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SOUNDSCAPE ASSESSMENT OF THE SCHOOL OF ENGINEERING EXTERNAL AREA AT THE UNIVERSITY OF PISA

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ABSTRACT

According to the EU Environmental Noise Directive, noise pollution mitigation is a key aspect in reducing the harmful consequences of environmental noise exposure. Within national and European regulations, noise exposure management is achieved only on the basis of sound pressure level limits, not covering aspects of sound perception. The soundscape approach provides a new key for the assessment of outdoor areas based on the subjective perception of users. This approach was used to assess the environmental noise exposure of students at the School of Engineering, University of Pisa, Italy. A soundscape analysis was carried out in five measuring points located in the defined area between Pisa San Rossore train station, Piazza del Duomo, and the School of Engineering. A classroom of university students was involved in the assessment of the soundscape and the overall environment of each measuring point, according to ISO/TS 12913-2:2018 procedure. In this article, a preliminary analysis of the main acoustic and psychoacoustic parameters is discussed, obtained by comparing subjective responses and assessments according to standards. As expected, the soundscape technique produces a more in-depth assessment of the perceived quality of outdoor areas, allowing both noise pollution to be countered and sounds to be included if they enrich life sounds.

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1. INTRODUCTION

As defined by Environmental Noise Directive [1], adopted by Italian legislation [2], strategic noise mapping has to be made to avoid, prevent or reduce the harmful effects of exposure to environmental noise, including annoyance. This document has to be produced by large municipalities, and by road, railway and airport managers.

Noise-mapping predicts noise contribution based on A-weighted sound pressure level. In this frame, noise exposure management is achieved only based on sound pressure level limits, not covering aspects of sound perception.

Perception of noise is a multidimensional phenomenon that involves physical characteristics of the sound event, psychoacoustical features of the human ear, and psychological aspects [3]. The possibility to integrate conventional noise mapping methods and soundscape methods has been investigated [4]. The methodology for the assessment of soundscape is defined in the standard ISO 12913-2:2018 [5] and it has been applied in several case studies [6–8], concerning university areas as well [9].

This study analyses the variability of the soundscape in a modestly sized area that can be reached on foot within 15 minutes. Different noise sources – due to railway, road traffic, and human activities – and different land uses – university areas, tourist sites, and connecting infrastructures – result in areas characterised by variable noise and different subjective perceptions. According to ISO/TS 12913-2:2018 [5], subjective impressions and objective psychoacoustics parameters collected in some measurement stations are reported.

2. MATERIALS AND METHOD

The soundscape investigation at the School of Engineering of the University of Pisa was conducted as a field study in accordance with ISO/TS 12913-2:2018 [5]. The measurements were carried out during a predefined soundwalk made by a group of students. During the Soundwalk, participants are guided through a predefined route spaced by listening points in which they are asked to focus their attention to the soundscape around them. At the same time, objective and subjective parameters were measured using an Artificial Head. At each listening point, the duration of the audio recording was 3 minutes. The route was created by analysing the main streets between the School of Engineering and the tourist pathways leading to the city centre and major public transportation stops, replicating the walkable routes most frequently used by students.

2.1 Description of the site

The soundwalk (Fig. 1) was planned to start from the Main Entrance of the School of Engineering of the University of Pisa (Point 1) and proceed to Via Bonanno Pisano (Point 2), the main and busiest street in the area. Following this street, participants were to arrive at Piazza Daniele Manin (Point 3), where the gateway to Piazza del Duomo is located. The route continued to the Tower of Pisa (Point 4), considered to be one of the main stopping and listening points of the tourist path (Fig. 2).

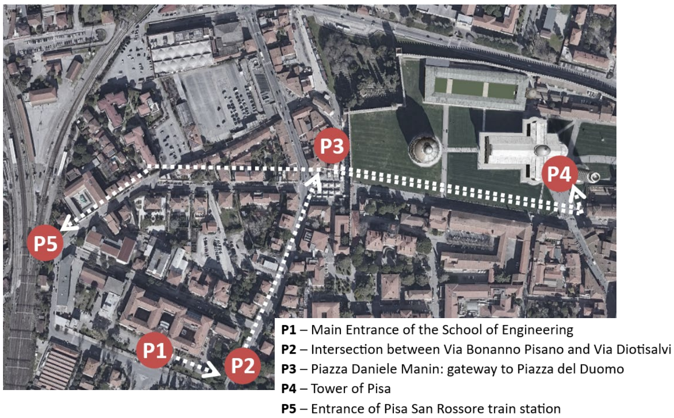

Figure 1. Predefined Soundwalk route and indications of the 5 measurement stations.

