Acoustic smartness and sustainability in urban planning and building design

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Summary

Solutions for the implementation of acoustic quality in urban areas and buildings have been proposed in different ways. In the frame of circular economy, smart and sustainable actions involving acoustics have been implemented, not only privileging sustainable acoustic materials but also applying new approaches like holistic and multisensory design of living spaces, temporal design and global comfort, connected with acoustics and noise protection. Users opinion have been taken in account as well, in terms of noise awareness an participatory design.
In this paper, starting from an overview of the most diffused methods for noise control and acoustic quality design of outdoor and built environment, a special evidence is given to approaches that consider smartness and sustainability, as derived by the experience of the authors.

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1. Introduction

We live in the anthropocene [1], a new geological epoch in which the habitat, defined as the place whose characteristics allow a given species to live and develop itself, is predominantly urban, linked to urban ecosystems and urban development models. Habitat influences the quality of life of the species that inhabit it. The design of functional elements and sources of well-being perceived in urban living spaces represents a new frontier to be known and explored and includes among its defining data the definition, correction and qualification of the sounds that contribute to making pleasant the use of a space and the protection against disturbing noises. The definition of sound space, as significant element for the aesthetic and functionality in the urban context is one of the basic elements of holistic design, a vision and methodology of architecture that aim to develop integrated, sustainable and environment friendly solutions. The need for an innovative approach to noise control in urban environments, which could overcome the mere compliance with noise limits set by laws and regulations, often leaves aside the cultural and functional contexts of regulated spaces. The consideration of the acoustic well-being, as perceived by those who live and animate urban living environments is an emerging approach, very useful for the correct assessment of the acoustic quality and for the design of the improvement of the usability of squares, urban green areas, public spaces.

2. Soundscapes and identity of places

The sound identity of places, identified via experiences based on Soundscapes Analysis combined with aesthetic, holistic and serendipity parameters that characterize it and link it to the variables of global comfort, is producing remarkable results. Research on the soundscape has acquired considerable scientific relevance in recent years, passing from only 5 works published in international journals in 2000 to more than 100 publications in 2016 [2].

To confirm this importance, the International Standard Organization in 2014 with ISO 12913-1: 2014 provided a definition and a conceptual picture of the soundscape, explaining the relevant factors for the measurement and reporting of studies and research concerning the soundscape, as well as for the planning, design and management of urban soundscapes.

The definition of noise as "sound out of place" given by W. Clarkson Kaye [3], takes on a meaning that can be read as a suggestion for performing analysis and corrective design of soundscape elements in urban scenarios, where every possible judgment of objective quality is subordinated to the evaluation of perceived quality linked to cultural factors and to people's life experiences. In urban planning, in the design of external and built spaces, the "immersive" perception of the landscape cannot be ignored: it represents the perceived surroundings of the observer, "the" world around us "and not" in front of us". In this transition from object of contemplation to a living space, perception of landscape is necessarily multisensory and the sound component becomes an important element in definition and use of the landscape.

As an example, we can remember the opening scene of "La La Land", the award-winning musical movie, blockbuster of 2016: the writer and director Damien Chazelle decided to set it in the chaotic ring road of Los Angeles, blocked by a colossal traffic jam. In this urban setting, where in the background you can see the natural landscape of the surrounding hills, the sound effects combined in harmony with music are car counters, engines, horns and voices, the song “Another day of sun” soon assumes the connotations of a hymn to the city, to the opportunities that the city offers and to its flaws, including the blocked highway and those thousands of cars stopped on the roofs of which a tribal dance choreography is unleashed.

The sounding landscape of our time, and of our cities in particular, is therefore the perceived neighborhood of every living being, which also becomes a common around shared cultural models are used. As a true autopoietic system, it redefines itself and within itself sustains, modifies and reproduces itself, thanks to the voluntary or involuntary contribution of those who live there, no longer as an observer but, fully, as an element of the dynamic system that we call urban soundscape.

Which sounds, which sources are part of the soundscape of a certain urban space and modify it, until creating a variant, perceived differently from the original? How do the sounds produced inside or outside the receiving urban environment propagate, and change, space for listening and

perception? And how to catalog urban, harmonic and non-harmonic sounds, and noises, the "sounds out of place"?
The idea of exploring the sounding soul of cities, from many possible points of view, through the sounds and the urban soundscapes generating and characterizing it, should urban interventions appointed by experts, researchers, designers, who operate in very different disciplines, but have developed this precise idea of the sound soul and soundscapes, as a possible derivation of their academic and professional experiences.
We can talk in a systematic way of the sound footprint of the cities and the method of sound walks, of the natural and artificial sounds of our era defined anthropocene, where the impact of human activities and associated anthropophonies is redefining the acoustic climate of the planet. We can talk about noise and annoyance, increasingly considered as a benchmark for the definition of perceived acoustic suffering, also in terms of designing urban spaces and built places for speech and listening. In the last years new methodological approaches and interesting case studies deriving from European projects have been developed and will be shortly reported in the following chapters.
Among these experiences, it is important to note that in urban planning, besides the main issue that drive the designer and planners choices we can talk of silence, of the relationship between noise and music, of the contamination between musical compositions, natural sounds and everyday sounds.

