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URBAN SOUNDSCAPE ANALYSIS: THE CASE STUDY OF THE DEPARTMENT OF HUMAN ARTS OF ROMA TRE UNIVERSITY

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Quiet areas have the unique function of resting places where the urban noise affecting people during daily life is temporarily interrupted and for this reason many soundscape studies have focused on these areas. This function should be guaranteed also in the open spaces of schools and universities, which may assume the role of both resting areas and places of discussion and education. Because of their urban settlement, schools and universities are often surrounded by areas with a high noise pollution that may compromise their good acoustic quality.
The paper presents the methodology and the results of a wide socio-acoustic survey performed in the external area of the Department of Languages, Philosophy and Human Arts of Roma Tre University, surrounded by high traffic flows streets. The area is interesting since it is characterized by various sectors with different features and functions. The study included both the acquisition of data thanks to *ad hoc* polls and acoustic measurements. Results highlight that both the overall quality and the acoustic quality of the area are considered good and that they are influenced by non-acoustical factors, such as architectural and psychological aspects.

Keywords: Soundscape, Environmental Acoustics, Phonometer Measurements, Psychoacoustic Measurements, Questionnaire

1. Introduction

Urban noise affects the health of exposed people so that the acoustical improvement of urban areas is an interesting issue for architects and city planners.

In the last decades several national noise regulations have been issued to control the urban acoustic environment and improve the acoustic comfort. Based on these regulations, many local authorities started to define urban noise maps to evaluate noise exposure and improve urban quality, with a specific focus on sensitive districts (residential areas, parks, schools, hospitals). The EU Directive 2002/49/EC introduces the concept of "quiet areas" either inside agglomerations or in open country. "Quiet areas" should be areas where noise pollution is controlled under certain levels, however, criteria based on measurements to identify such areas have not been defined yet, mainly due to the lack of knowledge of the effects of noise on the perceived soundscape quality [1]. Anyway, the importance

of "quiet areas" is widely recognized as they have the unique function of resting and recovery places where the urban noise affecting people during daily life is temporarily interrupted. This function becomes more important for open spaces of universities for their role of socialization and education.

The study presented in this paper is characterized by some measurements of the traditional indicators of cumulative noise, i.e. the equivalent sound pressure level (L_{Aeq}), performed during the hours of attendance of the external spaces of the Department of Languages, Philosophy and Human Arts of Roma Tre University. Moreover, a survey was carried out thanks to *ad hoc* questionnaires proposed to the users of the area (mainly students), along with binaural recordings of the sonic environment, taken contemporarily to the interviews. The goal is a comparison of acoustic and psychoacoustic measurements and an analysis of the perceived quality of the area, in order to set some principles of design for the urban space outside the buildings of the Department.

2. Literature review

The classical approach in presence of urban noise is based on acoustic plans and on the reduction and control of noises through different strategies, such as noise barriers. Different studies have shown that the reduction of noise not necessarily implies an improvement in the satisfaction of the people living in the area. Asdrubali et al. [2] for example show that, due to the influence of other factors (such as the presence of trees, natural features, etc.), the soundscape in three parks of Rome is considered positive by the people even if the sound pressure level is higher than the limits commonly used to define quiet areas. Also Raimbault and Dubois [3] agree that a simple decrease of the sound pressure levels is insufficient for an improvement of the sound experience of an urban environment. Jennings and Cain [4] demonstrate that soundscape cannot be controlled by the classical numerical acoustics metrics and that quiet areas are not necessarily perceived as better acoustic environments. Weber [5] agrees with this point of view and states that the traditional policy instruments for noise reduction based on acoustical limits and source regulations should be integrated with soundscape principles. Moreover comparing the sound environment with the perceived quality, some authors underline how the relation between noise intensity and soundscape quality is not linear, and how, sometimes, reducing the sound level does not necessarily lead to better acoustic comfort [6]. Other works underline similar findings [7], [8] confirming that a multidisciplinary approach is more appropriate rather than focusing on cumulative noise indicators only, i.e., the equivalent sound pressure level (L_{Aeq}). These researches underline how the evaluation of the acoustic environment should take into account several non-acoustical factors, such as visual and microclimatic aspects. The work of Brambilla et al. [9] analyses the soundscape and the subjective evaluation on different aspects of some urban parks in Naples and Milan. The research underlines the importance of the soundscape characterization, in order to preserve quiet areas, taking into account the several non-acoustic factors influencing the individual perception, such as the subject's expectation of the environment and the sounds expected to be heard there (as voices and dogs).