Participants were then led backward, back to Via Bonanno Pisano, and then proceed to Via Andrea Pisano. The Soundwalk concluded at one of the entrances to the Pisa San Rossore Train Station (Point 5).

Figure 2. Photo taken at Point 4 during the soundwalk, using the Binaural Sensor Unit Code 1508 by HEAD Acoustics at the Tower of Pisa.

This area is contained within the PCCA (Piano Comunale di Classificazione Acustica – Municipal Acoustic Classification Plan), which is a spatial planning tool that divides the territory into acoustically homogeneous zones (Fig. 3) to which correspond noise limits to be respected (DPCM 14/11/1997).

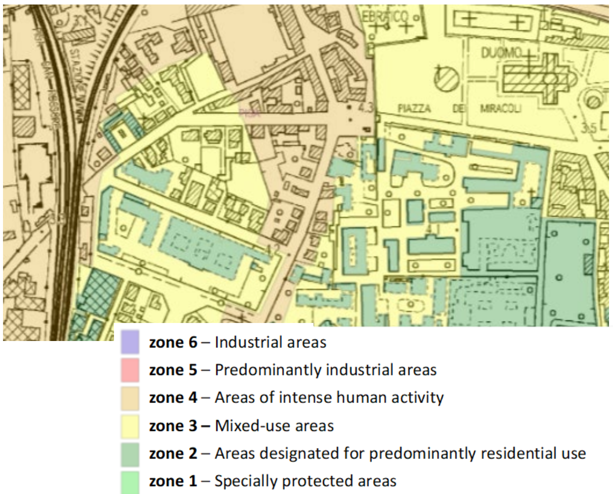

Figure 3. Municipal noise classification plan of the area under investigation.

2.2 Participants

The participants of the Soundwalk were a sample of 18 subjects, most of whom were selected from engineering students at the University of Pisa who regularly visit areas adjacent to the School and who have or had in the past taken the course in Lighting and Applied Acoustics. The soundwalk took place following a seminar on Soundscape topics organised as a training experience during the teaching hours of the Lighting and Applied Acoustics course in the Master's Degree Program in Building Engineering and Architecture. Lecturers and those who helped to organise the Soundscape seminar also participated. Overall, it can be specified that the participants were all regular visitors to the study area and were all familiar with the concepts of acoustics. Out of the 18 participants, 60 percent were women and 40 percent were men, and 83 percent of the entire sample was between 20 and 35. The remaining percentage consisted of 2 subjects aged 36 to 50 and 1 subject aged 51 to 65.

2.3 Data collection

Measurements were conducted on the morning of 2022 Nov. 28th between 11:30 a.m. and 1:30 p.m. in the absence of rain but under overcast conditions. The temperature was between 6° and 10° Celsius.
At the end of the seminar, participants were given instructions on how to conduct the soundwalk and quantitative data were collected for each listening station by administering questionnaires to participants. The questionnaires were prepared in Italian (there were no foreign students present that day) following Method A of ISO/TS 12913-2:2018 [5], containing questions regarding the identification of sound sources and their predominance, perceived affective quality, and assessment and appropriateness of the surrounding sound environment.
The Artificial Head Binaural Sensor Unit Code 1508 by HEAD Acoustics, connected to a laptop (software: ArtemiS SUITE 14), was placed at each listening station, and acoustic and psychoacoustic indicators were measured.
Participants were asked to be silent and pay attention to the soundscape and environment around them, standing nearby the measurement system. The latter was always directed to the same position as the participants' view and was never moved throughout the entire duration of the measurement.
The indicators measured were:

- SPL ($L_{eq,T}$)
- Average Loudness (N_{avg})
- Loudness Cubic Mean (N_{rmc})
- Loudness Percentiles (N_5, N_{95})
- Loudness Quotient (N_5/N_{95})
- SPL A-weighted and C-Weighted ($L_{Aeq,T}$, $L_{Ceq,T}$)
- SPL Percentiles ($L_{AF5,T}$, $L_{AF95,T}$)

3. RESULTS

The results of the measurements and questionnaires were collected for each listening station. The collected data has been subjected to descriptive analysis.
Considering the contribution this result can make in terms of subjective perception of road traffic, which is a sound source analysed in the above-mentioned mappings, the results of the measurements taken at Via Bonanno Pisano (Point 2), the main and busiest street in the area, are shown here. This listening point is characterised by traffic noise and high values of noise levels (Table 1) at low and medium frequencies (Fig. 4) have been measured, typically characterising vehicular traffic. The results of the questionnaires agree with the outcome of the measurements. 53% of the sample often goes through Via Bonanno Pisano to get to the University. Participants state that the noise from road traffic is completely dominant (Fig. 5) and mainly rate the environment as chaotic, unpleasant, and dynamic, as also evident from the Soundscape Scatter Plot in Fig 6 [10].

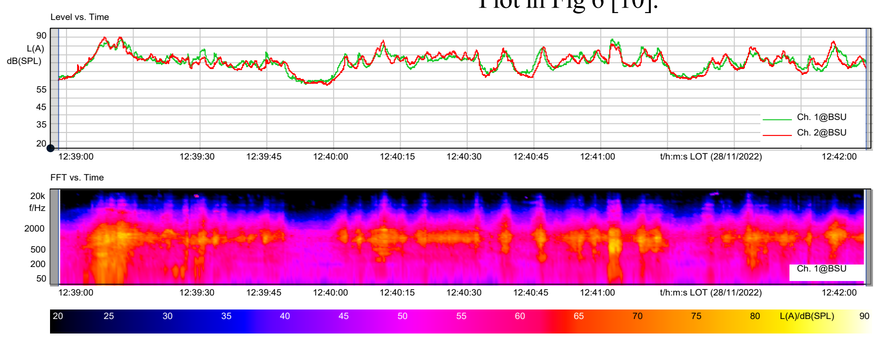

Figure 4. SPL and spectrogram measured at Point 2 in Via Bonanno Pisano, the busiest street in the area.

Table 1. Average values of the acoustic and psychoacoustic indicators of all measurement points, with Point 2 values highlighted. Only a few of the indicators – shown here for completeness – were considered in the article.

	P1	P2	P3	P4	P5
SPL	66.3 dB	80.9 dB	66.8 dB	65.9 dB	69.4 dB
N_{avg}	10.6 soneGF	32.5 soneGF	12.6 soneGF	15.4 soneGF	13.8 soneGF
N_{rmc}	9.2 soneGF	29.7 soneGF	11.4 soneGF	13.1soneGF	12.8 soneGF
N_{95}	5.8 soneGF	14.2 soneGF	8.3 soneGF	8.9 soneGF	7.6 soneGF
N_5/N_{95}	2.1	3.1	1.8	2.0	2.4
N_5	11.9 soneGF	44.3 soneGF	14.9 soneGF	18.1 soneGF	17.9 soneGF
$L_{Aeq,T}$	55.7 dBA	73.6 dBA	59.4 dBA	63.4 dBA	60.0 dBA
$L_{Ceq,T}$	65.0 dBC	80.1 dBC	65.6 dBC	65.7 dBC	68.2 dBC
$L_{AF95,T}$	47.9 dBA	61.3 dBA	53.1 dBA	55.0 dBA	51.3 dBA
$L_{AF5,T}$	58.9 dBA	79.4 dBA	63.6 dBA	69.0 dBA	64.7 dBA