3. Smartness and sustainability in urban planning of European cities

The EC Environmental Noise Directive [4] established the production and review of 5-yearly strategic noise maps and action plans which are largely focusing on number of exposed people.
The acoustic comfort in a city requires consideration of dwellings, streets, parks and areas where people gather. Neighbourhood noise is also a significant factor in the perceived quality of urban residential areas, yet it is not considered in END maps, as highlighted by various EU funded projects [5] [6]. Sound quality maps can provide an useful integration to noise maps by accounting for the meaning of sounds and the context. In addition, the ongoing transition of the urban tissue changes the sound focus from sources that can be managed at strategic level (traffic, industry) to neighborhood sounds.
These challenges are better faced with an acoustic sensor network and local citizen participation, as is being demonstrated by other projects [7]
The involvement of citizens is very important as shown in the LIFE+ projects HUSH [8] and QUADMAP [9]. However, a lot needs to be learned about the motivation of the public and how to engage them in a really effective process of participatory planning and design [10]
Dynamic aspects such as safety and mobility - key topics in smart cities - are best governed with continuous monitoring. However the collected big data needs suitable reduction to become meaningful to non-specialist. And the non-rethoric question “What to do with data?” assume a crucial significance in this scenario.
Finally, the willingness for society to accept and exploit new sensor technology - and in particular sound monitoring - depends on the balance between negative feelings of perceived invasions of privacy and positive feedbacks of proudly being a member of crowdsourcing mechanism.
On the other side, bringing the newest scientific understanding on urban sound quality to cities and citizens and by providing better information services, smartness and sustainable approaches will help to improve quality of life but also to promote the cities cultural and touristic attractiveness.
By harmonizing indicators derived from sound and air pollution sensing and making them more accessible to the public but also by investigating the participatory process, a smart and sustainable approach to urban planning and design of public places will stimulate citizen participation, direct governance and the evaluation of their living environment. This strengthens social cohesion by increasing the feeling of being part of a community. Engaged citizens will start changing their behavior towards urban areas. Participation is also a form of coping which mitigates a person-environment mismatch.

4. Smart and sustainable solutions in urban planning

Among the various possible examples derived by recent studies and projects sensor networks and

noise low emission zones seems to show a high level of applicative interest.
Sensor networks will provide detailed information about the dynamics of the city more efficiently. This information could be used to inform urban managers, but it could also be used for steering. The idea of Noise low emission zones, has been developed in the frame of MONZA project [11]. It shows how smart and sustainable traffic management can generate multiple benefits: reduction of traffic noise, carbon dioxide emission and energy consumption (and costs), all closely related. Information on use of public space (e.g. for lighting), non-motorised mobility, special events, etc. could be equally useful for managing the city of the future.
The definition, the criteria for the identification and the management methods of a Noise Low Emission Zone, the effectiveness and the potential benefits on noise reduction are studied in the frame of the project: one of the main interesting implemented top down measure is the design and implementation of a smart noise monitoring system, as a prototype, composed by low cost microphones, keeping in mind the aim of a long-term monitoring activities. These are expected to be useful to understand the variability of acoustic climate in the pilot area with mainly reference to "LAeq" parameter.
The DYNAMAP project [12] aims to develop a dynamic acoustic mapping system able to detect and represent in real time the acoustic impact generated by road infrastructures. The project is part of the Directive 2002/49 / EC (END) of the European Parliament relating to the assessment and management of environmental noise with the aim of making the updating of noise maps more streamlined and less expensive, facilitating the dissemination of results and simplifying the repetition of mapping activities through the preparation of a system of integrated data acquisition and processing. The system involves the use of low-cost sensors that directly measure the sound pressure level generated by the source at significant points of the road network and a software for the management, processing and representation of acquired data based on a general purpose platform of GIS type for updating maps in real time.
The real-time update of the maps is achieved by scaling a set of pre-calculated basic maps relating to a particular sound source present in the area to map and/or to different weather and traffic conditions. The selection of the basic acoustic maps and the subsequent scaling is performed according to the information collected by the installed sensors. The basic maps of each source, appropriately scaled, are then added together to form the global acoustic map.

