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NOISE CONTROL FOR A BETTER ENVIRONMENT

Soundscape approach for noise management of conflict urban areas. The PTS case in Granada (Spain)

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ABSTRACT

The assessment and management of environmental noise in Granada has been done, according to law, through the elaboration of Strategic Noise Maps (SNM) and Noise Action Plans (NAP). This approach does not include how the urban ambient quality is perceived and understood by citizens, a question studied in Granada by means of Local Agenda 21 actions, especially those on noise annoyance evaluation. After 2016 SNM results, in the preparation of the new NAP, the city came across a great acoustic challenge in a new area located outskirts characterised by a growing urbanisation, still under development, the greatest legal protection because of sensitive teaching and hospital buildings and, at the same time, the greatest noise exposure from the ringway supporting heavy traffic flows. Finding the best actions for noise control exclusively under the traditional technical approach appeared as a rather complicated task, resulting in the soundscape approach assumed for the first time in Granada. As quiet urban areas are not characterised by the absence of noise but for the presence of the right noise, this research intends to provide the local administration with results and proposals to help transform this conflict area in a pleasant or quiet urban area.

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1. INTRODUCTION

Urban sounds can be transformed from pollution to a valued resource if the development of quiet spaces characterised by adequate sound levels rather than by low levels is promoted. Pleasant, but not necessarily silent, soundscape emerges as an extraordinary key figure in current sustainable urbanism. As stated by EEA [1], the term "quiet" may accidently lead to the assumption that a quiet area is an area with very low noise or even no noise, when it is well known that in urban environments it is difficult, not to say impossible, noise levels under 45 dBA day time or 40 dBA night time [1]. Local administration should strive to achieve urban areas where noise is not the dominant element. Calm areas need to be identified, delimited and protected, a task that must involucrate local administration and citizens at the same level of compromise and effectiveness [1] And this noise management and control new approach acquires an special magnitude when the widely and commonly used technical approach appears useless or insufficient. It is time for citizens empowering in a real way. It is the time for the soundscape approach.

1.1 Soundscape approach

There is a great variety of definitions for "soundscape" depending on discipline. With respect to urban environmental acoustic, we find valid references as early as 1967 [2], stablishing basic objectives among which are the analysis of acoustic environment as perceived by humans and the inclusion of acoustic design in urbanisation. More recently, Truax [3] defines soundscape as "an environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society". The International Organisation for Standardization (ISO) standardized these definitions in 2014 [4] referring to soundscape as the "acoustic environment as perceived or experienced and/or understood by a person or people, in context". Later, in 2018, ISO also standardized the way to collect and report soundscape data [5].

The prevention, management and control of noise issues by means of standardized methods has a long tradition in the city of Granada, where high concern has always been expressed by citizens and a high degree of commitment has always been proved by local administration too. Nevertheless, the assessment of the urban acoustic environment taking into consideration people experiences, perceptions or interpretations in context, is something that had never been done before. Local Agenda 21 in Granada has traditionally encouraged citizens participation towards general sustainable development matters. The later certainly includes noise management and control, but this participation has not been conducted on a generalised and harmonised way, as desired in noise assessment, nor has been connected and integrated within noise management according to END (Directive 2002/49/EC). After more than 10 years of strategic noise maps (SNM) and noise action planning (NAP) according to END, everything suggested that it was time for the soundscape approach in the city. The soundscape approach should not be considered as an alternative but a complement to the traditional technical approach relying on SNM and NAP. Perception driven approaches are becoming fundamental tools and mechanisms in order to understand municipal management and urban design nowadays [6] The main argument in this change process is that characteristic sounds in the city don't necessarily have to represent a form of contamination but a part of its patrimony and cultural heritage and, consequently, something to be preserved and protected. The later reinforces the legal requirement for quiet areas promotion and protection in European cities, preserving urban areas that already present that condition and promoting other urban areas into such qualification at shortest possible time. But until now, the determination of "quiet areas" has only been a matter of decibels, a matter of the magnitude of environmental noise levels. This fact has turned into a partial and incomplete methodology for noise control, giving way to perception driven approaches in Granada for urban soundscape design with a focus on environmental noise control and the preservation of the cultural sound heritage.

1.2 The PTS urban area

The pilot area for the soundscape approach research in Granada is a new urban area located outskirts characterised by a recent growing urbanisation, the so-called in Spanish "Parque Tecnológico de la Salud" (PTS) urban area. This area was typified as "*Sanitary, Educational and Cultural*" (SEC) in the acoustic zoning of the city carried out in 2009. According to law, this means that acoustic quality objectives (AQO) are set to Ld=60 dBA, Le=60 dBA and Ln=50 dBA. This AQO are the lowest in legislation, as recommended because of the "*sanitary*" and "*teaching*" activities that take place in the area. The northern part of the study area also includes territory typified as "*Residential*" (R) in acoustic zoning, where AQO are 5 dBA higher (Ld=65 dBA, Le=65 dBA and Ln=55 dBA). An increasing number of citizens are moving their homes to this area, mainly to new buildings being built in the limits between the SEC and the R part of the study area.