Soundscape studies involve an interdisciplinary approach including not only the reduction of the level of environmental noise but also the relation between the environmental acoustics with human expectations, natural sounds and society. Filipan et al. [10] recently applied the soundscape approach in order to investigate the concept of tranquillity in the mind of the visitors of several city parks in Antwerp, Belgium. The three main viewpoints that have been identified associate the tranquillity with silence, natural sounds or social relationships. Moreover, the results show that the higher are the expectations about the soundscapes of the parks, the more critical is the appraisal of the visitors. Some studies also focus on the relation between soundscape and visual-scape [11], [12]: when sonic and visual sensations are coupled, attention to the visual aspects may reduce the conscious perception of sound, and vice versa. The soundscape considers the mean subjective perception of noise and evaluates the acceptability of the environmental sound from the users point of view. The strategy adopted in a lot of literature works is an integration of acoustic measures and psychoacoustic ones. For example a study that makes a comparison of acoustic and psychoacoustic measures has been proposed by

Raimbault et al. [13] for public spaces in Nantes and Lyon: while some questionnaires about the soundscape were submitted to the pedestrians, the recording of the sound environment permitted to calculate the acoustic parameters in order to apply a multidisciplinary approach able to integrate physical and psycho-sociological parameters. Similarly Aletta et al. [14] compare the binaural recordings and questionnaires submitted to the participants of a sound walk in Brighton Valley Gardens. The sound walk consisted in the selection of some locations in the park where questionnaires were submitted to participants and where soundscape was recorded by binaural microphones. The study detects the presence of a high perception of traffic noise and the authors suggest design interventions able to introduce more positive sounds, like the sound of people and nature. The positive sense of relaxation induced by natural sounds has been demonstrated by a study on the relation between soundscape and mood of people with profound intellectual disability [15]. Finally, Kang et al. [16] used the soundscape approach to get a comprehensive understanding of the perception of walking sounds on different paving materials in urban parks contests.

In this way, it is possible to integrate the classical physical-engineering aspects with the psychological and social consequences that sound generates in the perceivers and to propose some design principles in order to improve the soundscape the urban environments.

3. Methodology

3.1 Case study

The design area is an open space located in the proximity of the Department of Languages, Philosophy and Human Arts of Roma Tre University located in Rome in the Ostiense district, and surrounded by three streets characterized by high traffic flows: Viale Marconi, Via del Varco San Paolo and Via Caduti Senza Croce (see Fig. 1). The area, that is at a lower level with respect to Viale Marconi, is about 15000 square meters wide and characterized by different University buildings, a car park, some green areas and a courtyard with a fountain. The "T" shaped plan building hosts university classrooms, the library of the Department and some reading rooms (see Fig. 1a, red line). The second building hosts a lecture hall, some offices and professor's halls, a coffee bar and a large semicircular multimedia classroom (see Fig. 1a, blue line). The third building detached from the others is the newest one and hosts the spaces of the Faculty of Literature (see Fig. 1a, black line). A new building for classrooms is going to be built in the border area in correspondence to the intersection between Viale Marconi e Via Caduti Senza Croce. The buildings are located in correspondence of the borders fixed by the streets and create a large courtyard open only towards Via del Varco San Paolo and used primarily for parking. The spaces among the buildings and the car park are places for social life, relaxation and pedestrian mobility. The main current use of the area, apart from the parking facility, is of resting place and sociality for students attending lessons at university, and especially the area surrounding the fountain.

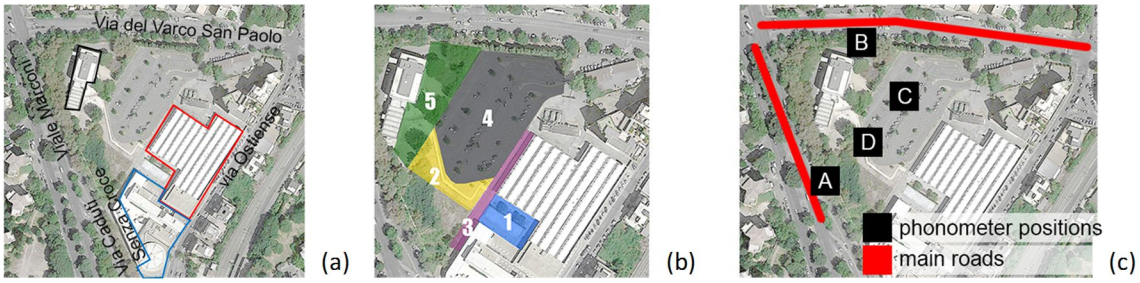

Figure 1: a) Map of the area; b) different sectors; c) main roads and noise measurements points.