5. Smartness and sustainability for the built environment

Authors have been involved in a study regarding recycled and sustainable materials for building insulation.
The main sustainable acoustic materials exhamined are recycled rubber from exhausted tires, polyester fiber, recycled textile fibers, polylactic acid fibers (corn), vegetable fibers (cotton, hemp, coconut, cellulose, etc.), animal origen fibers (sheep wool, goose feathers, etc.), evergreen plants.
A Project, funded by Ecopneus, the non-profit consortium for the tracking, collection, processing and final destination of end-of-life tyres (ELT) created by the major manufacturers operating in Italy, and developed by Vie en.ro.se. ingegneria, was launched in 2014 to analyze the effectiveness of these building materials and systems, with particular attention to the solutions that use recycled rubber dust.
The project has been structured through various studies and activities, including research and measurement campaigns performed in laboratories and on field. During the various phases, the acoustic, thermal and structural properties of the materials have been considered and analyzed.
Three volumes have been published reporting the main results of the study.
The first volume regards acoustic, thermal and structural properties of materials: it reports a typological study and cataloging of building products using recycled materials, divided by categories of use like resilient floors, anti-vibration materials, materials for acoustic insulation of walls, machineries, etc. The volume deals with the typical applications of these materials and building systems and concludes with summary data and tables on effectiveness of recycled products.

The second volume deals with the installation of recycled rubber insulators. It is a rational collection and analysis of manuals for the installation of products in the various typological categories defined in volume 1. In order to take in account the peculiarities of rubber-based products compared to other products, further study was carried out by comparing with some of the major companies involved in the study who have made available their work experience in the field over the years. The main topics are insulation of horizontal partitions of a building (mixed floors, wooden floors, raised floors, countertops, terraces, stairs, etc.), insulation of vertical partitions of a building (hollow space, wall plating, wooden walls); insulation of foundations of a building; insulation of building's facilities (continuous and discontinuous operation).
The third volume deals with the performance of rubberized insulators, defined by the collection of experimental data obtained from on field tests. Performances measured in typical scenarios were compared with the values obtained from calculations in order to evaluate the reliability of the numerical predictions with respect to the experimental values.
One of the most demonstrative cases that has been implemented in the frame of the project is the acoustic requalification of the Rispescia Auditorium, located in a church, transformed in a multipurpose hall, for conferences, concerts and other events. In the original scenario the high reverberation time made any perceived sound confused and scarcely intelligible. The goal of the project has been to create an acoustically comfortable and versatile space, provided for different types of functions. Solutions have been designed by choosing products that results environmentally sustainable and fully respectful of the architecture of the church as well.
A 3D model of the church has been created and calibrated by comparing the reverberation times measured in significant environmental points with the simulated reverberation times in the same locations.
The proposed acoustic solutions have been designed keeping in mind the virtuous constraint of sustainability for all selected construction materials in order to create a space that is eco-compatible and aesthetically attractive as well.
Only natural materials have been used, being them recycled and/or recyclable (plants, wood, recycled rubber from discarded tires, polyester from recycled PET bottles).
The project of acoustic correction of the church involved design and construction of three integrated solutions summarized below:
1. sound-absorbing evergreen plant coating for the improvement of absorption on the back wall of the church;
2. sound absorbing curved acoustic panels suspended from the ceiling (36 baffles arranged in parallel rows);
3. mobile network of double-face reflecting/absorbing panels on wheels for acoustic separation in different configurations of sub-areas.
Depending on their position and side, the reflecting/absorbing panels curved panels can perform a double function:
- sidewalls lining panels that, depending on the side facing the interior of the church, are sound-absorbing or reflecting and diffusing sound;
- acoustic separation elements between different sub-areas of the hall.
The variable acoustics of the church, required to ensure optimal acoustic conditions in correspondence with the different uses is determined by the combination of three solutions and by the configuration of movable panels.

The more general idea that in the design of buildings, architects should explore the notion and role of acoustic architecture, has been developed by the authors in the frame of a structured collaboration with Ab Rogers Design Studio.
Some projects have been developed for spaces designed to control sound, crafting it into something that brings its surrounding environment alive, giving it warmth and animation without compromising or impinging on private experiences. Rather than removing sound as part of acoustic design of a space, we have investigated the positive influence of the right sounds, of the impact of soft sounds to mitigate the effects of hard environments and how they can be seamlessly integrated into interior design and architecture, a fundamental part of the sensory programming of a space. In this way, good listening spaces are about achieving a sensitive balance. Silence can be intimidating and can act to inhibit natural, relaxed social interaction whether in a restaurant, a shop or a hospital waiting room. In this way, how a space sounds can be as important as how it looks in terms of the user experience - making them feel welcome or

