The Use of Virtual Reality Technology in Noise Action Planning

Seckin Basturk
basturk@soundimensions.eu
Soundimensions SC., Seville, Spain

Francisca Perea Perez
fpereaperez@soundimensions.eu
Soundimensions SC., Seville, Spain

Abstract

Technical noise information, conventionally communicated through noise maps and numbers, is far away of depicting complex sonic environments and not comprehensible for general public. For this reason, in noise action planning, the dialogue between the stakeholders usually faces difficulties and the public information and participation process fails.

This paper introduces an innovative approach to enhance public information and participation processes in noise action planning. This approach employs virtual reality technology in order to enable public listen and see a priori the results of proposed corrective measures in noise action plans. In this way, the public can comprehend the results in an intuitive manner and generate own opinion on the issue without any requirement of technical acoustics knowledge. The utility of the proposed method is evaluated by its application on a case study (Plutarco Av. Noise Action Plan-Malaga/Spain) which deals with noise from places of entertainment and agglomeration of people.

Keywords: noise action planning, public participation, virtual reality, noise from entertainment venues

1. Introduction

In last decades, the scientific society has seen the gap between individuals' experiences and the actions taken (in a conventional manner) to improve acoustic quality of environments. Conventional methods and actions taken were successful to a certain extent, especially regarding higher levels of noise exposure conditions (so-called black areas), but do not offer consistent solutions for relatively lower levels of noise exposure (so-called grey areas that are characterized with 55-65 dBA). In these areas, noise exposure is assumed to be acceptable and not harmful for individuals' health. However it can still cause serious annoyance that plays an important role affecting the overall well-being and quality of life of the exposed population.

In this context, in the last decade, soundscape theory (Schafer 1977)has been revisited by the scientific society and practitioners in order to fill this mentioned gap and achieve successful noise action plans(Brown 2007; Kang 2007; Botteldooren et al. 2008). These efforts trigged a paradigm shift in our understanding of noise control. Today, it is widely accepted that noise control engineering and soundscape concept are complementary approaches to achieve a better acoustic environment. As a matter of course, the toolbox of noise action planning practice has been enriched with techniques like soundwalks, narrative interviews, listening tests, etc. that deal with full spectrum of human experience(Adams et al. 2008; Fiebig et al. 2010; Schulte-Fortkamp 2010).

Beside the technical benefits, the use of such tools in noise action planning is also advantageous to enhance collaboration between different stakeholders and to achieve a more democratic governing practice. The involvement of stakeholders in decision making process enables a better understanding of users' needs and expectations, and also helps to build trust, increase user satisfaction and facilitates acceptance of new interventions in urban area.

As involvement process deals with different stakeholders with different levels of technical knowledge and utterly different agendas, these processes usually face communication difficulties. The lack of comprehensible information flow between stakeholders underlies such communication difficulties. Technical noise information, conventionally communicated through noise maps and numbers, is far away of depicting complex sonic environments and not comprehensible for general public. Thus, usually the dialogue between the stakeholders (public – policy makers – practitioners) faces difficulties and the public information and participation process fails.

There are several attempts to achieve better practices covering these gaps of conventional procedures of noise control and public involvement. Three dimensional representations and virtual reality simulations (Murphy, Rice, and Meskell 2006; Kurakula and Kuffer 2008; Law et al. 2011) have shown promising results to overcome these issues. With the recent developments in VR technology and auralization techniques, it is much easier to communicate complex noise information making it audible and present it in its multisensory context (Maffei, Masullo, and Basturk 2011). Thus the general public can experience the urban environment with the changes in its aural and visual aspects in a realistic way and understand noise information without any prior knowledge of complex noise indicators.

This paper introduces an innovative approachwhich makes use of virtual reality technology to complement conventional noise control studies through active participation of the effected people (end users) in decision process. With this approach it is intended to enable an easy and intuitive comprehension of noise problems so as to encourage non-technical stakeholders to participate in solution seeking and decision processes. In collaboration with the Municipality of Malaga, the proposed method is applied to an actual project which deals with noise from places of entertainment and agglomeration of people.

