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NOISE CONTROL FOR A BETTER ENVIRONMENT

Evaluation of acoustic comfort and improvement needs in green spaces in Valencia as a contribution to the Action Plan

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ABSTRACT

The city of Valencia wants to incorporate in the city's next Noise Action Plan the positive perspective that considers the soundscape. As a first step, the degree of acoustic comfort of the urban spaces most used by the citizens was evaluated. The diagnosis was focused on the districts where population values the tranquillity of their neighbourhood with a lower score. The Results of the Barometer of public opinion were analysed, both to select the districts to analyse, and to know the use of the green spaces in each zone. The paper presents the results of the acoustic comfort assessment and the improvement needs of the selected spaces. The work focuses specifically on the acoustic variable but adds a holistic perspective of Urban Comfort in urban environment. TECNALIA combined in this work a methodology based on expert judgment or observation of subjective variables that characterize the environmental comfort (CUP-Lite), which includes the inquiry of the opinion of users on aspects that can be improved. In parallel, a collaborative evaluation process was opened with the ComfortUP! App, which is an application that allows users to collect their opinions on environmental comfort.

Keywords: Quiet Areas, Soundscape, Citizen Observatories

I-INCE Classification of Subject Number: 61

1. INTRODUCTION

In general, studies on acoustic exposure of the population in our cities have focused on the negative perspective of sound, that is, noise. From these studies, sufficient evidence has been obtained to confirm that exposure to environmental noise in our towns and cities causes a deterioration of the well-being and integral health (physical, psychological and social) of people and communities, due to the capacity of this environmental pollutant to disturb the various facets of life (work, rest, sleep, communication, etc.), which is accompanied by reactions both physiological and psychological and social, thus affecting the overall health of people.

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However, this approach must be complemented by the positive perspective, which considers sound as a soundscape, integrating these two visions. From the positive view of sound, it is observed that exposure to sound environments considered pleasant and / or quiet can be associated with benefits for the health of people. For this reason, in recent years, the 70s tradition of soundscape studies has recovered.

Based on this general framework of urban comfort, the City Council of Valencia addressed the identification and assessment of potential quiet areas in the districts of the city with a lower perception of tranquillity, identified by analysing the results of the Municipal Barometer of citizen opinion.

This work was made in coordination with the activities carried out by the Delegation of Environmental Quality of the municipality in terms of noise pollution and taking advantage of the synergies with the Barometers content of February 2018 which addresses the use of green spaces in the city.

This work allowed to complete the information extracted in the Noise Map of Valencia, with the purpose of adapting and improving its municipal policies for the protection and prevention of the Urban Environment, in general, and the Sound Environment, in particular that will contribute to integrate the positive perspective of sound and the perception of citizenship in the future Noise Action Plan of the city.

2. METHODOLOGY

A reference for the identification, evaluation and management of quiet areas that respond to one of the issues required in the European Noise Directive is the QUADMAP project which considers that in this field one must go beyond noise pollution by integrating other variables in the concept of "tranquility". The Directive establishes the following definition of a quiet area: 'quiet area in an agglomeration' shall mean an area, delimited by the competent authority, for instance which is not exposed to a value of L_{den} or of an appropriate noise indicator greater than a certain value set by the Member State, from any noise source. The QUADMAP project complemented the previous definition with another perspective: 'a QUA is an urban area whose current or future use and function requires a specific acoustic environment, which contributes to the well-being of the population'. As you can see, this definition includes not only the acoustic dimension but also issues related to the user of the space and its design: the use of the function and its capacity to contribute to an improvement of health through the increase of well-being.

The QUADMAP methodology for the analysis of Quiet Areas proposes those variables that are considered of interest for the evaluation of the quality of a quiet area. The variables considered are: acoustic (sound levels, presence of sound events and dominant noise sources), and other general ones (landscape, uses, cleanliness, safety and accessibility), as well as psychosocial ones, referring both to the perception of the sound environment and to the other dimensions of the place indicated above.

In view of the above, the theoretical and methodological framework of this study is environmental psychology, in terms of the study of the beneficial effects for health of urban soundscapes; the psychosocial area dedicated to the study of well-being and health or the quality of life; and the analysis of urban comfort, specifically focused on acoustic comfort.