If we focus now on noise sources, we find the ringway around the city, limiting the area almost to an 80% of its south-east perimeter supporting heavy traffic flows. The University Hospital also contributes to environmental noise because a great number of cars and other vehicles drive in demand of sanitary services. Little noise contribution come from technologic and innovative business around except that from people working there (mainly offices) and from private transport. The metropolitan line going through PTS from north to south on a regular basis contributes lowering noise levels as it decreases the number of private vehicles around. Putting all this together, the acoustic situation is dramatically complicated as we have the lowest legal acoustic quality objectives and the greatest noise exposition from heavy traffic flow driving the nearby ringway. This road traffic noise also smashes upon façades of present buildings facing the ringway and propagates through holes and empty spaces between buildings to public gardens and squares in the area. Acoustic screens may be a good technical solution to be installed along the outer limit of the area, but not a real alternative to cope with inner environmental noise issues. Other technical solutions like acoustic cushions, elevated crossroads, lower traffic speeds, different road colours, reducing vehicles flows, etc may be adequate but clearly not the definitive solution. The soundscape approach comes to give a new vision of the problem in the area and supplement traditional acoustic engineering practices and urbanisation design advice from community engagement in urban planning and development.

2. METHODOLOGY

2.1 Environmental noise at PTS

If we look at Granada 2016 SNM, the acoustic situation at PTS area can be inferred from Ld, Le, Ln and Lden noise indices maps. Traffic noise from nearby ringway, absolutely dominates and conditionate the situation, with night noise indices over 50 dBA at most places at a distance of around 500 meters from highway. During the day and evening, almost the whole corner is over 65 dBA, houses facing the ringway to the east are fully affected with noise levels over 70 dBA, while parks and avenues behind these houses are all over 60 dBA. If we take into consideration legal AQO, noise levels can be combined with AQO to produce the so called "conflict maps", urban areas presenting noise conflict because environmental noise is over legal limits. If we have a look at Granada conflict map for Ld index, we can see that noise issues concentrate along main streets and avenues, as the main noise source in Granada is road traffic. Most of the city appears without conflict except at PTS area. Our study area corner appears as the main conflict area in Granada, together with the perimeter of the ringway bordering the city. A close look at PTS area conflict map, shows exceedances over 20 dBA near the ringway during the day and over 15 dBA at almost the whole extension of the corner and the east side of the highway. The acoustic situation described before determines that the PTS area is a ZPAE, in Spanish "*Zona de Protección Acústica Especial*" and, according to law, it demands the elaboration of a specific local noise action plan. To do so, environmental noise levels have been recorded in order to revise SNM results and see how the situation has progress since 2016. On twelve locations, 15 minutes noise levels have been measured and Table 1 shows some results. This experimental noise level campaign was carried out with a Rion NL-52 type 1 sound level meter during day (d) and evening (e) periods. Traffic flows refers to number of vehicles driving along the street where measurements were made.

Table 1: Basic results from environmental noise levels measuring campaign.

PTS study area – 15 minutes Leq (dBA) day period						
ID	Date	Time	Acoustic Zone Type	Light vehicles	Heavy vehicles	Leq (dBA)
1	20-03-18	9.00	SEC	244	13	69,1
2	20-03-18	9.15	SEC	108	11	71,7
3	20-03-18	9.30	R	575	42	69,1
4	20-03-18	10.00	R	742	55	68,6
5	20-03-18	10.15	R	124	4	70,7
6	20-03-18	10.30	R	176	12	72,3
7	20-03-18	10.45	R	56	3	67,1
8	20-03-18	9.15	SEC	105	5	79,2
9	20-03-18	9.30	SEC	118	11	71,3
10	20-03-18	9.45	SEC	80	2	69,8
11	20-03-18	10.00	R	99	14	80,4
12	20-03-18	10.30	R	132	9	65,0
PTS study area – 15 minutes Leq (dBA) evening period						
1	11-04-18	19:22	SEC	206	6	70,1
2	11-04-18	19:51	SEC	92	3	69,6
3	16-04-18	21:04	R	289	6	64,3
4	16-04-18	21:31	R	288	10	65,2
5	16-04-18	21:59	R	58	13	64,1
6	16-04-18	22:27	R	45	6	64,3
7	16-04-18	22:46	R	53	6	55,7
8	11-04-18	20:18	SEC	77	0	65,9
9	11-04-18	22:01	SEC	35	5	65,3
10	11-04-18	21:36	SEC	6	0	59,9
11	11-04-18	20:45	R	87	10	64,8
12	11-04-18	21:16	R	90	0	62,4