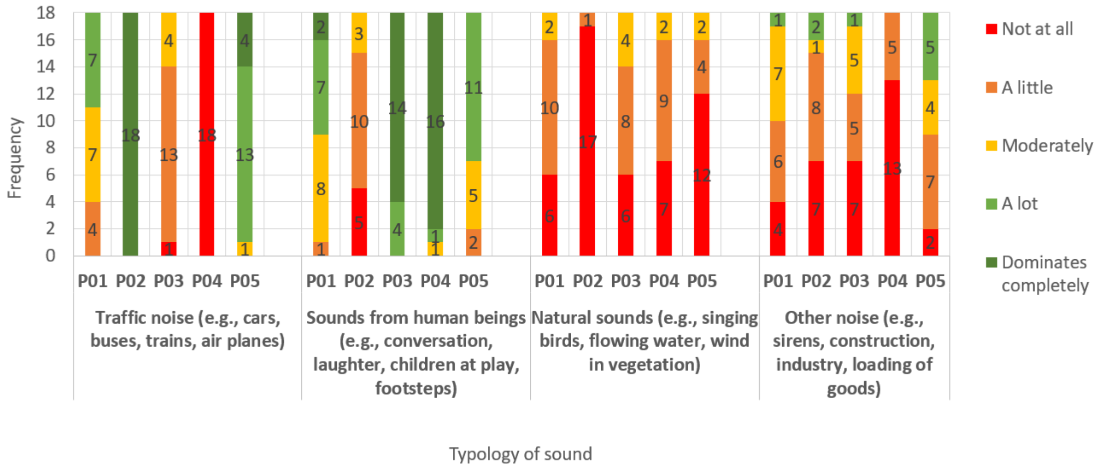

Figure 5. Results of the questionnaire on the sound sources' identification for the five measurement points.

4. DISCUSSION

A comparison was conducted between the different sites regarding loudness, noise levels, and sound perception. Road traffic and anthropogenic sounds were perceived as predominant sound sources at all points (Fig. 7). According to the sound sources identified by the participants, in Point 2 traffic noise was the main sound source, whereas in Points 3 and 4, which were characterised by the presence of tourists, anthropogenic activities were reported as predominant (score of 4 out of 5 or 5 out of 5) by 18 out of 18 participants. The highest value of loudness – 32.5 soneGF – was observed at Point 2, while the loudness of the other points ranges between 10 and 15 soneGF. Loudness is influenced by the frequency content and the duration of the sound stimuli. In general, it can be stated that the lower the noise levels the more positive the sound quality of the environment has been assessed by participants (Fig. 8).

Traffic noise negatively influenced the assessment of Point 2 and Point 5: in both the listening stations the average score of the perceived sound quality was lower than 2.5 out of 5. Whereas Point 3, which had a dB(A) value closer to Point 5 than the other points, was characterised by a positive assessment, having unintelligible anthropogenic background noise as its main sound source.

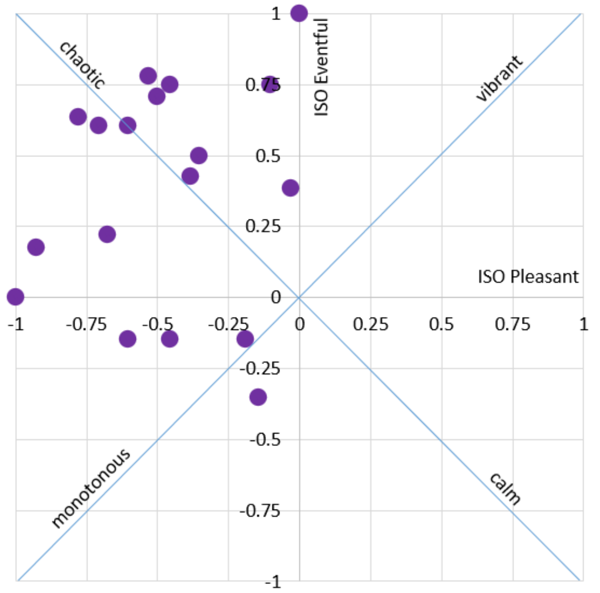

Figure 6. Soundscape Scatter Plot reporting the answers of single individuals for Point 2.

One hypothesis made by the authors is that the perception of sound quality is not strictly related to the type of sound source and its pitch, intensity, or timbre, but was also influenced by the landscape: architectural landmarks along the route may have reduced the negative perception of the soundscape due to unwanted noise.