The applied methodology is the expert evaluation of the following aspects of each one of the zones studied:

- Identification of uses and activities.
- The quality of the area in terms of its cleaning, maintenance, security, accessibility, furniture conditions, pollution (smell ...), commercial activity and the conditions of the surrounding buildings.
- Description of the type of people who use each zone.
- Perception of public space globally through a semantic differential of 14 pairs of bipolar adjectives.
- Perceived acoustic quality:
 - o Identification of the two most relevant sound sources in each zone of use, assessing the pleasantness on a scale of 3 points (low, medium and high).
 - o Evaluation of the soundscape of public space through a semantic differential of 12 pairs of bipolar adjectives.

The evaluations were made through observations made by an expert person who visited each of the urban public spaces at times of the day of greatest use: in the mornings between 11 a.m. to 15 p.m. and in the afternoon after 4 p.m. In very large spaces, specific areas were identified to carry out the expert evaluation campaign.

To carry out this evaluation, a data loading tool was used: the CUP-Lite Sheet, developed by TECNALIA within the framework of the Comfort Urban Place (CUP) concept.

In addition, during the visits, on-site information was collected among the users of the selected urban spaces on possible improvements to the spaces analysed.

Within the framework of the project, a campaign was developed, led by the City Council, which invites citizens to upload their environmental experience by visiting the selected potential Quiet Areas, using the ComfortUP! App, which is an application that allows to collect on site the opinion of the users themselves about the space visited, as well as objective parameters of the sound environment and thermal conditions of the place.

2.1 Identification of urban spaces to analyse

The approach of the City Council was to focus the study on those districts in which the perception of citizenship of tranquillity is lower. For this selection, the results of 3 municipal barometers of citizen opinion carried out in March 2017, December 2017 and May 2018 were analysed. The barometer's technical data sheet indicates that the sample size of the target sample is 2,100 personal interviews, carried out on the street with a distribution proportional to the size of the district's population. The universe of the study of the city of Valencia is 660,822 people over 18 registered in the city.

The study districts are identified according to the answers to the recurring question in the three mentioned barometers: What do you like most about your district? Question that offers 14 response items, among which one is tranquillity. Likewise, the most used green spaces by citizens in each of the districts are identified. To this end, the spaces mentioned by the interviewees in the barometer of February 2018, which deals with the use of green spaces in the city, are contrasted with the Valencia City Council. The spaces finally selected for the study under study are shown in the table and figure below.

A total of 15 spaces were analysed. El Jardín del Turia is an extensive natural corridor that runs through part of the city of Valencia and was divided into 4 sections.

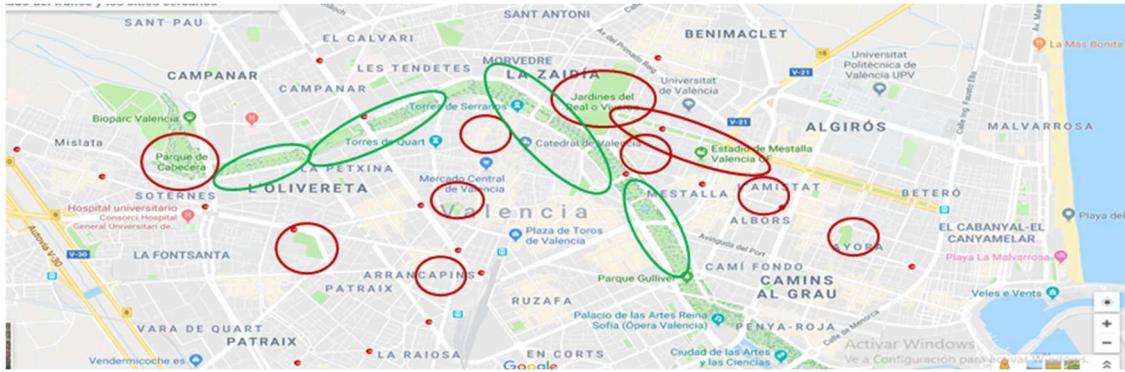


Figure 1. Location of the studied urban spaces

| | | |
|--|---|---|
| <ul style="list-style-type: none"> - District 7 (4 spaces): Jardines del Turia, Zona de Naturaia Parque de Cabecera Parque Oeste - District 3 (2 spaces): Jardines del Turia, Zona del Botánico Plaza Albacete/Marvá | <ul style="list-style-type: none"> - District 1 (3 spaces): Jardines del Turia, Zona de Benlliure Entorno antiguo Hospital Plaza Mosen Sorell - District 2 (2 spaces): Jardines del Turia, Zona del Puente del Mar Plaza Manuel Granero | <ul style="list-style-type: none"> - District 6 (4 spaces): Jardines del Turia, Zona del Puente del Mar Jardín del Real Av. de Blasco Ibáñez Jardín Monforte - District 13 (2 spaces): Parque Ayora Plaza Cedre |
|--|---|---|