These experimental results confirm global diagnosis of the study area given by 2016 SNM results. But if we concentrate on people exposed to noise, the magnitude of the problem has a different interpretation if we take into consideration that still few people are living there. In this sense, 51% of the population at SEC area of PTS study area are exposed to Ld over 60 dBA, 44% to Le over 60 dBA and 72% to Ln over 50 dBA. But in absolute terms we are talking about 252 persons during day time, 218 during the evening and 356 during nigh time. The population is still low, so when studying which part of the city noise conflict areas deserves to be attended first by local administration (NAP design), the PTS emerges as a second priority. To get to this recommendation, we have first represented the urban areas where noise conflict exists (the so-called ZPAE) as pink areas and areas without conflict (the so-called quiet areas, QA) in yellow in Figure 1. Then we have identified the most exposed areas (MEA) within the conflict area (ZPAE) by studying the conflict level. To do so, two variables have been considered: the annoyance of residents and number of noise sensitive institutions (schools and hospitals) in the area. The total noise exposure of a defined area has been calculated by multiplying the number of people exposed to different noise bands by an annoyance factor depending on noise level during night time (Ln). Results for study area are also shown in Figure 1. It can be seen that the corner of PTS area, the most exposed area because ringway traffic noise, appears as second priority. We should focus on residential area of PTS first, which gives us time to carefully plan noise actions at the SEC side of PTS study area

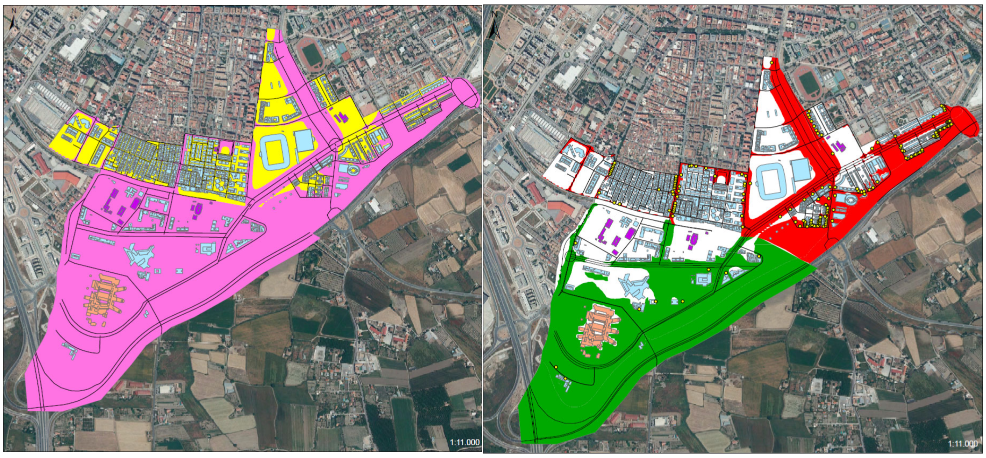

Figure 1: Conflict noise areas in Granada (pink - ZPAE) and quiet areas (yellow - QA). Right: Most Exposed Areas (MEA) Green area means "low conflict" and red area means "high conflict"

2.2 Soundwalk design

PTS study area ranges from the north-east "*Residential*" (R) area, characterised by higher population density and less business activity, to the south-east "*Sanitary, Educational and Cultural*" (SEC) area, characterised by less but growing population and greater activity from businesses, hospital and university faculties. Inspired and advised by works from F. Aletta and A. Radicchi [7, 8] and also by personal advice from both of them, the final soundwalk path across the study area was delimited as shown in Figure 2. The soundwalk took place on a Friday morning (13-04-2018) and later on a Monday evening (23-04-2018) Fourteen persons, 20 to 55 years old (3 women, 11 men; average age 29,3; SD=10,5) participated in the morning soundwalk and nine persons, 20 to 55 years old too (3 women, 6 men; average age 34,9; SD=14,1) participated in the second evening soundwalk. From them, 4 men participated in both soundwalks (55, 24, 23 and 20 years old each) Participants were equally distributed in both soundwalks among these groups: university (students taking a degree in Physics and environmental noise researchers), local administration (environmental techniques and Local Agenda 21 techniques) and citizens that attended our invitation.

Figure 2: Soundwalk path across PTS study area, stopping at eight selected locations.

