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SOUNDSCAPES: WHERE ARE WE?

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1. INTRODUCTION

Soundscape represents a step change in the field of environmental acoustics in that it combines physical, social and psychological approaches [Kang, 2006]. Although the term soundscape was introduced in the 1960s, significant attention to it has mainly been paid in the last decade or so in the field of community noise and environmental acoustics by researchers and recently by practitioners, including policy makers.

This paper aims to explore the current situation and future challenges in soundscape. Starting with a framework on research and practical needs in soundscape, and a brief introduction of some recent/current networks, activities, projects and publications, this paper then presents a systematic review of recent progress in soundscape research and practice.

2. A SOUNDSCAPE FRAMEWORK

To review the existing research and explore future challenges, it is important to establish a framework about what are needed, taking into account both research and practice facets. Such a framework is proposed in Fig. 1, where five main issues are considered [Kang and MC, 2008], as discussed below.

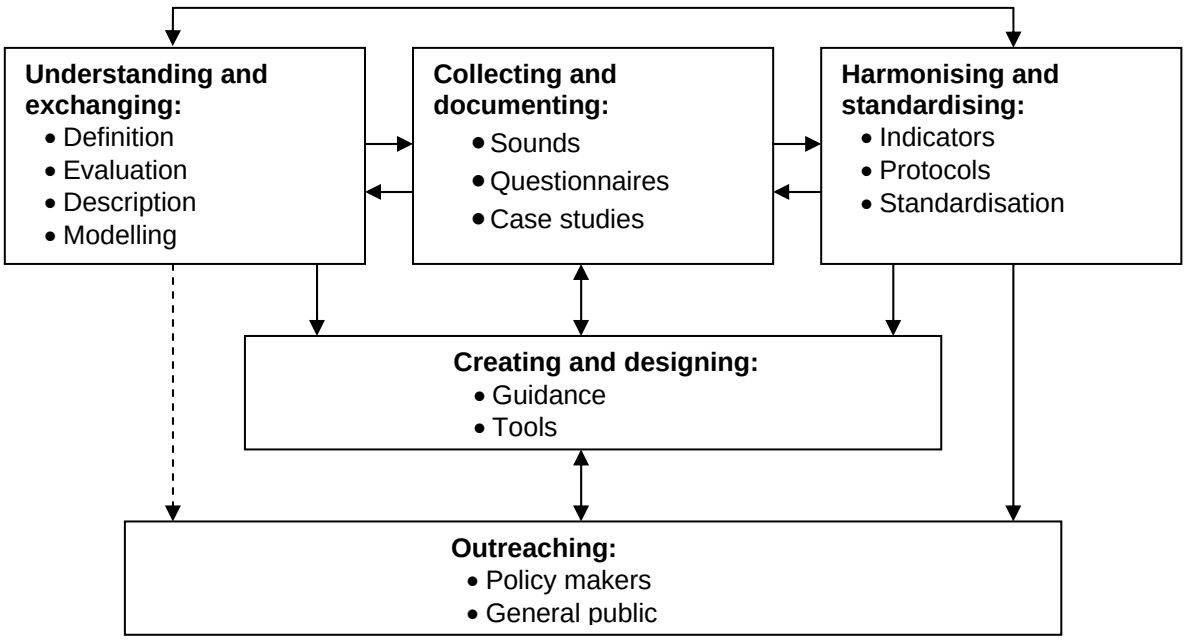

Fig. 1. Soundscape framework considering both research and practice facets.

(1) Understanding and exchanging. There is a need to better understand the overall and diverse effects of soundscapes on citizens, in positive or negative ways. For this, several facets needed to be considered:

- Soundscape *definition*, to define the scope.
- Soundscape *evaluation* with interdisciplinary cross-breeding of innovative and emerging scientific concepts and methods related to the main facets of soundscape research, connecting physiological (sensory), psychological, psycho-physical, cognitive, emotional, social, physical and architectural approaches. It is also important to examine cultural differences.
- Determining essential factors for soundscape *description*.
- It is important to integrate the knowledge acquired from different fields into explicit *modelling* (physics and computational intelligence).

(2) Collecting and documenting. Given the wide scope of soundscape, it is important to gather and maintain a repository of experimental *sound* data to be re-analysed and studied from inter- and trans- disciplinary perspectives. Also useful would be a database of *questionnaires*, and a database of *case studies*. Such databases will be an invaluable resource for scientists and practitioners for years to come, allowing effective testing of new models and insights.

(3) Harmonising and standardising.

- While soundscape has been researched from a range of viewpoints, it is important to review and harmonise the current vocabulary and methodology and consequently, develop a new set of exposure *indicators* to characterise sound quality of environments that improves significantly on the conventional decibel level approach that has been the basis of current European and international regulations. The indicators should be suitable to assess health related quality of life and functional health which can then be used to evaluate claims related to health promotion benefits.
- There is also a need to develop *standard protocols*, such as text and/or audio-visual documentation, which can be used to better assess cross-contextual and cross-cultural differences that may be responsible for discrepancies of study results.
- The indicators and protocols could lay the foundations for *standardisation* and lead to future European/international standards.