A slight difference can be observed in terms of the average score of soundscape quality for Point 3 (3.58) and Point 4 (3.11). The authors believe that the difference in anthropogenic sounds characterising the areas may also have influenced this data, as in Point 4 people's voices were more intelligible than the background noise of the commercial activities in Point 3. Listening to intelligible speech could be more distracting and therefore probably perceived as more annoying.

The focus on Point 2, as illustrated in the results section, shows how road traffic negatively influenced the perception of the space. A possible way for reducing the dominance of road traffic could be the introduction of positive sounds, as mentioned in a study carried out by Aletta and Kang in the city of Brighton [4]. In Point 2 it can also be stated that road traffic resulted in noise levels above the noise immission limits defined for the assigned zone (zone 4 - areas of intense human activity) by the Municipal Acoustic Classification Plan.

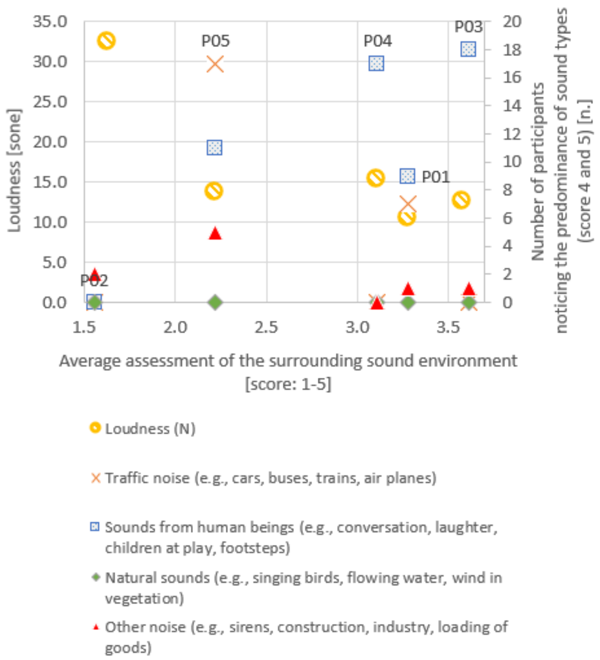

Figure 7. Comparison between loudness and typologies of sounds perceived as predominant, considered according to the number of participants who gave the sound type a score of 4 out of 5 or 5 out of 5.

Although the short noise measurement (3 minutes) cannot be considered representative of the entire daytime reference period, the average A-weighted sound pressure level measured at Point 2 (73.6 dBA) is observed to be more than 8 dBA higher than the noise immission limit set for the Municipal Acoustic Classification Plan in this area ($L_{Aeq,T}$ = 65 dBA for daytime: 06 a.m. – 11 p.m.).

The Soundscape Scatter Plot (Fig. 9) summarizes the perceived affective quality in a two-dimensional graph, where each listening station is reported as a single coordinate pair. The 8 adjectives used for the affective quality evaluation are encapsulated in two coordinates: ISO Pleasant and ISO Eventful [10]. In this type of graph, the difference already mentioned between Point 3 and Point 5 is even more evident: although the A-weighted SPLs are closer together than the other points – 66.8 dBA in Point 3 and 69.4 dBA in Point 5 – it can easily be seen that the perception in Point 5 is closer to the chaotic evaluation and consequently considered less pleasant. In general, the five measurement points are mainly defined as eventful and the terms “monotonous” and “calm” are not used to describe their soundscape. For different reasons, Points 2 and 5 are assessed as more chaotic than the others: the predominant sound source is road traffic in Point 2 and railway traffic in Point 5. This aspect underlines the need for an appropriate analisys of the sound sources which are involved in the perception of environments, to design punctual acoustic interventions.