As shown in Figure 2, the group was guided along a path with eight listening stops. First morning soundwalk started at stop number 1 located at the residential (R) part of study area, and ended at stop number 8 located at the sanitary (SEC) part of PTS area. During the evening, second soundwalk, the itinerary was taken the other way round, starting at stop number 8 and ending at stop number 1. As recommended by A. Radicchi [8], because the purpose of a soundwalk is listening to the environment, participants were instructed to listen for a couple of minutes in silence at every stop and then answer a questionnaire. They were also instructed to walk in silence along the path from one stop to the next one. At the end of the soundwalk, participants were asked to share their impressions, maintain a brief group discussion and scribble their thoughts drawing whatever feelings they had experienced on a sheet supplied with the questionnaire. Stop number 4 could not be completed during morning soundwalk (13/04/2018) because of heavy rain. It later stopped raining, but the group decided to move to next location in order to complete the soundwalk in no more than two hours. No incidences took place during the evening soundwalk (23/04/2018)

2.3 Soundwalk questionnaire

Brighton soundwalk questionnaire from F. Aletta et al. [7] was the germ for our questionnaire. Personal conversations with Francesco Aletta pointed out that one important thing when asking citizens on their perceptions was to get information whether something was happening and how did it make people feel, but not if it was something good or bad. A quiet complicated task, complemented by difficulties with the translation into Spanish so that proposed questions would be interpreted in the same way. Personal conversations with Antonella Radicchi also contributed to the final version of the questionnaire and some verbal questions that she normally uses were included, as well as the possibility to draw a "mental sound map" of the experience and scribble feelings and thoughts, in order to be later assessed by environmental psychoacoustic specialists. Hush City App was also taken into consideration, grounded on Antonella's proposed notion of "*quietness as a commons*" [9], but it was considered something that would later complement our soundwalks when the mobile app would be translated into Spanish. Nevertheless, A. Radicchi "open source soundscapes" methodology can effectively contribute to the development of environmentally and socially just urban planning processes and some work was already in progress. After this review work, Granada soundwalk questionnaire consists in a set of 10 questions with pre-defined answers, a demographic info page and a free creativity drawing page. Among the 10 questions are 4 that uses a 5 items verbal answers scale (Q7, Q8, Q9 and Q10) and 5 that uses a numeric (1-10) scale (Q2, Q3, Q4, Q5 and Q6) among which main question is Q5 for soundscape quality description according to O. Axelsson soundscape perception model [10] Altogether, even though ISO standard [5] was still not published when the soundwalk took place, we can say that Granada questionnaire includes most of ISO 12913 recommendations.

2.4 Soundwalk environmental noise descriptors

Environmental noise levels were recorded with a Rion NL-52 type 1 sound level meter during ten minutes at every stop, both during the morning and the evening walks. Main noise descriptors are shown in Table 2, but data collected include 1 second **Leq**, dBA and dBC logging as well as spectral information during recording period.

Table 2: Main noise descriptors during first (morning) and second (evening) soundwalk

Morning soundwalk – 13/04/2018 – dBA – N=14 participants						
ID	Time	Leq	Lmax	Lmin	L10	L90
1	12:15	57,3	63,7	54,5	58,9	55,5
2	12:41	66,3	74,5	57,8	70,7	58,9
3	12:57	58,7	65,6	52,6	62,8	53,2
4	*not done*	*no data*	*no data*	*no data*	*no data*	*no data*
5	13:16	64,6	73,5	56,4	68,7	57,4
6	14:11	69,8	79,4	60,0	73,2	61,2
7	13:32	66,3	74,8	55,6	70,6	56,9
8	13:48	61,0	66,2	57,1	64,1	57,8
Evening soundwalk – 23/04/2018 – dBA – N=9 participants						
ID	Time	Leq	Lmax	Lmin	L10	L90
1	19:45	59,9	63,9	56,4	62,3	57,3
2	19:20	60,0	66,1	56,6	62,8	57,2
3	18:59	59,3	69,8	50,9	63,0	51,9
4	18:40	57,3	63,8	52,4	60,1	53,2
5	18:23	64,9	73,3	56,3	69,6	57,0
6	18:07	66,7	75,4	57,7	70,9	58,4
7	17:47	64,5	75,1	53,3	68,3	54,2
8	17:31	57,7	63,2	53,9	60,0	54,5

A representation of these levels shows that P6 (stop number 6) present highest noise levels and variation and P1 and P8 the lowest. If compared with acoustic quality objectives (AQO) for the typified “residential” (R) and “sanitary” (SEC), we can see that they exceed limits during morning and evening periods. Locations 5, 7 and 8 are placed in SEC terrain and the rest in R terrain.