For the aim of the study the area has been divided in five sectors. Sector 1 is the external court, open on one side, located between the "T" shaped building and the office building. The sector is characterized by the presence of a fountain and some benches. Sector 2 is the connection path from the court to the external spaces of the Faculty of Literature, while sector 3 a straight path separated

from the car park (sector 4) by a low wall where students often sit. Finally, sector 5 is a green space in front of the Faculty of Literature equipped with a pedestrian access from Via del Varco San Paolo.

3.2 Methodology

The soundwalk method was applied and five key locations (each one representative of a specific sector) were individuated in the area, one for each sector. Moreover, in each of the sectors, some users were selected randomly and they were asked to answer to a questionnaire that contained the following six questions:

1. Which sectors do you frequent more?
2. Are you globally satisfied of the area?
3. Are you globally satisfied of the soundscape of the area?
4. Give a score from 1 to 10 to some aspects of the area including cleanness, security, tranquillity, quality of air, silence, accessibility by bike or foot, natural sounds, parking availability, coolness, presence of wildlife, presence of noise etc.
5. Which sounds do you hear in the area?
6. Which sounds would you like to hear in this area?

Concerning questions 2 and 3 interviewees were asked to evaluate the sound environment of the site, using a scale of five scores: 1, very bad; 2, bad; 3, neutral; 4, good; and 5, very good. At the end of the survey 120 interviews were obtained and elaborated with a statistical analysis.

During the interviews, one operator carried out some recordings using a mobile recorder equipped with a binaural headset (model binaural headset Head Acoustics). The binaural recordings were then used to correlate psychoacoustic parameters with subjected evaluations obtained from the pools. Furthermore, the traffic sound pressure levels (L_{Aeq}) were determined with a phonometer (model Sinus Apollo), in two points of the area perimeter: one in correspondence to the junction between Via dei Caduti Senza Croce - Viale Marconi and one at the pedestrian entrance from Via del Varco San Paolo (fig. 1b). The microphone was installed on a tripod placed near the acoustic source (about 1 m from the street). The acoustic measurements were carried out during the day, taking into account different traffic flow conditions. The acquisition intervals were set equal to 10 minutes.

On the other hand, the psychoacoustic measurements were carried out during the interviews in order to better understand the relationship between the acoustic environmental conditions and the perceived quality. The binaural headset was worn by an operator (height equal to 1.7 m) positioned at a distance such as to not alter the psychoacoustic measurements and turned toward the acoustic source. Also in this case, the acquisition time intervals were equal to 10 minutes, equal to the time spent for an assessment questionnaire.

Considering the acoustic measurements, the Sound Pressure Level (SPL) along time, the equivalent sound level A-weighted (L_{Aeq}) and the frequency analysis were evaluated. Regarding the binaural recording, Loudness (N), Sharpness (S) and the sound pressure level were obtained.

Furthermore, the correlation between Loudness and the assessment questionnaires results was founded and analyzed.

4. Results and Discussion

4.1 Results from subjected data

The main results obtained by the analysis of 120 questionnaires are reported in this section. The largest part of the respondents (about 94%) are students of the Department with an age from 18 to 25 years, followed by Phd students aging between 25 and 30 years (about 18%) and people over 30 years old who are mainly researchers or professors of the department (about 8%). The sample of the respondents is well distributed between male (45%) and female (55%). In addition, all of the respondents of the sample frequent the area more than 4 times a month in the working days. The main reason why the respondents frequent the area is for relax (73%) and only some of them (17%) use the external

spaces of the Department for studying. The 74% of the sample stays in the area for a period from 30 min to 2 h. The most used area (45%) is sector 1 where students have the possibility to seat around the perimeter of the fountain (see Table 1); sector- 3 and 5, used by the 19% and 24% of the samples, guarantee also the possibility of resting in sitting areas. Sector- 2 and 4 configure as transit areas and are less frequented. Regarding the perceived quality of the area, the users were asked to express a score from 1 to 5. Fig. 3a shows that they gave positive ratings, with the 87% of the sample that gives a score of 3 or 4. Similarly also the soundscape of the area is perceived in a positive way with the 75% of the respondents giving a score of 3 or 4.

Table 1: Percentage of sector mostly used.