2. What is Virtual Reality?

Virtual reality (VR) is a thriving technology which serves wide range of activities; basically psychological therapy, technical training and education in numerous fields, social and professional networking, gaming, art and any kind of design activity including urban design. In broad terms, virtual reality can be defined as an environment generated in the computer, which the user can operate and interact with in real-time. Virtual reality systems employ various output devices (effectors) in order to reproduce full spectrum of sensory information, and input devices (sensors) which provide lifelike interaction.

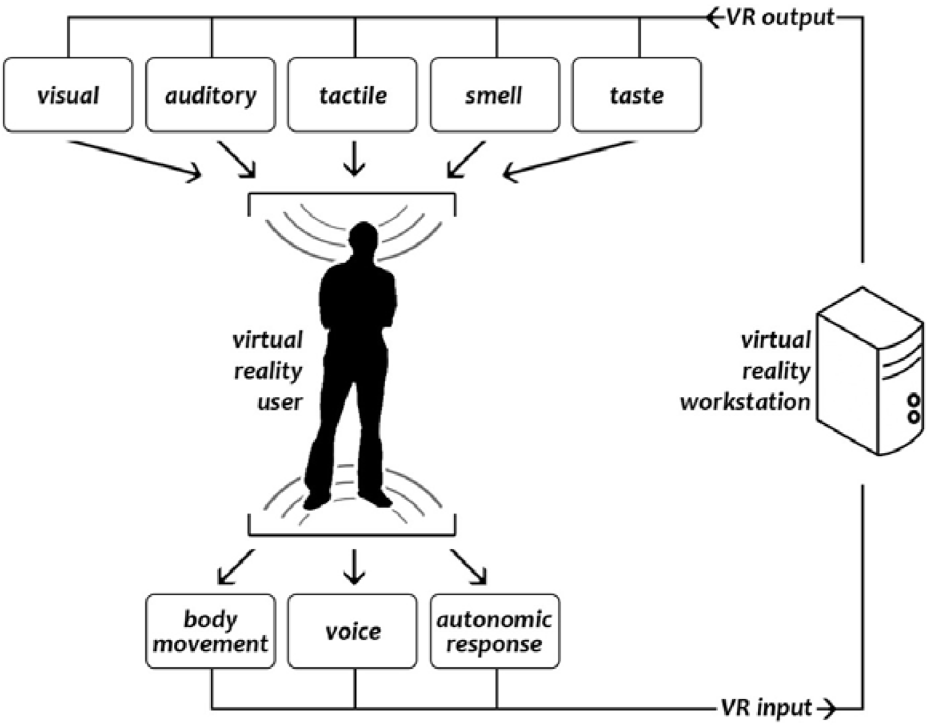

Figure 1. Range of possible input (sensors) and output (effectors) devices for a VR system (adapted, Biocca and Delaney 1995).

Realistic audio representation is important in virtual reality applications as it enhance the sense of immersion and spatiality. In the last decade, scientific research is engaged in improving the auralization systems which is "the technique of creating audible sound file from numerical (simulated, measured, or synthesized) data"(Vorländer 2008) . Auralization techniques for indoor environments are notably advanced but for complex outdoor environments it is still an important challenge to achieve real-time auralization due to computational shortcomings. In order to lower computational load of auralization for complex outdoor environments with relatively higher number of sources and higher level of interaction, perceptually plausible resulting sounds are usually aimed rather than physically correct results, in outdoor auralization processes (Funkhouser, Min, and Carlbom 1999; Tsingos, Gallo, and Drettakis 2004; Vorländer 2008).

3. Virtual Reality in Noise Action Planning

The proposed method is based on the use of virtual reality technologies to enable end users, who do not have technical acoustics knowledge, listen and see a priori the predicted impacts of proposed corrective measures. In this way, users can comprehend the noise control measures in an intuitive manner, generate their own opinion on the issue and actively participate in decision making. As it is shown in the figure, the proposed method includes the virtual reality design step in addition to the conventional steps of noise action planning.