3. RESULTS AND DISCUSSION

In this section we will refer to first soundwalk (morning period) as **SW_M** and second soundwalk (evening period) as **SW_E**. The eight stops locations will be referred as **P1** to **P8**, and questions will be numbered as **Q1** to **Q10**. We will analyse correlations between acoustic metrics and individual responses and correlations between numeric scale and verbal scale responses on connected items. Pearson’s correlation coefficient and corresponding p-values (*r,p*) will be given in every stage of the analysis.

3.1 Evaluation of the environment: overall appraisal and appropriateness

Mean values per site answers to Q2 (overall appraisal) and Q3 (appropriateness) give similar results in both soundwalks, getting almost same mean responses when noise levels are low (P8). Results also show that Q2 and Q3 increase with lower environmental levels but not to the same amount at every stop location, pointing out the importance of site location and local characteristic of the acoustic environment, as shown in Figure 3.

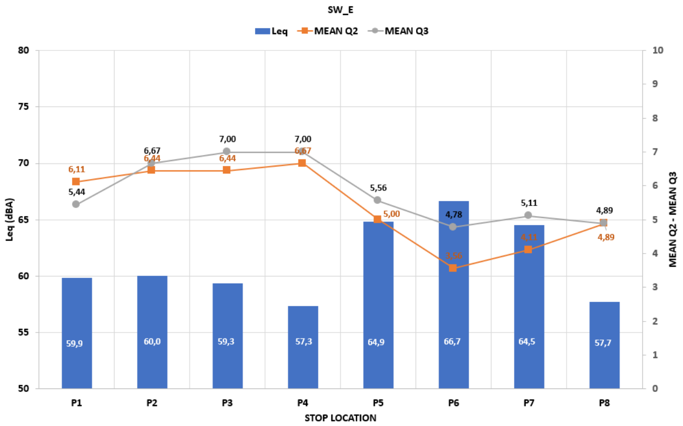

Figure 3: Mean responses to Q2 [overall sound environment "very bad" (1) to "very good" (10)] and Q3 [sound environment appropriate "not at all" (1) to "perfectly" (10)] at different stop sites SW_E.

Results show positive correlation between mean Q2 and mean Q3 per site as stated by Aletta et al. [7], but this correlation is greater during SW_E (r=0,8709, p=0,005) and not as important during SW_M (r=0,6933, p=0,084) In any case, results seem to confirm that high level of appropriateness (Q3) are indeed necessary to appreciate an overall good sound quality of the environment (Q2). Results also show negative correlation between overall appraisal (Q2) and some physical noise descriptors, but only during the evening as show in Table 3. The highest correlation coefficient corresponds to Leq while Lmax and L10 presents close results. If we analyse correlation between appropriateness (Q3) and noise descriptors, we also find a better correlation during evening, but the improvement not reaching significance (p-values much greater than 0,05). Our results for Q2 differ from those of F. Aletta et al. [7], stating that L50 is the most suitable indicator for quietness, as we find in Granada greater relevance of high environmental noise levels (better Lmax and L10 correlation) On the other side, results for appropriateness (Q3) seems to indicate low dependence on environmental noise metrics. Only L50 and Leq during the evening show some correlation but significance level doesn't let us establish a general assert about this.

Table 3: Overall sound quality (Q2) and appropriateness (Q3) correlation vs noise descriptors

	SW_M			SW_E	
r *(p)*	**Q2**	**Q3**	**r *(p)***	**Q2**	**Q3**
Leq	-0,1548 *(0,740)*	0,1705 *(0,715)*	**Leq**	-0,7865 *(0,021)*	-0,5590 *(0,150)*
Lmax	-0,0892 *(0,849)*	0,2583 *(0,576)*	**Lmax**	-0,7136 *(0,047)*	-0,3658 *(0,373)*
Lmin	-0,1893 *(0,684)*	-0,2636 *(0,568)*	**Lmin**	-0,3885 *(0,342)*	-0,5117 *(0,195)*
L10	-0,0772 *(0,869)*	0,2934 *(0,523)*	**L10**	-0,7537 *(0,031)*	-0,4974 *(0,210)*
L50	-0,3039 *(0,508)*	-0,0820 *(0,861)*	**L50**	-0,6526 *(0,079)*	-0,6129 *(0,106)*
L90	-0,2243 *(0,629)*	-0,2553 *(0,581)*	**L90**	-0,3831 *(0,349)*	-0,5086 *(0,198)*

3.2 Evaluation of the environment: overall quietness, pleasantness and loudness

We focus now on results from the other three questions rated on a 5 items verbal scale, that is, overall quietness (Q7), overall pleasantness (Q8) and overall loudness (Q9). Quietness (Q7) positively correlates with (Q8) pleasantness (r=0,6207, p=0,137) and negatively with (Q9) loudness (r=-0,7072, p=0,076), but the correlation is much better during the evening both for Q8 (r=0,9482, p<0,001) and Q9 (r=-0,8843, p=0,004). Pleasantness (Q8) presents a weak negative correlation with loudness (Q9) during the morning (r=-0,5123, p=0,240) that, once again, increases considerably during the evening (r=-0,8290, p=0,011). So, overall loudness (Q9), which refers to environmental noise magnitude, volume, not quality, appears as quite responsible for the overall feeling of quietness and pleasantness, a perception that strengthens during the evening when peaks and maximums in a lower environmental noise background generate greater annoyance.