In the Strategic Noise Map made in 2012, we can see the global noise levels in the daytime period caused by noise sources associated with traffic, rail and industry.

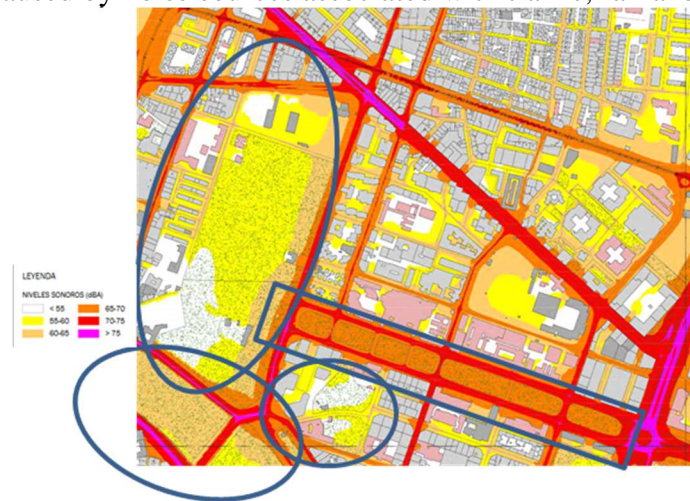


Figure 2. Strategic Noise Map (day period) of District 6, in which part of the Zona del Puente del Mar in Jardines del Turia, Jardín del Real, Jardín Monforte and part of Av. Blasco Ibáñez are identified

2.2 Evaluation campaign

The evaluation campaign was carried out on the days between November 5th and 9th, 2018. The 15 urban spaces under study were visited, in which 22 evaluation points were established. In total, around 30 evaluations were made.

3. RESULTS

3.1 General comments

Regarding the general condition of the urban spaces analysed and the presence of urban facilities, a good location and state of facilities were observed in the large or medium urban spaces. In addition, it can be intuited that there could be problems with coexistence with loose dogs.

The following table summarizes the evaluations of the general quality and of the existing facilities in the spaces studied. As you can see in the table, the Jardines del Turia and the Parque de la Cabecera stand out as the most cared, clean and maintained urban spaces, while the rest of the urban spaces would need some improvement.

| | Overall status | District | Cleanliness | Maintenance | Security | Accessibility | Urban Furniture | Gardening | Comercial activity | Facilities in general |
|------------------|----------------|----------|-------------|-------------|----------|---------------|-----------------|-----------|--------------------|-----------------------|
| Natural Corridor | Cabecera | 7 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 3 |
| | Turia Naturia | 7 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 |
| | Turia Botanico | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 1 | 3 |
| | Turia Benliure | 1 | 3 | 2 | 2 | 2 | 2 | 3 | 1 | 2 |
| | Turia P Mar | 2,6 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 3 |
| | Real | 1,7 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 2 |
| Multi-purpose | Oeste | 7 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 |
| | Ayora | 13 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 |
| | M Granero | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 |
| | Cedro | 13 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 |
| | Hospital | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 |
| Primary Use | Monforte | 6 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 3 |
| | Albacete | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 2 |
| | Blasco Ibañez | 6,13 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |
| | Mosen | 1 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 |

Table 1. Description of the general quality variables of the spaces studied

The different urban spaces analysed could be grouped around 3 general types:

- Natural Corridor: large urban spaces located in the old bed of the Turia river. These spaces are very well maintained and are used mainly for physical exercise or dog walk.
- Multi-purpose spaces: extensive urban spaces located in the urban fabric where different population groups develop different uses.
- Primary Use Spaces: spaces in which, due to their size or to some other characteristic, a type of use predominates.