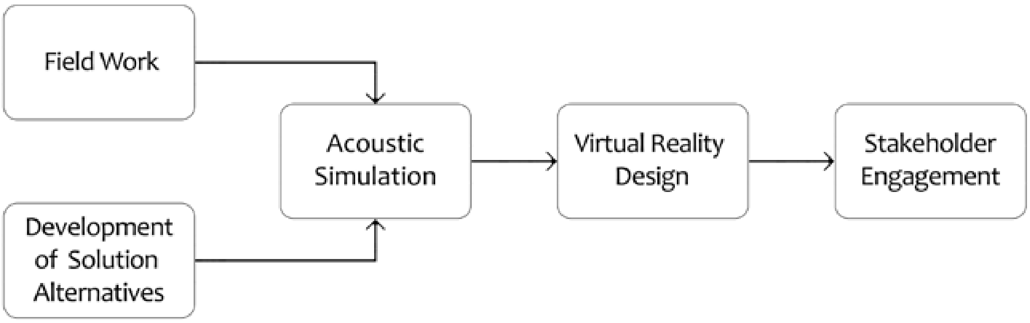

Figure 2. Steps of the proposed method.

In accordance with the defined steps, field work comes first. In this step, in addition to the usual techniques, it is necessary to capture detailed visual (video&photo shooting) and aural (audio recording) information that will help to depict the existing situation of the studied area in virtual reality design step. Captured visual and aural materials provide input to the acoustic simulation step together with the developed solutions (corrective measures). In the acoustic simulation step, acoustic models of the study area (existing situation) and each of the solution alternatives should be prepared in order to predict the noise attenuation in case of application. In the next step, the objective is to create realistic audiovisual depictions of the solution alternatives. In this context, to obtain a realistic audio representation of the design alternatives, audio material captured in situ should be convolved with signal processing algorithms in accordance with the noise attenuation values extracted from the acoustic simulation. This process should be realized for multiple receiver points which will cover the possible navigation area and head orientation of the virtual reality user.

Afterwards, these obtained auralizations should be merged with visual models so as to complete the virtual reality application. This final virtual reality application should introduce an interactive and immersive interface to its user letting him/her to navigate freely in these environments. The last step of the proposed method is public information. In this step it is intended to present the resulting virtual reality application as a common frame of reference to the stakeholders and enhance communication and the understanding of the problem. Thus better informed stakeholders can contribute to further decision making processes.

4. Project Plutarco

Places of entertainment are a major source of neighborhood noise problems in Europe. The statistics show that the main reason for noise complaints in Spain is entertainment activities (35% of all complaints (Contaminaciónacústica 2005)). The noise from entertainment activities arise not only from amplified music but also from agglomeration of people on public spaces during night time in residential areas. Being directly related to behavior of individuals and to culture and lifestyle of communities, for such noise problems do not exist neither standardized assessment methods nor easy solutions.

In particular, in Malaga (Spain), noise problems from entertainment activities are focused on a recently developed residential zone (district of Teatinos-Universidad). The rapid growth of this zone caused proliferation of commercial activities in the area without giving any chance to assess progressively its acoustic and environmental impacts. Initial noise complaints followed the emerging noise problems in 2005. In 2007 residents of the mentioned district founded an association against noise(Asociación de Vecinos El Romeral Contra El Ruido, 2014). Efforts to solve the problem with bilateral agreements between the association and the business owners gave no result and in 2008 the municipality started a study to analyze the situation to take a legal action. The study showed evidence of high noise levels but, according to the legislation in force, it was not sufficient for a legal action by the municipality(AvanceSobre La Situación de La Zona Del Romeral, 2008). Between 2008 and 2013, the number of entertainment venues has increased by approximately 37%, outdoor seating of these premises occupied major part of the sidewalks, the noise problem and related complaints persisted. For this reason in 2013 a mediation and solution seeking process has been started in which the proposed method employed.

4.1. Field Work

In accordance with the proposed method, a series of fieldwork was carried out in a selected area on Plutarco Av. where noise problems concentrate.