Table 4: Overall quietness (Q7), pleasantness (Q8) and loudness (Q9) correlation vs noise descriptors

	SW_M				SW_E		
r (p)	**Q7**	**Q8**	**Q9**	***r (p)***	**Q7**	**Q8**	**Q9**
Leq	-0,8115 *(0,027)*	-0,6498 *(0,114)*	0,8490 *(0,016)*	**Leq**	-0,8048 *(0,016)*	-0,6559 *(0,077)*	0,8810 *(0,004)*
Lmax	-0,7976 *(0,032)*	-0,6588 *(0,108)*	0,8755 *(0,010)*	**Lmax**	-0,8157 *(0,014)*	-0,6722 *(0,068)*	0,7459 *(0,034)*
Lmin	-0,7856 *(0,036)*	-0,3562 *(0,433)*	0,7077 *(0,075)*	**Lmin**	-0,2806 *(0,501)*	-0,1646 *(0,697)*	0,6367 *(0,090)*
L10	-0,7819 *(0,038)*	-0,6568 *(0,109)*	0,7785 *(0,039)*	**L10**	-0,8047 *(0,016)*	-0,6609 *(0,074)*	0,8634 *(0,006)*
L50	-0,8303 *(0,021)*	-0,6491 *(0,115)*	0,8812 *(0,009)*	**L50**	-0,5909 *(0,123)*	-0,4707 *(0,239)*	0,8756 *(0,004)*
L90	-0,7799 *(0,039)*	-0,3898 *(0.387)*	0,7572 *(0,049)*	**L90**	-0,2664 *(0,524)*	-0,1505 *(0,722)*	0,6333 *(0,092)*

On the contrary, when we study the relation of these magnitudes with noise metrics, we find similar correlations during morning and evening as shown in Table 4. Overall quietness (Q7) negatively correlates with most descriptors except background noise (Lmin and L90) during the evening. Pleasantness (Q8) doesn't really present good coefficients during the morning, but it presents negative correlation with Leq, Lmax and L10 during the evening. Finally, overall loudness (Q9) correlates with every descriptor and period, except for L90 and Lmin, which appears as a reasonable result. Noise indicators Leq and Lmax seem to be good and stable indicators in most cases in this assessment. General sound quality (Q2) and appropriateness (Q3) do not correlate at all with Q7, Q8 or Q9 (overall quietness, pleasantness and loudness respectively) during the morning walk, but they do during the evening. Q2 correlates positively with Q7 (r=0,9367, p=0,001) and Q8 (r=0,9145, p=0,001) and negatively with Q9 (r=-0,8836, p=0,004). On the other hand, appropriateness Q3 correlates positively with quietness Q7 (r=0,6944, p=0,056) and pleasantness Q8 (r=0,7549, p=0,030) and negatively with loudness Q9 (r=-0,7437, p=0,034). This fact may be pointing out the importance of background levels and city life agitation in the perception and interpretation of the urban soundscape. It can also be pointing out the importance that citizens attribute to less noisy environments during the evening, manifesting more tolerance to high levels during the morning.

3.3 Assessment of emotional components

Question 4 and question 5 give us information on sound sources (Q4) and attributes (Q5). Q4 answers ranges from "*I don't hear at all*" to "*it completely dominates*" and Q5 ranges from "*strongly disagree*" to "*strongly agree*". Individual responses have been averaged for each one of the eight stop locations. "*Traffic noise*" is always de dominant source during the morning and, to a lesser degree, during the evening. But the most relevant result is that other sources gain protagonism during the evening, such us "*natural sounds*" and "*sounds of individuals*". This confirms, once again, the important change that takes place in the acoustic environment along the day, making it a significative difference to take into account. Most dramatic changes take place at stops number 5, 7 and 8 which corresponds to the "sanitary" part of study area. If we look at Q5 answers, we can see that the differences between morning and evening sound sources perception turns out in a quite different soundscape interpretation from emotional components analysis, as shown in Figure 5 where the following contrast differences (Axelsson's model components response differences) of every participant (14 participants during SW_M and 9 during SW_E) at stop location 3 (P3) are represented: "P-Up" (Pleasant-Unpleasant), "Ch-Cl" (Chaotic-Calm), "Uv-E" (Uneventful-Eventful) and "Ex-M" (Exciting-Monotonous). Though some participants collaborated in both soundwalks, the designation on the right do not correspond to the same participants (for example, Part_3 during the morning is not the same as Part_3 during the evening). We can see how the interpretation of P3 moves from a somewhat "unpleasant-chaotic-eventful" soundscape to a more "pleasant-calm-uneventful" interpretation. This change affects sites number P1, P2, P3 and P4 and to a lesser extent site number 5, as it can be seen in Figure 5 following Ö. Axelsson model [10] where a typical "upper left side" site would appear from low (P-Up), high (Ch-Cl) then low again (Uv-E) and finally high (Ex-M) in Figure 4 and a typical "lower right side" site would have the inverse appearance in Figure 4. If we look at stop site P3 again, we can we can visualize different morning/evening sound sources perception as P3 is placed towards "upper left side" in Figure 5 and in the evening moves towards the "lower right side" of this figure.