In general, the Parque de Cabecera and the analysed sites of the Jardines del Turia can be considered clean, safe, bright, spacious, beautiful, natural, peculiar and quiet, so their enjoyment is associated with a pleasant ambient experience (HIGH comfort).

The results of the assessment of the global perception of public spaces can be summarized as follows:

- The urban spaces in the natural corridor group are perceived more luminous, warm, spacious, clean, safe, quiet, beautiful and peculiar, and therefore they are MORE PLEASANT than the spaces the other groups: multipurpose and primary use spaces.
- The average ratings of the three groups of spaces are very similar in relation to the perception of their liveliness and fun, as well as their climatic conditions of humidity and wind.

3.2 Soundscape assessment

Regarding the assessment of the soundscape, a description is presented below for each group of spaces, referred to the two most relevant sound sources, assessing their pleasantness, and to the evaluation of the soundscape.

| N a t u r a l C o r r i d o r | | District | Most significant sound source | Perception rating (1-3) | Second significant sound source | Perception rating (1-3) | Date |
|---|----------------|----------|-------------------------------|-------------------------|--|-------------------------|------------|
| | Cabecera | 7 | Water fountain | 3 | Wind | 3 | 06/11/2018 |
| | Turia Naturia | 7 | Wind | 3 | Traffic background | 2 | 06/11/2018 |
| | Turia Botanico | 3 | Traffic | 1 | Birds | 3 | 06/11/2018 |
| | Turia Benliure | 1 | Traffic background | 2 | Human activity (voices, laughs, steps) | 3 | 06/11/2018 |
| | Turia P Mar | 2,6 | Birds | 3 | Traffic far | 2 | 05/11/2018 |

Table 2. Natural corridor: relevant sound sources and their pleasantness



Figure 3. Water fountain in the lake in Parque de Cabecera

There are pleasant sound sources in this group of areas: the jets of water from the fountains that are in the park's lagoon, as well as sounds of nature (wind, birds) or human activity. In some spaces the traffic noise is perceived, either as a second sound source after those positive sounds, or as the most significant sound source, from which it is difficult to abstract.

In the next figure it can be seen how the presence of dissonant or inappropriate sounds with the environment where they occur entails a less positive perception of the soundscape and, therefore the space is perceived less pleasant. This is the case of the presence of ambient music or the presence of engine noise.

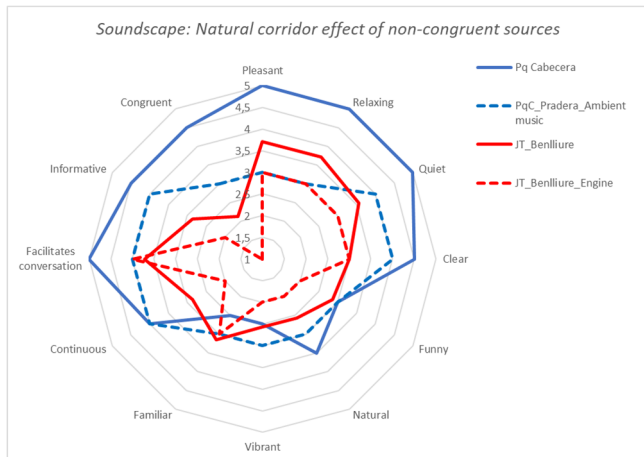


Figure 4. Natural corridor: evaluation of the soundscape

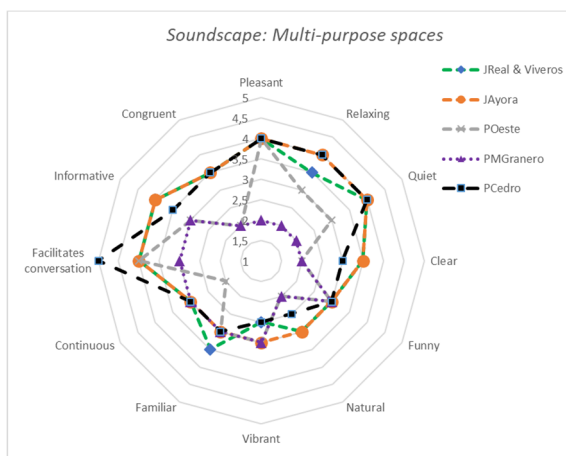
| | | District | Most significant sound source | Perception rating (1-3) | Second significant sound source | Perception rating (1-3) | Date |
|----------------------|-----------|----------|-------------------------------|-------------------------|---------------------------------|-------------------------|------------|
| Multi-purpose spaces | Real | 1,7 | Water | 3 | Traffic | 2 | 05/11/2018 |
| | Oeste | 7 | Few Traffic | 2 | Breeze in the trees | 3 | 06/11/2018 |
| | Ayora | 13 | Birds | 3 | Traffic | 2 | 05/11/2018 |
| | M Granero | 2 | Traffic background | 1 | Human activity | 2 | 05/11/2018 |
| | Cedro | 13 | Human activity | 3 | Traffic background | 2 | 07/11/2018 |