Sector 1 [%]	Sector 2 [%]	Sector 3 [%]	Sector 4 [%]	Sector 5 [%]
45	9	19	2	24

Furthermore, the quality of the soundscape is correlated with the overall rating of the quality of the area. This confirms that other aspects, like architectural, aesthetics, social and psychological have a positive contribution in the perceived soundscapes. Calculating the mean value of the scores given to soundscape and to the general quality, it is possible to notice that, in both cases, we have the same value, equal to 3.5.

Fig. 3b shows the average score given on the quality of 16 aspects of the area proposed by the interviewer; the evaluation has been presented also for the sub sectors of the area in order to asses if some sectors were considered better than others. Considering positive all the scores higher than 6 and negative all the scores lower than this value, the aspects of the global area seen in a positive way are security, tranquillity, accessibility by bike or foots and for disabled, quality of air.

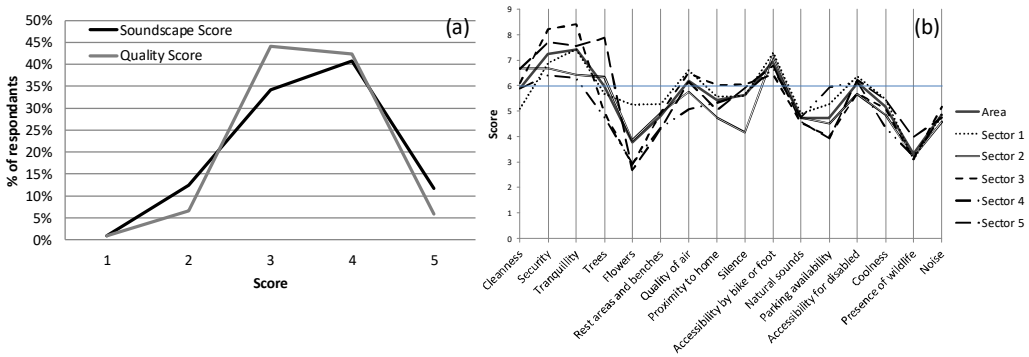

Figure 3: (a) Overall score of the area versus its sonic environment (scores from 1, poor, to 5, very good); (b) Average rating on the quality of 16 aspects of the area.

The mean scores for every sector are in general similar and significant differences are detected only in some cases: for example the tranquillity in sectors 3 (8.4) and 5 (7.5)is higher than the mean value.

The answers about the most perceived sounds show that the soundscape of the area is characterized by the sounds of people talking, the water spray from the fountain and the noise of the traffic coming from the surrounding streets (see Fig. 4a).

Natural sounds are perceived with a low frequency and the sound of the water coming from the fountain seems to be considered as not natural. The first result of the analysis is that the sounds of people's voice characterize generally all the sectors of the area with a percentage between 30 and 40% of the total sounds perceived. It is also possible to notice how the sound of the fountain and the sound of the people's voices are predominant in area 1 (48% and 40% respectively) and they succeed in masking the undesired sound of the traffic. On the contrary sector 5, that is the most far from the fountain, is characterized by a more intense presence of the traffic noise. The role of the fountain in the soundscape of the area is to make the soundscape of the area softer and to provide a background acoustic environment able to reduce the perception of undesired sounds.

Looking at the desired sounds (Fig. 4b) it is possible to see that the noise of traffic is not desired at all, as the sounds of chatting people. The latter can be explained because the voices are yet strongly present in the area. On the other hand, the most desired sounds are the ones linked to nature but also the fountain sound and in some cases a background music sound is desirable. A not negligible part of the sample would also like to hear no sounds at all and another part is satisfied with the actual soundscape. The higher percentage of satisfied users are in sector 1 confirming the good quality of the area around the fountain. Comparing the data about the perceived and desired sounds a large dispersion and indecision is found for the second ones and it is not easy to find some clear preferences. The 34% of the sample doesn't have desired sounds demonstrating that a large part of the respondent doesn't have expectations about the soundscape of the area. Concerning in particular the respondents without expectations, we can observe that they are mostly in sector 1 (41%) and 3 (32%), sectors characterized by a good soundscape environment.