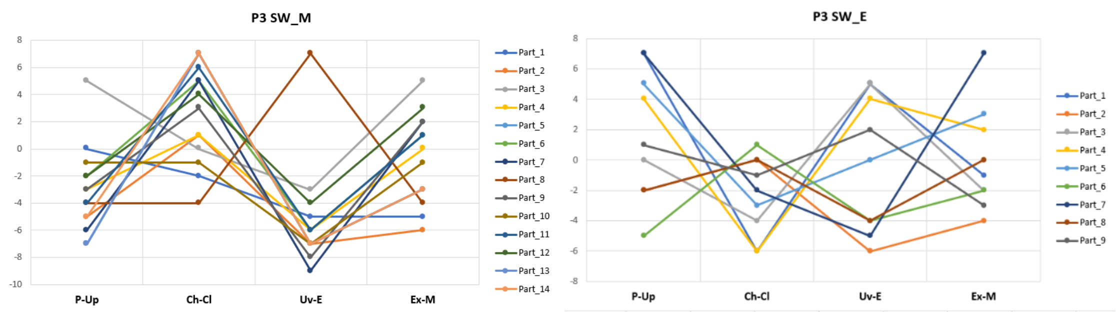

Figure 4: Axelsson's model components contrast differences for every participant at stop location P3 during morning soundwalk (left) and evening soundwalk (right)

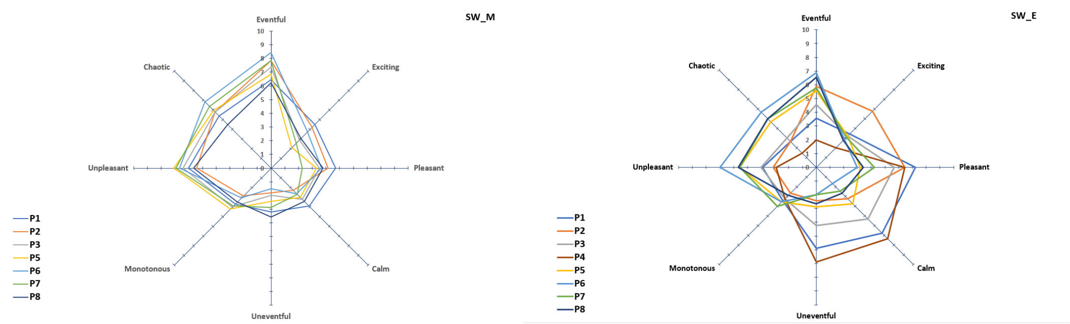

Figure 5: Mean Q5 answers for morning soundwalk (left) and evening soundwalk (right) according to the model from Ö. Axelsson et al. [10]