uncomfortable depending on the private interactions in public places. As an example, in the design for the restaurant 'Ametsa with Arzak Instruction' in the Halkin Hotel, Mayfair we used a suspended ceiling raft to act as an acoustic baffle ensuring that you can hear perfectly what the people at your table are saying but not the conversations of those at the tables around you.
In this collaboration between designers and acousticians, we went further than just looking to mitigate these negative or 'bad' sounds, exploring the impact of positive sounds to create a sense of escape from harmful environmental factors.
In all these projects across commercial, cultural and healthcare sectors we have sought to create environments that are acoustically programmed to nurture the user - whether that means supporting evocative storytelling, sustaining private experiences in public spaces or providing peace and quiet - empowering them both to speak and to listen.

6. Awareness is important

As said in the previous chapters, the holistic (smart and sustainable) approach to plan and design comfortable urban soundscapes and buildings is based on the principle of maximizing the pleasantness of places and the global satisfaction of people, considering sustainability like a positive karma that can stop the planet's degradation and the discomfort of its inhabitants. In planning strategies and designing solutions for urban development a set of variables representing smartness and pleasantness can be defined, representing comfort level categories in terms of visual, thermal, acoustic, safety, energetic, cultural, social, welfare, etc. In the global comfort approach to noise control and noise mitigation, costs and benefits of actions become weighted sums which take in account social and induced costs and benefits defined by considering the values of different variables, allowing to achieve the primary objective of the design with one or more free secondary pleasant added benefits. Awareness and participatory design should be a part of the definition and implementation of this scheme, where action planners and solutions designers collect stakeholders and users opinions on strategic issues, useful for planning and designing phase.

Awareness and Participation are important keywords: their influence should be properly evaluated in every policy regarding noise control, considering also the inter-relationships among noise and other factors of global environmental comfort. Policy makers should start to consider acoustics and noise control as a matter of smartness in cities and as a good indicator as well. Public participation contributes to make better decisions because decision-makers have more complete information – in the form of additional facts, values, and perspectives obtained through public input – to bear on the decision process. They can incorporate the best information and expertise of all stakeholders. Decisions are more implementable and sustainable as they consider the needs and the interests of stakeholders and final users, that, by the way, can better understand problems and solutions, being more invested in the outcomes.

The International Noise Awareness Day (INAD), suggested in 1996 by the Center for Hearing and Communication (http://chchearing.org/noise/day/) is celebrated every year all over the world. A series of events addressed to the society with special emphasis to young people who are among the most sensitive parts of our society. In 2017, a wide awareness campaign in order to raise the interest of the European citizens towards noise and its effects on the quality of life and health on the occasion has been coordinated by the European acoustics Association (EAA) in collaboration with the DG Environment of the European Commission, for promoting and coordinating specialized activities during the whole year, among the EAA members Societies, the European and national authorities, the noise associations, schools, museums, etc. aiming that a wider public will receive the most accurate and scientifically correct information on noise effects.

Among the many initiatives, the very successful organization of two pan-European competitions for students of primary and secondary schools, with more than 4.500 participants that produced texts, drawings and recorded audio/video files related to typical noise and typical sounds of their places and countries.

The aim to raise awareness about sounds and noises that characterize landscapes and define the identities and soundtracks of places has been also in the screenplay of the cartoon "Noisella in Sound Space" produced by EAA for young people across Europe.

7. Conclusions

Climate change and radical transformations of the landscape that we are experiencing require profound reflections on how to design and build spaces for work and live. Urban areas, public and private buildings, should be thought designed in a sustainable and holistic way: to conceive human beings with their need for happiness and the environment surrounding them as separate elements is no longer reasonable.
In this scenario sustainability takes into account how we might live in harmony with the natural world around us, protecting it from damage and destruction. Sustainability and quality of life must be considered by those who administer and plan cities in all their aspects, considering open spaces and built environment. Urban action plans and design of new buildings should follow an encompassing view, based on the knowledge of nature, functions, and properties of the components, their interactions, and their relationship to the whole.
The professional acousticians can give qualified contributions for effective strategies and solutions for noise control, public health, land use and preservation.
The holistic approach to plan and design can be referred to acoustic design of urban areas and buildings: it is based on the principle of maximize the pleasantness of places and the global satisfaction of people, considering sustainability like a positive karma that can stop the planet's degradation and the discomfort of its inhabitants.

Developers of urban noise maps and urban noise action plans, acoustic planners and designer of actions and solutions for urban areas and buildings, should apply holistic approaches to noise mitigation and reduction of annoyance, creating new comfortable soundscapes in urban spaces, and protecting the new ones, making possible the listening of good sounds.

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