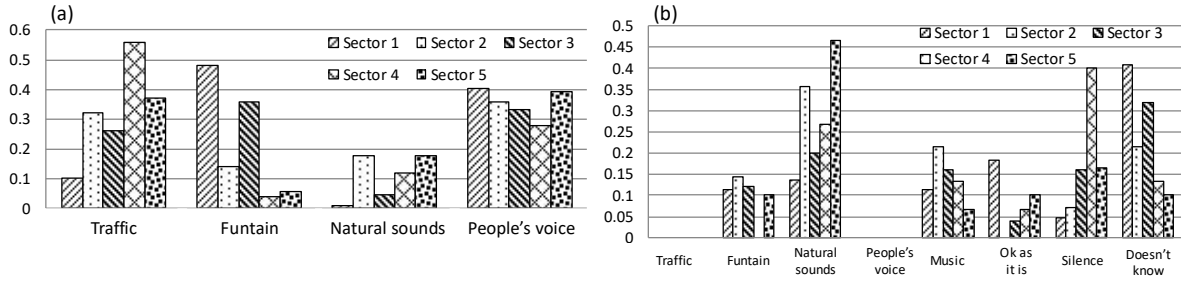

Figure 4: (a) Sounds perceived in the various sectors; (b) Sounds desired in the various sectors.

4.2 Acoustical data

Table 2 lists the positions of the phonometer measurements positions and related significant results. Four measurements campaigns in different days were carried out and for each day data were collected in five different moments of the day, during the building opening time. The obtained results show constant equivalent sound pressure level in each different position (see Fig. 1). This sound pressure level is due to the traffic conditions which are quite congested in the analyzed area. It is possible to observe the positive effects of the site morphology: the height difference between the main road and the internal area and the boundary greenery decrease for example the LAeq from 63.5 dB(A) to 54.7 dB(A). Inside the area (points C and D), the level is higher that the Italian limits for quite areas (50dB(A)), even though most of the respondents judge the quality of the area good or neutral.

Table 2: Measurement points L_{Aeq} and percentiles.

Point A [dB(A)]		**Point B [dB(A)]**		**Point C [dB(A)]**		**Point D [dB(A)]**	
LAeq=72.6	LA10=75.2	LAeq=63.5	LA10=66.7	LAeq=54.7	LA10=55.9	LAeq=57.9	LA10=59.1
LA50=71.3	LA90=67.2	LA50=60.7	LA90=56.1	LA50=54.1	LA90=52.4	LA50=57.2	LA90=55.8

People in the surroundings of each measurement site were interviewed in order to match as closely as possible their sound exposure with their answers to the questionnaire, and in the same moment the psychoacoustic measurements were carried out. Referring to the latter, Table 3 summarizes the results obtained taking into account the 5 investigated sectors, considering the left and right values (obtained by the binaural headset) of the SPL, the Loudness and the Sharpness. Furthermore, the table lists the average and the maximum recorded levels.

Finally, the responses on perceived quality of the overall area and sonic environment were compared with the binaural surveys carried out for each point of the analyzed area. Fig. 5 shows the corresponding percentages of respondents plotted versus the loudness average value for all the questionnaires associated to acoustical data, namely, 120 interviews linked to 5 groups of recording sites. In particular, the correlation among Loudness, percentage of respondents' satisfaction of the environment as whole and percentage of respondents' satisfaction of the sonic environment are shown.

The perceived quality of the sonic environment decreases with decreasing of loudness, it can be unexpected but analysing the results it is clear that the users' perception is strongly influenced by the presence of the fountain. In fact, site 1 is the external court characterized by the fountain and it is identified as meeting point by the students; here the loudness is higher due to the fountain sound and people voices but it is perceived as positive.

Table 3: Psychoacoustic measurements results (L=left, R=right, av=average).

