 dB in the ΔL_{A10}, and 5 dB in the ΔL_{A50} or ΔL_{A90}, were recorded. These decreases are an important indicator of the noise evolution in this type of urban structure, since it measures a loss of capacity, by the urban gardens of Oporto, of noise reduction of extreme (L_{A10}), median (L_{A50}) and background (L_{A90}) noise levels, from the exterior, despite the external noise having been reduced, in general in those 21 years.



Figures 12 (left) and 13 (right) - Comparison of the variation of the exterior L_{A10} values (left) and L_{A90} values (right) regarding the interior values ($\Delta L_{A\,n} = L_{A\,n\ exterior} - L_{A\,n\ interior}$), measured in 1990 (superior blue dotted line) with the measured in 2011 (inferior continuous red line).

7 Conclusions

The noisiest gardens are the smallest and are located in the most central areas of the city, with exterior noise levels of 62 to 67 dB(A). The soundscape is dominated by road traffic noise while the presence of "urban" birds is less significant in these spaces.

The less noisy gardens are the largest and are located in more peripheral areas of the city, in residential areas and with roads where traffic exerts less influence on its soundscape especially due to its large size.

The gardens with the highest interior *LAeq* were #2 and #5 (*Marquês* and *S. Lázaro*), both with 61 dB(A), justified by their smaller size, leading to greater proximity to traffic roads, and the presence of a high concentration of visitors on leisure. The quietest was #6 (*Serralves*) (47 dBA), due to its location in a residential area, a considerable extent and the walled perimeter serving as an acoustic barrier. Here a high sound level variation (ΔL_{Aeq}) from exterior to interior (17 dBA) was observed. The highest variation (exterior-interior) was measured in #7 (*Ocidental*) (19 dBA) and the lowest in #1 (*República*) and #5 (*S. Lázaro*) (3 dBA), registering a maximum variation, on average, of 15 dB(A) in the various measured parameters between the noisiest and the quietest garden.

The noise levels in 60% of the tested gardens (#1, 2, 3, 4, 5 and 10: *República, S. Lázaro, Marquês, Boavista, Velásquez* and *Cordoaria*) are higher than recommended by WHO for outdoor spaces (55 dBA), causing possible interference in speech intelligibility and may cause some inconvenience to visitors who wish to communicate or relax in these spaces. There is therefore no evidence to suggest that citizens of Oporto can expect to find a quieter environment in most gardens and urban parks than in their homes. These high noise levels also reflect the size of most parks that are not large enough to significantly attenuate external noise levels.

Inside the gardens, noise levels were lower than those measured outside. The differences in outside and inside *LAeq* sound levels are between 3 and 19 dB(A). This can be explained by the presence of walls functioning as acoustic barriers and/or by the sound attenuation due to the

increase of the distance from traffic roads. It seems possible to create quiet soundscapes in the gardens and parks of Oporto, providing reasonably peaceful environments that are potentially reducers of everyday stress.

Regarding the capacity of noise "isolation" of the gardens from extreme sound levels (L_{A10}) against background noise (L_{A90}), it was possible to detect a mean difference of 10 dBA, with the largest difference (17 dBA) recorded in park #7 (*Ocidental*) and the lowest (6 dBA) in garden #1 (*República*). In the interior, the difference between the extreme noise and the background noise was on average 5 dB(A), and the largest difference (6 dBA) was recorded in garden #5 (*S. Lázaro*) and the lowest (3 dBA) in park # 9 (*S. Roque*).

Using the proposed Garden Classification, garden #6 (*Serralves*) and #7 (*Ocidental*) had the highest rating (*excellent*) and the gardens #1, 2 and 5 (*República*, *S. Lázaro* and *Marquês*) received the lowest rating (*very bad*). These are the smallest and downtown gardens.

A decrease of 5 to 7 dB(A) was detected in all the parameters' differences from 1990 to 2011. This decrease is an important indicator in the study of the evolution of noise in this type of urban structure since it measures a loss in capacity, by urban gardens of Oporto, in reducing noise from the outside, despite a general reduction in their external noise.

The results of the questionnaires conclude that the gardens of Oporto are visited by an aging population, mostly older than 46 years (62%) and predominantly male (66%).

Traffic noise was identified as a constituent of the urban parks soundscape by a minority that feels displeased (21%), with a majority (85%) that expects it when attending these locations and a large percentage (66%) that likes this type of sound in the soundscape. However, largely (53%), visitors do not feel uncomfortable with the interference in soundscape, leading to a habituation.

These results confirm that in the presence of a pleasant sound, like birdsongs, the degree of annoyance for the prevailing sound level in the soundscape is relatively low.

These analyses require a reassessment of the role of urban parks and gardens. These suggest that the ability of urban parks and open spaces in greatly improving the sound quality is limited. However, these spaces must be designed to provide vegetation and social space to citizens in order to facilitate mutual interaction, not excessively stressing the functions of the environmental noise. It was found that the perception of visitors is more related to the green space (vegetation) than with the acoustic environment. The gardens and parks should be designed and managed emphasizing their social functions more than environmental.

REFERENCES

1 Dias, R. A. F. C., *O Som e o Ruído nos Jardins Urbanos do Porto* [*The Sound and the Noise in Urban Gardens in Oporto*]. M.Sc. thesis Environmental Engineering, College of Engineering, U. Porto, Portugal, 2012.

2 Portuguese standard NP 4476:2008, *Acústica. Avaliação da incomodidade devida ao ruído por meio de inquéritos sociais e sócio-acústicos* [*Acoustics. Evaluation of annoyance due to noise by social-acoustic inquiries*], IPQ, Lisbon, 2008.

3 Pereira, M., *Percepção Sonora no Espaço Público: Indicadores de Tolerância ao Ruído na Cidade do Rio de Janeiro* [*Sonorous perception in the Public Space: Indicators of*

Acceptability to Noise in the Town of Rio de Janeiro]. National Meeting of Comfort in the Built Environment, Curitiba, Brazil, 779-786, 2003.

4 Schafer, M., *A Afinação do Mundo, (Soundscapes)*, Ed. UNESPE, São Paulo, Brazil, 2001.

5 *Carta digital de condicionantes da Cidade do Porto* [*Digital map of restraints of the town of Oporto*]: http://sigweb.cm-porto.pt/MIPWEB, accessed on Nov. 23, 2011.

6 *Google Maps*©: http://maps.google.pt, accessed on Nov. 10, 2011.

7 World Health Organization, *Occupational and Community Noise*, WHO fact sheet N258, 2001.

8 Andrade, A. L.; Cruz, R. M.; Paul, S. B., *Construção de escalas de diferencial semântico: medida de avaliação de sons no interior de aeronaves* [*Creating semantically differential scales: Measure of evaluation noise within aircrafts*]. *Scale building.* Aval. psicol., **8**(2) 197-208, 2009.

9 Carvalho, A. P. O., Jardins urbanos da cidade do Porto [*Urban gardens in the town of Oporto*]. Análise acústica. *Colóquio Viver (n)a Cidade*, Lisbon, Portugal, 1990.