Table 3. - Multi-purpose spaces: relevant sound sources and their pleasantness



Figure 5. Social activity in one of the areas

In these spaces, positive, natural or human-made sounds (playgrounds and terraces) are present, being in some cases the most relevant sound source. However, traffic noise is present in all of them.



In multi-purpose spaces, where many activities coexist, the assessment of the different dimensions of their soundscapes is generally neutral, which is accompanied by a certain perception of tranquillity and therefore a moderate feeling of pleasantness.

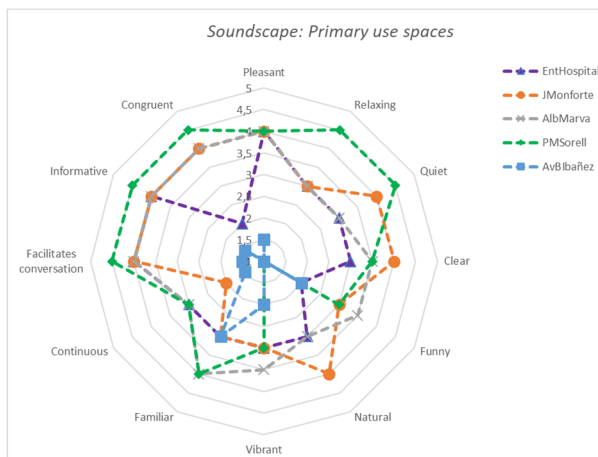
| | | District | Most significant sound source | Perception rating (1-3) | Second significant sound source | Perception rating (1-3) | Date |
|---------------------------------|---------------|----------|-------------------------------|-------------------------|---------------------------------|-------------------------|------------|
| P r i m a r y | Hospital | 1 | Voices | 3 | Traffic background | 2 | 06/11/2018 |
| | Monforte | 6 | Birds | 3 | Screaming children | 2 | 05/11/2018 |
| | Albacete | 3 | Children's voices | 3 | Social adult activity | 3 | 06/11/2018 |
| | Blasco Ibañez | 6,13 | Traffic | 2 | Horns | 2 | 05/11/2018 |
| | Mosen | 1 | Quiet market activity | 3 | Human activity (voices, steps) | 3 | 06/11/2018 |

Table 4. Primary use spaces: relevant sound sources and their pleasantness



Figure 6. Space with natural elements

In most primary use spaces, the most relevant sound sources are originated by human activity, valued positively. It could be highlighted how the bustle of a school near a very pleasant environment can make evaluation worse.



In general, soundscapes of primary-use spaces, where sound sources of human activity predominate, are valued positively, even those spaces where traffic noise is noted but it is not predominant.

Despite the differences commented above between the three defined groups of urban spaces, the total average soundscapes pleasantness of the urban spaces analysed is HIGH-MIDDLE.

The soundscapes of the spaces of the natural corridor group are considered more relaxing and quieter and that facilitate communication more than those of multi-purpose

group, and these spaces result somewhat better perceived than the spaces in the primary use group.

3.3 Results of Citizen Evaluation: ComfortUp!

The app can be freely downloaded, and a period was established for the participants to make observations and upload them on the platform. The data collected between October 25, 2018 and January 15, 2019 are analysed.

The communication campaign to motivate participation was led by the City Council. Its goal is to describe the aim and the framework of the study, and to publicize the 15 urban spaces where the study is focused on.

During the project 50 observations were made using ComfortUP, although the majority of them correspond to people linked to the development of the project and, therefore, the results obtained have a representativeness similar to the evaluation made by experts in a parallel way and that has been previously explained. Therefore, we can conclude that the participation of citizens was not sufficiently stimulated, and it is an aspect that should be improved in later uses of the application. In this sense, the following presents the additional possibilities offered using the application with respect to the data obtained with the expert evaluation methodology.