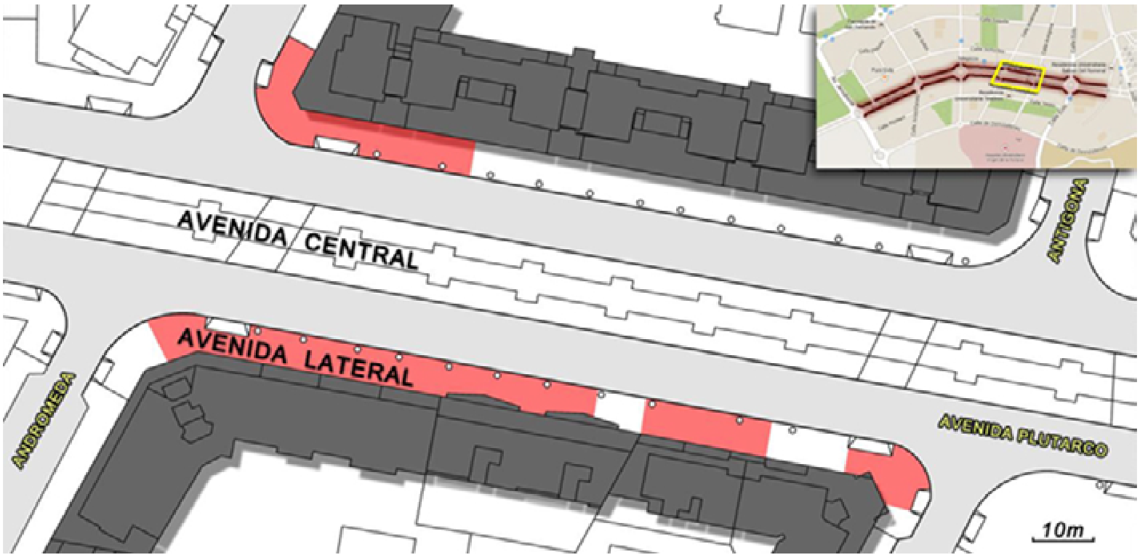

Figure 3. Plutarco Avenue and the selected study area (top-right). Outdoor seating areas of entertainment venues are marked in red.

During August and September 2012, acoustic measurements, audio and video recordings, vehicle and pedestrian (users of outdoor seating of entertainment venues) traffic counts were conducted especially in weekend periods when the conflict was more noticeable.

Audio recordings (16 bit/44.1 kHz) were realized using a portable two-channel device in different timeframes of the day -12:00, 18:00, 21:00, 23:00, 01:00- along the center line of the avenue and the south sidewalk. Concurrently, sound pressure levels were measured with a Larson Davis 824 sound level meter. In addition, 24hrs long audio recordings and measurements were conducted at a fixed point in a selected first floor residence. As shown in figure 4 the selected measurement point is situated just above the entertainment venues.

Figure 4. 24hrs long measurements at a first floor residence.

The results of the fieldwork show that outdoor seating on sidewalk can accommodate approx. 220 people and the point of highest gathering of people is around 11 p.m. (65% occupancy), henceforward, even the number decreases gradually, the presence of people on sidewalk lasts until about 3 a.m.

The change in sound pressure levels throughout the daywas studied based on 24hrs long measurements. As shown in figure 5, between 9 a.m. and 3 a.m. sound pressure level does not show significant variations. However, it is expected to see a significant decline in sound pressure levels starting from 11 p.m. as the night time period (11 p.m. – 7 a.m.) require lower noise levels to avoid sleep disturbance. Particularly, at his point, the measurements show that sound levels persist between hours 11 p.m. and 3 a.m. because of the noise from outdoor seating of the entertainment places.

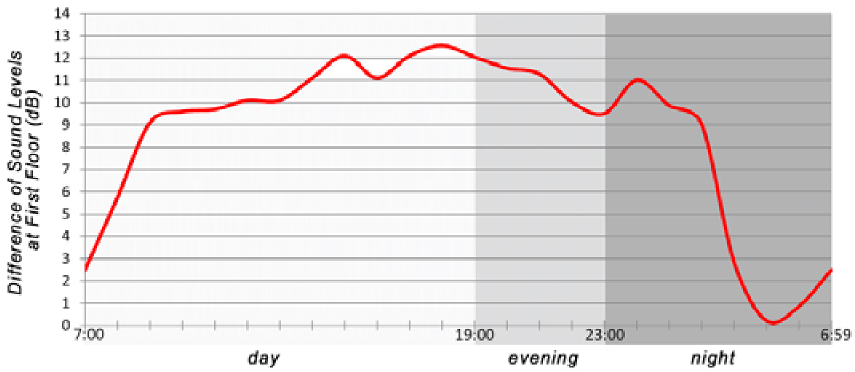

Figure 5. 24hrs long measurements at a first floor residence.