When analysing correlation between the eight emotional components and noise descriptors, it is found that "*chaotic*" and "*eventful*" present positive correlation against Leq, Lmax and L10 during the morning, and opposite feelings "*calm*" and "*uneventful*" negative correlation with these descriptors (absolute r > 0,6) But only "*eventful"* and "*calm*" correlations have significative p-vale under 0,05. On the contrary, during the evening all except "*exciting*" correlates (absolute r > 0,6) with Leq, Lmax and L10, negatively for "*pleasant*", "*uneventful*" and "*calm*" and positively for the rest of the components, but only "*unpleasant*" has significative p-value under 0,05. Additionally, "Traffic noise" Q4.1 was found to be positively correlated with Q5.2 "*chaotic*" (r=0,8553, p=0,007), Q5.6 "*unpleasant*" (r=0,7633, p=0,028) and Q5.7 "*eventful*" (r=0,8838, p=0,004) and negatively correlated with Q5.4 "*uneventful*" (r=-0,8435, p=0,008) and Q5.5 "*calm*" (r=-0,8401, p=0,009) but only during the evening walk. On the other hand, "Sound of Individuals" Q4.2 was found to correlate with Q5.7 "*eventful*" both during the morning (r=0,7104, p=0,074) and the evening walk (r=0,7210, p=0,044) but be negatively correlated with Q5.5 "*calm*" in the morning (r=-0,7678, p=0,044) and the evening (r=-0,7523, p=0,031). "Natural sounds" Q4.3 positive correlates with Q5.1 "*pleasant*" both in the morning (r=0,7855, p=0,036) and the evening (r=0,8327, p=0,010) and with Q5.3 "exciting" in the morning (r=0,8195, p=0,024) but negatively with Q5.2 "chaotic" (r=-0,7163, p=0,046) and Q5.6 "unpleasant" (r=-0,7170, p=0,045) during the evening. These results disagree with those of F. Aletta et al. [7] with respect humans and calmness but agree in the other components. Similar results are found as in J. Kang et al. [11] with respect the positive influence of natural sounds in the evaluation of environmental pleasantness or traffic noise as a negative factor for pleasantness. Finally, if we compare results from Q5 against Q2, we find again important differences between morning and evening soundwalks, being the most important that the overall appraisal of the environment (Q2) is closer to emotional component Q5.1 "*pleasant*" and, to a lesser extent, to Q5.5 "*calm*" and Q5.3 "*exciting*" especially during the evening. On the other hand, Q5.7 "*eventful*" and Q5.8 "*monotonous*" are emotional evaluation of the environment quite distant from its overall sound quality assess by Q2 (Figure 6).

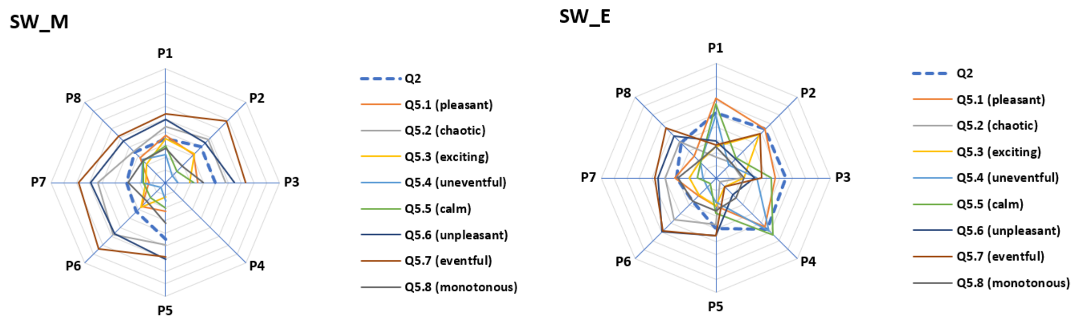

Figure 6: Mean Q2 answers for morning (left) and evening soundwalk (right) and mean Q5 according to [10] at each stop site.

3.4 Assessment of perceived intensity from individual sounds

Answers from question Q10 "*Perceived intensity from different noise sources*" (perceived dominance) on a five items verbal scale, complements question Q4 about "*Environmental sound dominance*" on a (0-10) numeric scale. Sounds from adults dominate "Human" noise sources during the morning and evening, sounds from bicycles moving around and emergency vehicles dominate "Mechanic" noise and near road traffic noise clearly dominates "Traffic" noise sources followed by motorcycles especially during the evening. Birds flying around dominate "Biologic" noise sources and vegetation and water are the main "Geophysics" noise sources. Most important conclusion from Q10 is that pleasantness (Q8) positively correlates with birds and movement of vegetation and trees to a greater extent during mornings than evenings and negatively correlates with motorcycles but only during evenings.

4. CONCLUSIONS

As it was thought, the soundscape approach applied to a new urban area affected by high road noise levels and growing urbanization pressure, clearly contributes to a better characterization of noise issues connected to human perceptions. Our results show that high level of appropriateness is necessary to appreciate an overall good sound quality of the environment and that overall loudness appears as responsible for the feeling of quietness and pleasantness, a perception that strengthens during the evening. Personal judgment about the overall surrounding sound environment shows a greater tolerance to high environmental levels during the morning. The overall appraisal of the environment is found to be closer to emotional component "*pleasant*" and, to a lesser extent, to "*calm*" and "*exciting*" especially during the evening. All these findings should be taken into account when designing the new urbanisation of the area, in order to incorporate all those urban elements that reduce environmental noise prominence and increment overall good appraisal of the environment. The elaboration of noise control plans should also take these results into consideration, as great differences between morning and evening have been found connected to subjective judgment rather than to environmental noise levels.

5. ACKNOWLEDGEMENTS

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