The most important contribution of this technology is that citizens participate in the evaluation by directly reporting their perception at the time they are in each space, and the system also collects the objective environmental conditions of the moment of observation.

Thus, theoretical comfort indicators are calculated, such as the Environmental Sound Experience Indicator (ESEI), which uses data on noise levels, events, the identification of the sound sources that are perceived and how they are assessed by each participant.

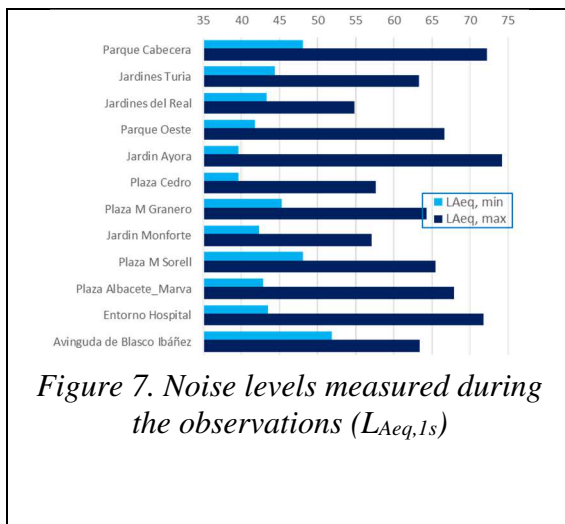


Figure 7. Noise levels measured during the observations ($L_{Aeq,1s}$)

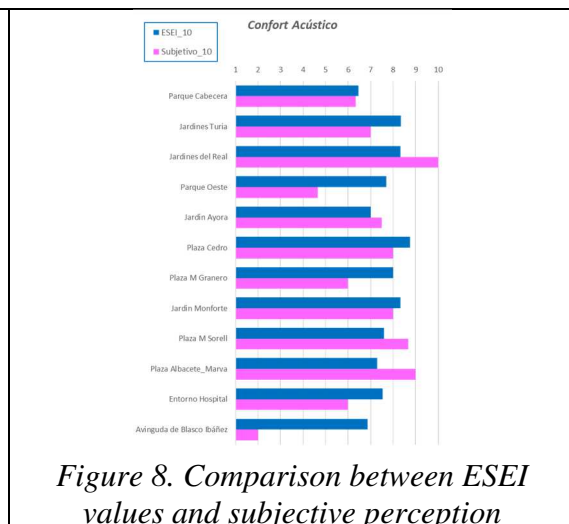


Figure 8. Comparison between ESEI values and subjective perception

The results of the acoustic comfort indicator ESEI, calculated with the data of the observations made, are compared with the subjective perception of pleasantness of the soundscape, reported directly by the participants through the app.

The values of the ESEI indicator coincide with the acoustic comfort perceived in 7 of the spaces studied, while the perception is more negative than what the indicator calculates in 3 spaces, in those where there is more presence of traffic noise. Finally, in 2 spaces where there is a lot of human activity, the indicator indicates less comfort than users actually perceive.

Finally, emotions and perceived health are recorded before and after the observation. From the analysis of these results, the restorative capacity of urban spaces is assessed, in terms of reducing negative emotions and perceived stress.

3.2 Contributions to the Action Plan

Analysed the result of the evaluation of the potential quiet areas of the city, it can be said that among the 15 urban spaces studied in the selected districts, 6 of them have a good quality, assessed both with general criteria and with acoustic criteria, and that are also very used by the surrounding population. These zones are clear candidates to be declared as Quiet Areas and the actions in them would be to guarantee the preservation of their current quality, without the need for improvement actions.

Additionally, other conclusions are aspects that could be improved and that could be incorporated into the future Noise Action Plan of Valencia. As general lines, the actions could focus on the following lines:

- Continue caring for and improving the urban spaces of the Natural Corridor of the city of Valencia, valued very positively.
- Improve the quality of the spaces in the group “Multi-purpose Spaces”, considering their function as a place of coexistence and encounter between different groups of population (socio-diversity).
- Consider some of the spaces included in the group called Primary Use Spaces, which, despite their small size, may be small oases of tranquillity within the city.