4.2 Development of Solution Alternatives

In this study, it is intended to involve all stakeholders in solution seeking process rather than a top-down process with concrete decisions. Within this context a series of solution alternatives were proposed in order to present an initial framework to the stakeholders and encourage participation. The proposed solution alternatives:

- Introduction of absorbent awnings on outdoor seating of each entertainment venue
- Introduction of a pergola along the sidewalk
- Covering the sidewalk with sound absorbing carpet
- Limiting the number of tables to half of the existing situation

4.3. Acoustic Simulation

After determining the solution alternatives, three-dimensional models of the study area and the solution alternatives were prepared employing a 3D modelling software. These models were transferred to CadnaA (DataKustik GmbH 2012) noise prediction software in order to analyze how the corrective measures might affect the acoustic environment.

In acoustic modelling, outdoor seating areas were characterized with area sources at 1 m height above the terrain. Considering the characteristics of human voice, emission of these sound sources is adjusted to 86 dB sound power level between 500Hz and 4000Hz(Sepulcri et al. 2011). One other sound source, road traffic, was also modelled based on the traffic counts realized in situ.

On the other hand, in order to simulate the corrective measure that offers reducing the number of tables by half, the sound power level ofarea sources was reduced by 3 dB. In acoustic modelling of the other solution alternatives, commercially available and acoustically tested products were preferred (Diseño y Validación de Carpas de Exterior Para la Minimización del Ruido Por Actividades de Ocio 2011).

Table 1. Parameters related to the acoustic modelling of the solution alternatives.

Solution alternative	Description	Sound absorption coefficient	Altitude above terrain (m)
Awning	absorbent	0.3	3.45
Pergola	reflective	0.2	4.00
Carpet	absorbent	0.3	0.02

In order to complete the acoustic modelling, 2 receiver points were defined. One of them (R1) was located at the same place where the 24hrs measurements took place at a height of 4.7m above the terrain. The other receiver point (R2) was located on the center line of the avenue at a height of 1.6m above the terrain (Figure 6). The receiver point R1 was intended to calculate the noise attenuation at the first floor residences in case of application of the corrective measures. On the other hand, receiver point R2 was employed to test whether the reflective pergola increases the noise immission level in other parts of the avenue.

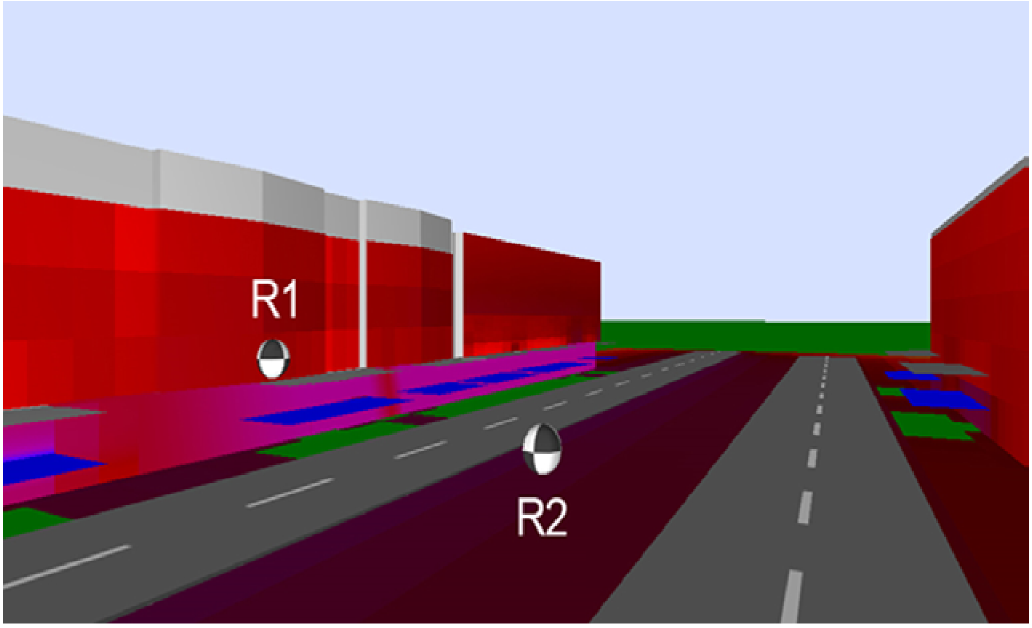

Figure 6. Acoustic model of the study area and the receiver points.