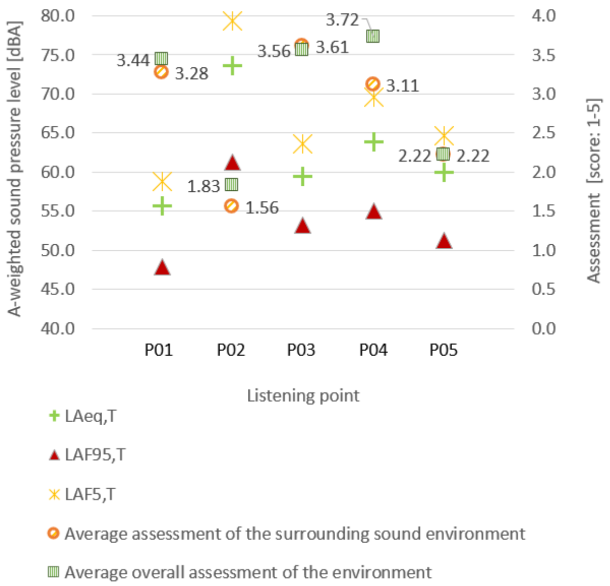

Figure 8. Comparison between noise levels and perceived quality of the soundscape.

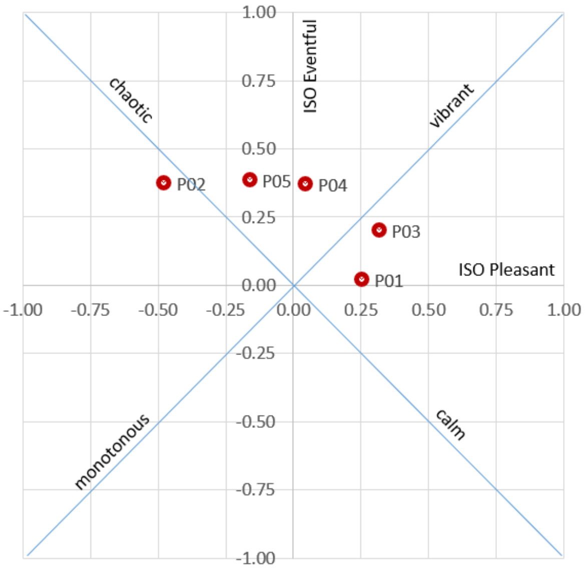

Figure 9. Soundscape Scatter Plot representing the average assessment for each of the five listening stations.

5. CONCLUSIONS

In the present study, the subjective perception of soundscape in five outdoor areas near the School of Engineering of the University of Pisa has been investigated. The measurement points have brought to light the different features which characterise the close – but at the same time various – soundscape around the School.

Road traffic and anthropogenic activities are stated as predominant sound sources in all the sites. Mainly, traffic noise negatively influences the perceived sound quality.

The soundscape technique produces a more in-depth assessment of the acoustic subjective quality in outdoor areas. This aspect is crucial for monitoring the overcoming of noise limits, ensuring noise pollution to be countered, and enhancing positive sounds.

The present analysis involved a sample of university students who frequently pass by the investigated points.

This, combined with the classical assessment of maximum noise levels, may allow new types of interventions to specifically improve the perceived quality of environments. By way of example, the types of interventions useful in Points 2 and 5 are completely different. While in Point 2 the acoustic intervention is much closer to that adopted in the classic condition of unpleasant and excessive background noise levels, in Point 5 this type of intervention may not be as effective. A future outlook could be to compare and unify Point 5 (San Rossore train station stop) with Point 3 (Piazza Manin, where the access door to Piazza del Duomo is located), which are closer in measured sound levels, but very different in perceived quality. The main reasons for this difference in perception could be the presence of a much more pleasant visual scenery at Point 3 and the presence, once again at this point, of an anthropogenic sound source, associated more with a pleasant evaluation (vibrant in the Soundscape Scatter Plot). To improve the acoustic quality of Point 5, a positive sound masking of the sounds present and the enhancement of social interaction can therefore be planned, with areas equipped for students and commercial activities. The presence of anthropogenic sources could move Point 5 in the Soundscape Scatter Plot (Fig. 9) towards the right-hand side of the graph, bringing it closer to the similar Point 3, whose soundscape was assessed as more pleasant. In general, the proximity of the selected listening points and their differences make it possible to extend the optimal conditions found at a specific point to other sites, depending on their use and noise sources.

In conclusion, the sound level is not the only parameter to be considered. There are other aspects, such as visual perception and the inclusion of positive sound masking, that should be part of acoustic requalification design.

What has been done is a preliminary study, which can be developed and further deepened, of an urban area of considerable interest in which very different uses and functions are combined, leading to a strong presence of motorised traffic and human presence.

6. ACKNOWLEDGMENTS

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