Sector 1	**SPL (L)**	**SPL (R)**	**N(av) (L)**	**N(av) (R)**	**N(max) (L)**	**N(max) (R)**	**S(av) (L)**	**S(av) (R)**	**S(max) (L)**	**S(max) (R)**
	[dB]	**[dB]**	**[sone]**	**[sone]**	**[sone]**	**[sone]**	**[acum]**	**[acum]**	**[acum]**	**[acum]**
	72.2	72	23.1	21.8	53	44	3.25	3.03	5.49	4.83
Mean value	72.10		22.45		48.50		3.14		5.16	
Sector 2	**SPL (L)**	**SPL (R)**	**N(av) (L)**	**N(av) (R)**	**N(max) (L)**	**N(max) (R)**	**S(av) (L)**	**S(av) (R)**	**S(max) (L)**	**S(max) (R)**
	[dB]	**[dB]**	**[sone]**	**[sone]**	**[sone]**	**[sone]**	**[acum]**	**[acum]**	**[acum]**	**[acum]**
	70.7	70.8	17.6	14.1	46.2	37.6	2.6	1.97	4.17	4.84
Mean value	70.75		15.85		41.90		2.28		4.50	
Sector 3	**SPL (L)**	**SPL (R)**	**N(av) (L)**	**N(av) (R)**	**N(max) (L)**	**N(max) (R)**	**S(av) (L)**	**S(av) (R)**	**S(max) (L)**	**S(max) (R)**
	[dB]	**[dB]**	**[sone]**	**[sone]**	**[sone]**	**[sone]**	**[acum]**	**[acum]**	**[acum]**	**[acum]**
	70.8	70.5	13.6	13.2	35.8	29.3	1.89	1.96	4.13	4.73
Mean value	70.65		13.4		32.55		1.92		4.43	
Sector 4	**SPL (L)**	**SPL (R)**	**N(av) (L)**	**N(av) (R)**	**N(max) (L)**	**N(max) (R)**	**S(av) (L)**	**S(av) (R)**	**S(max) (L)**	**S(max) (R)**
	[dB]	**[dB]**	**[sone]**	**[sone]**	**[sone]**	**[sone]**	**[acum]**	**[acum]**	**[acum]**	**[acum]**
	70.9	70.7	13.9	13.6	41.7	29	1.94	1.95	4.41	3.79
Mean value	70.80		13.75		35.35		1.945		4.10	
Sector 5	**SPL (L)**	**SPL (R)**	**N(av) (L)**	**N(av) (R)**	**N(max) (L)**	**N(max) (R)**	**S(av) (L)**	**S(av) (R)**	**S(max) (L)**	**S(max) (R)**
	[dB]	**[dB]**	**[sone]**	**[sone]**	**[sone]**	**[sone]**	**[acum]**	**[acum]**	**[acum]**	**[acum]**
	69.5	69.2	12.1	11.8	31.6	24.3	1.86	1.92	4.36	3.52
Mean value	69.35		11.95		27.95		1.89		3.94	

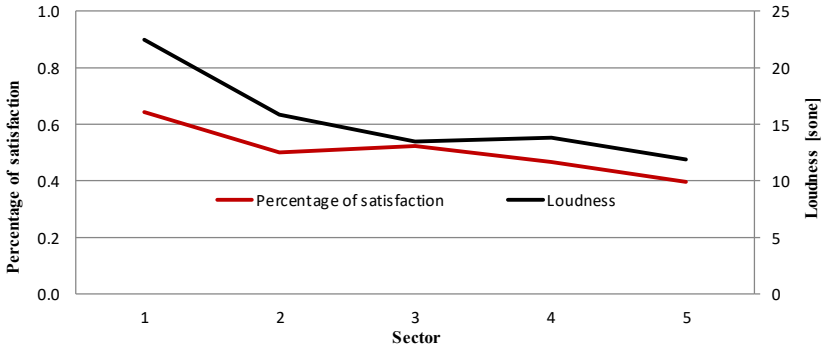

Figure 5: Perceived quality of the sonic environment of each sector vs Loudness values in each measurement internal to the sectors.

The sound generated by the fountain's water and people voices increase the loudness value but, at the same time, it is able to cover the noise produced by the traffic. The other measurements positions are gradually located far from the fountain (see Fig.1) and, consequently, the sound perceived by the users is mainly due to the traffic conditions and then considered as a negative site characteristic.

5. Conclusions

The paper describes a socio-acoustic survey carried out in an urban open public space in Rome, the area outside the Department of Languages, Philosophy and Human Arts at Roma Tre University, aimed to investigate the users' perception of the acoustical quality in the area and its relationship with selected acoustical parameters.

The results underline the correlation between the rating given to the quality of the global area and its soundscape: they have the same mean value. This fact suggests that an improvement of the architectonic characteristics of the space can also bring to an improvement of the perceived soundscape.

The sound levels in dB(A) inside the area exceed the noise limits of Italian law for quite areas, but the area is not perceived as noisy by respondents: this is a confirmation that the classical approach of environmental acoustics, based mainly on levels expressed in dB(A), is limited and not exhaustive.

From the psycho-acoustic measures, it possible to observe that sector 1 shows the highest Loudness level. However, the psychoacoustic perception of the total area is quite good and the sectors around the fountain (sectors 1 and 3) have the highest score in soundscape quality. This confirms how some architectural elements – and in this case the fountain - affect the general soundscape in a positive way.

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