The results of the acoustic simulation show that there is no significant impact of the solution alternatives at the receiver point R2. The results obtained at receiver point R1 are shown in the following table.

Table 2. Noise attenuation values obtained at R1 receiver point.

Solution alternative	Calculated sound sources	Lp (dB)	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Pergola	outdoor seating + road traffic	8.6	6.2	8.1	8.8	8.3	8.5	10.8
	road traffic	7.4	5.8	6.8	7.4	7.4	7.7	8.7
Awning	outdoor seating + road traffic	2.7	1.6	1.8	2.3	2.5	3.1	4.6
	road traffic	1.9	1.6	1.8	1.9	1.9	2.0	2.0
Pergola + Awning	outdoor seating + road traffic	8.7	6.2	8.1	9.0	8.4	8.6	11.0
Pergola + Awning + Carpet	outdoor seating + road traffic	8.7	6.2	8.1	9.0	8.4	8.6	11.0
Reduction of outdoor seating by 50%	outdoor seating + road traffic	0.5	0.0	0.0	0.3	0.4	0.7	1.5
Reduction of outdoor seating by 50% + Awning	outdoor seating + road traffic	2.9	1.7	1.9	2.5	2.6	3.3	5.3

As seen in Table 2 the corrective measure that introduces pergola has the highest noise attenuation value with 8.6dB. On the other hand, the awning solution offers 2.7dB of noise reduction at the receiver point R1. Different combinations of these solutions (pergola + awning and pergola + awning + carpet) do not offer significant improvements respect to single applications. Even there is no significant effect in the results, the carpet solution may play an important role in reduction of noise annoyance at night-time as it damps the noise generated by the moving tables and seats during the closure of the entertainment places. The results also show that reduction of the outdoor seating by half does not offer a significant improvement.

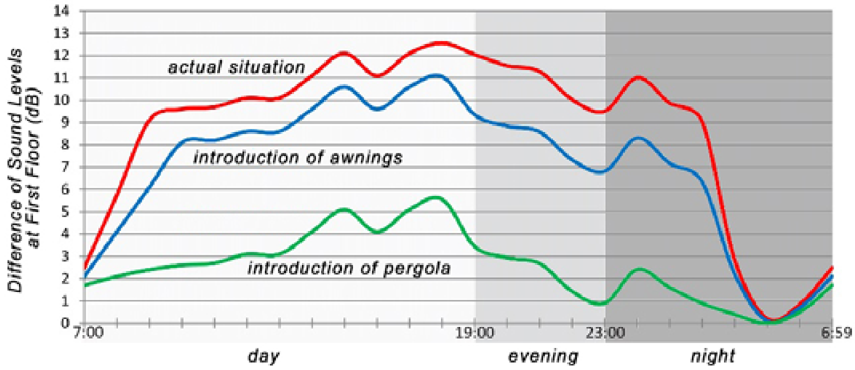

Figure 7. Reduction of environmental sound levels by proposed corrective measures. The lowest value indicated as 0dB.

4.4. Virtual Reality Design

In this step, the objective is to create realistic audiovisual depictions of the solution alternatives in virtual reality medium. Within this scope, first, previously captured *in situ* audio recordings were analyzed and various soundscapes that represent existing situation were generated. In addition to this, these soundscapes (audio signals) were processed (Perea Pérez et al. 2010)with appropriate attenuation filters which had been calculated previously by noise prediction software, so as to obtain new soundscapes that represent post-application situation. This signal processing step was repeated for each solution alternative.

After obtaining the audio component, the next step is the preparation of the visual component of the virtual reality application. Previously prepared (in the acoustic simulation step) simple 3D model was improved by adding building façade elements, street furniture and vegetation. Also, the solution alternatives were detailed and placed at corresponding locations (Figure 8).In order to increase the visual realism, previously captured photos and videos were processed and applied as textures (texture mapping)on 3D model.

Figure 8. Still images from the interactive application. Introduction of awnings (left) and pérgola (right).