The result of the study allowed identifying possible actions to improve each of the spaces whose current quality is not considered optimal. In this sense, improvements differentiated those with a purely acoustic purpose and those of a more general nature.

The proposed acoustic improvements focus on the reduction of the traffic noise that is perceived in some of the spaces, suggesting in some cases lines of work to define possible abatement measures. There is a common case present in several spaces, which is also shared with other European cities, which is the reduction of the noise caused by traffic circulating on bridges and elevated areas that increases noise levels in recreational or pedestrian areas at level lower, near rivers courses.

On the other hand, non-acoustic improvements were proposed that refer to improving the maintenance of spaces with good acoustic quality and that are used by citizens, in one case, and in actions to encourage the use of little used spaces but that offer a quality very interesting.

| | N spaces | N Multi-purpose spaces | N with Optimal Quality | General improvements | | Acoustic Improvements | |
|-------------|----------|------------------------|------------------------|----------------------|------------------------|-----------------------|--------------------|
| | | | | | | | |
| District 1 | 3 | 1 | 0 | Z | Maintenance of an area | | |
| | | | | | | A | Noise from bridges |
| | | | | | | B | Traffic noise |
| District 2 | 2 | 1 | 1 | Y | Urban Renovation | D | Acoustic criteria |
| District 3 | 2 | 0 | 1 | | | A | Noise from bridges |
| District 6 | 4 | 1 | 3 | | | E | Complex solution |
| District 7 | 3 | 1 | 1 | | | A | Noise from bridges |
| | | | | | | C | Traffic noise |
| District 13 | 2 | 2 | 1 | X | Encourage its use | | |

Table 5. Analysis of possible measures to be integrated in the Action Plan

One of the areas studied is identified in both districts 2 and 6. It is the Space Puente del Mar of the Jardines del Turia, and has a good quality.

A summary was made of the improvements identified for each of the districts analysed. The study proposes an initial prioritization of the measures to be included in the Noise Action Plan so that they can be addressed in the next environmental noise management period. In this prioritization, in addition to criteria of efficiency, assessed qualitatively, and equity between districts, the interest of taking care of multi-purpose spaces in each district was considered, as a possible means to promote social cohesion and the integration of the diversity of the city.

Finally, it is worth mentioning the analysis made of the possible improvements of the spaces commented by the users. They can be summarized as: positive comments on the good quality of the spaces and some comments on the need to install specific urban facilities, such as water sources near children's playground areas, public toilets and solutions to differentiate drinking fountains for the population and for dogs

4. CONCLUSIONS

The results of this study reinforce the interest and the need to specifically analyse the quality of urban public spaces for recreational use. This work is complementary to the results of the strategic noise maps of the city that consider only traditional noise sources. As proposed by the QUADMAP Guide, the evaluation of potential quiet urban areas should not only consider noise levels, but above all the citizens' perception of these spaces and of their general quality. In this way, its use can be encouraged, and the restorative function offered to the Valencian population preserved.

It is interesting to prioritize the care of the quality of spaces for recreational use in those districts that the citizens perceive as less tranquil, which could lead to the identification, declaration and management of Quiet Areas in these districts.

On the other hand, it is worth emphasizing the validity of a tool as the barometer of public opinion for the general knowledge of the perception of city and for its monitoring. In this sense, this study provides an additional value to the conclusions of the barometer, to respond to the objectives pursued.

It is considered of interest to use apps that facilitate the direct participation of citizens in the evaluation of the quality of urban spaces and the comfort they provide. The information that is extracted from the observations registered by ComfortUP! allows analysing additional aspects to the expert evaluation methodology, such as the objective description of the sound environment during the observation period and the evaluation of the restorative capacity of staying in spaces that have good quality. However, the development of a communication campaign to promote the use of the app is a key issue. The integration of the elements of gamification in the design of the app increases the intensity of the participation of people already registered, but it remains a challenge to overcome the barrier of registering the first time. In this sense, this is an aspect that needs procedures and means of improvement.

The proposals resulting from this study may be considered in the subsequent elaboration of the Noise Action Plan, complementing those that pursue the reduction of the indicators of population exposure to noise or the integration of acoustic criteria in urban planning. The study also raises possible contributions for the management of urban public spaces, reinforcing the link between the environmental noise policies and the maintenance and quality of squares, parks and gardens of the city.

5. ACKNOWLEDGEMENTS

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