The completed visual model was merged with the prepared soundscapes employing Worldviz Vizard (Worldviz LLC 2014) virtual reality development software. In this stage, programming is the main task in order to define how each element will act in virtual environment and interact with other elements. The final virtual reality application offers an interactive and immersive interface that the user can switch between scenarios (solution alternatives) and walk through the Plutarco Av. while he/she listens and observes in an intuitive manner his/her surroundings. In this case, considering the complexity of the immersive virtual reality hardware and difficulty to reach the large target audience, an informative video was extracted from the mentioned interactive application. This informative video represents a virtual walk in Plutarco Av. showing the existing situation and the proposed solution alternatives.

4.5. Stakeholder Engagement

The informative video, details of its preparation process and other information related to the noise issue were presented to the stakeholders through following mediums:

- Professional forums/meetings: The project was presented for the first time on 12 April 2013 at Dept. of Environment and Sustainability of Municipality of Malaga and discussed by the noise control specialists. On 23 April 2013, the project was presented to the urban planners, environmental engineers and economists in a conference titled "Effects of Acoustics on Urban Planning", which was organized by Municipality of Malaga. Later on, the project was presented and discussed in two other conferences in Spain.
- Local press: On 13 May 2013 a press conference was held and the Plutarco Project was presented. By means of this, the project reached to a large audience through local newspapers and news portals.
- Meetings with stakeholders: On 22 May 2013, a meeting was held with the residents and the business owners of the district Teatinos-Universidad in order to discuss the

project and get feedback about new suggestions for the solution of the noise problem.

- Internet: The prepared informative video and a poster which explains the details of the project were published on the website of the municipality. Also a dedicated webpage was prepared for the project.

The project aroused the interest of stakeholders in relation to noise problems in PlutarcoAvenue. During the professional forums, many professionals from different backgrounds (noise control specialists, urban planners, architects, economists and politics)contributed to gain awider insight into the problem. On the other hand, the residents of the district found possibility to discuss and express their opinions for the solution of the problem, both on web (discussion forums related to the press news) and directly via the district meeting held by the municipality. At the same time, the project has been a major awareness campaign for general public of Malaga as it has brought the noise problem from entertainment activities into view.

The stakeholder engagement process has not ended up yet with a definitive solution. Notwithstanding, business owners, on their own initiative started to consider introducing sound absorbent awnings in their premises. Almost all of the entertainment venueshaverecently installed new awnings to participate in the solution. Today, the municipality is studying the efficiency of these installed awnings realizing in situ measurements and interviewing local people in order to encourage a wider and correct application of this solution in future.

Figure 9. Installation of new awnings at entertainment venues.

5. Conclusion

This paper introduces an innovative approach to noise control practice that usually lacks in public information and participation as it conventionally uses complex acoustic parameters to describe noise issues which are not comprehensible for general public. In this context, a theoretical framework which makes use of virtual reality technology to enhance public information and participation processes in noise action planning process is developed.

Also, the proposed method is implemented within Plutarco Av. noise action planning study and its efficiency is proved with this real life example. The results demonstrate that it is a promising approach for the solution of the complicated noise issues related to behavior of individuals and to culture and lifestyle of communities. Employing the proposed approach, the municipality had the opportunity to evaluate the perception and the opinion of the public before implementing any corrective measure. Moreover, with this approach, the overall success of the action plan is ensured as it is the product of a consensus of the stakeholders.

REFERENCES

Adams, Mags D., Neil S. Bruce, William J. Davies, Rebecca Cain, Paul Jennings, Angus Carlyle, Peter Cusack, Ken I. Hume, and Christopher J. Plack. "Soundwalking as Methodology for Understanding Soundscapes."In Institute of Acoustics Spring Conference 2008 – Widening Horizons in Acoustics, 552–58. Reading, UK.2008.

Asociación de Vecinos El Romeral Contra El Ruido. 2014. Accessed June 8. http://elromeralcontraelruido.wordpress.com/.

Ayuntamiento de Málaga - Área de Medio Ambiente y Sostenibilidad. AvanceSobre La Situación de La Zona Del Romeral. Málaga, Spain. 2008.

Biocca, Frank, and Ben Delaney. Immersive Virtual Reality Technology.In Communication in the Age of Virtual Reality, 57–124. Hillsdale, NJ, USA: L. Erlbaum Associates Inc.1995.

Botteldooren, Dick, Bert De Coensel, Timothy Van Renterghem, Luc Dekoninck, and Dominique Gillis. The Urban Soundscape: A Different Perspective.In Sustainable Mobility in Flanders: The Livable City, 177–204. Belgium: Institute for Sustainable Mobility, Ghent University. 2008.

Brown, Lex. The Noise Control and Soundscape Paradigms: Complementary Approaches to a Better Acoustic Environment.In 36th International Congress and Exposition on Noise Control Engineering, Inter-Noise 2007. Istanbul, Turkey.2007.

Defensor del Pueblo. Contaminaciónacústica.Madrid, Spain. 2005.

DataKustik GmbH. Cadna A Reference Manual.Greifenberg, Germany.2012.

Aitex. Diseño Y Validación de Carpas de Exterior Para La Minimización Del RuidoPorActividades de Ocio.Alcoy, Spain.2011.

Fiebig, André, Viviane Acloque, SeckinBasturk, Maria Di Gabriele, Marko Horvat, Massimiliano-Masullo, RetoPieren, et al. Education in Soundscape - A Seminar with Young Scientists in the COST Short Term Scientific Mission „Soundscape - Measurement, Analysis, Evaluation".In 20th International Congress on Acoustics - ICA 2010. Sydney, Australia. 2010.

Funkhouser, Thomas, Patrick Min, and Ingrid Carlbom. Real-Time Acoustic Modeling for Distributed Virtual Environments.In Proceedings of the 26th Annual Conference on Computer Graphics and Interactive Techniques, 365–74. Los Angeles, CA, USA.1999.

Kang, Jian. Urban Sound Environment.Taylor & Francis Group.2007.

Kurakula, Vinay Kumar, and Monika Kuffer.3D Noise Modeling for Urban Environmental Planning and Management.In REAL CORP 008 Proceedings, 517–23. Vienna, Austria: CORP, Competence Center of Urban and Regional Planning.2008.

Law, Chi-wing, Chee-kwan Lee, Aaron Shiu-waiLui, Maurice Kwok-leung Yeung, and Kin-che Lam. Advancement of Three-Dimensional Noise Mapping in Hong Kong.Applied Acoustics 72 (8): 534–43.2011.

Maffei, Luigi, Massimiliano Masullo, and Seckin Basturk. Potentialities of the Immersive Virtual Reality in Environmental Noise Annoyance Studies.In 42nd Spanish National Congress on Acoustics - TecniAcustica 2011.Cáceres, Spain. 2011.

Murphy, Enda, Henry J. Rice, and Craig Meskell. Environmental Noise Prediction, Noise Mapping and GIS Integration: The Case of Inner Dublin, Ireland.In 8th International Symposium Transport Noise and Vibration. St. Petersburg, Russia.2006.

Perea Pérez, Francisca, Seckin Basturk, Massimiliano Masullo, and Ricardo Hernandez. A Tool for Environmental Auralization of Stationary Sound Sources.In 1st European Congress on Sound and Vibration - EAA EuroRegio 2010. Ljubljana, Slovenia. 2010.

Schafer, R.M. The Tuning of the World. Borzoi Book. New York, NY, USA: Knopf.1977.

Schulte-Fortkamp, Brigitte. The Tuning of Noise Pollution with Respect to the Expertise of People's Mind.In 39th International Congress and Exposition on Noise Control Engineering, Inter-Noise 2010. Lisbon, Portugal. 2010.

Sepulcri, Daniele, Alessandro Buoso, Francesca Remigi, Angelo Scarpa, and Roberto Spinazzè. Valutazione Di ImpattoAcustico Di SorgentiSonoreCostituite Da Aggregazioni Di Persone.In 38th National Congress of Italian Acoustical Society - AIA 2011. Rimini, Italy. 2011.

Tsingos, Nicolas, Emmanuel Gallo, and George Drettakis. Perceptual Audio Rendering of Complex Virtual Environments.In SIGGRAPH 2004.Los Angeles, CA, USA.2004.

Vorländer, Michael. Auralization: Fundamentals of Acoustics, Modelling, Simulation, Algorithms and Acoustic Virtual Reality. RWTHedition.Springer.2008.

Vorländer, Michael. "Virtual Acoustics: Opportunities and Limits of Spatial Sound Reproduction for Audiology." In 39.DGMP Tagung. Oldenburg, Germany.2008.

Worldviz LLC. "Vizard 4.0 User's Manual."Accessed June 8. http://docs.worldviz.com/vizard/.2014.