(4) Creating and designing.

- There is a need for practical *guidance* in soundscape design, based on research as well as successful practical examples. It is also of significance to provide guidelines for preserving architectural heritage sites from soundscape perspectives.
- It would be important to develop *tools* and corresponding software for the design and implementation of soundscapes for use by urban planners and policy makers. Auralisation tools are especially relevant and important for soundscape design.

(5) Outreaching.

- It is important to create awareness and promote communication concerning urban soundscapes and quiet areas amongst the *policy makers* and stakeholders, especially with the requirements in the END [EU, 2002]. It should also be recognised that soundscape studies are not only for the improvement of the current sound environment but also for the conservation of our sound environments which can be classified as acoustic heritages.
- It is equally important to create awareness amongst the *general public*, especially given that soundscape is relevant to a much wider range of citizens than noise.

Good soundscapes strengthen and promote the image of the city/landscape, stimulate tourism, create healthy stress releasing settings for its inhabitants and improve social cohesion. The health, cultural and economic benefits include:

- Health: Due to the increasing numbers of elderly people in the EU there is a need to provide supportive environments which prevent the degradation of functional health. Moreover, the

engagement in health promoting activities such as walking and running is less likely in unpleasant neighbourhoods. Furthermore, the design/re-design of well perceived soundscapes is a prerequisite of an adequate learning environment for children to foster language and cognitive development, motivation and social interaction.

- Culture: Soundscape is a significant factor in the 'sensing of places'. Cities and landscapes are now becoming more and more similar in terms of their sound environment, and the diversity of sounds that distinguish and characterise places are to be lost and therefore, the issue of maintenance and restoration of diversity of cultures, and of their soundscapes is vital, also as an important dimension of tourism. Soundscape studies will help the understanding of acoustic conservation and restoration, adding a new component/dimension to the "World Heritage" concept.
- Economy: Attractive soundscapes can enhance not only cultural identities but also on economic grounds enhance property prices, create an attractive setting for economic investment, offset health costs through provision of restorative living spaces, and reduce costs caused by anti-social behaviours. Soundscape research could help to prevent costly unnecessary infrastructural noise mitigating activities, and to provide more cost-effective solutions.

3. RECENT ACTIVITIES

With the growing interests in soundscape, there have been increasing activities in the field/sector, including networks, research projects, standardisation, practice and publications. Some of the activities are reviewed briefly in this section.

3.1. UK EPSRC NoiseFutures Network

This network (http://noisefutures.org/) arises from the participation of the members in the UK Engineering and Physical Sciences Research Council (EPSRC) Ideas Factory "A Noisy Future? Making the World Sound Better". This brought together participants from a wide range of academic backgrounds and experiences alongside contributions from policy makers and consultants. The skills and backgrounds of the participants include: social science, transport engineering, traffic noise emissions modelling and 2.5D mapping, management and control of traffic noise, economics, media and cultural studies, maths, electronics, sound art, room acoustics, acoustics, building acoustics, psychoacoustics, noise control, health sciences, sound quality engineering, environmental acoustics, aeroacoustics, auditory psychophysics, structural dynamics, mechanical engineering, micro mechanics and noise mapping. The network started from June 2006. The primary purpose of the network is to facilitate interdisciplinary (multi-interest) research on future soundscapes [Bristow and Kang, 2006]. More specifically, the objectives of the network are:

- To engage with policy makers, industry representatives and other interested in future soundscapes.
- To generate a suite of research proposals to EPSRC and other sponsors.
- To expand the network to include expertise required for future research needs.
- To build the legitimacy of the group as an advisory body.
- To create a new research community that integrates researchers, artists, industry, educational bodies and policy makers and enables effective communication across disciplines and sectors.
- To explore the best methods of involving the public in research on soundscapes.
- To raise the profile of future soundscapes in the media.
- To encourage interdisciplinary training and information exchange for research students and research assistants in the fields.
- To create a critical mass in the field, placing the UK in a world-leading position in research into soundscapes.
- To encourage and deliver international collaboration.

Main activities include:

- Sounder Spaces Conference, jointly organised with Greater London Authority (GLA), 2007.
- Low Frequency Noise Conference, jointly organised with UK Noise Association, 2007.
- The Future of Computational Acoustics Conference, jointly organised with Isaac Newton Institute, 2007.
- Tranquil Space Conference, jointly organised with Greater London Authority, 2009.
- UK SoundMap project, 2009.
- Soundwalks in London and Edinburgh, 2009.
- Workshops relating to issues in soundscape and future development, 2006-2009.

3.2. EU COST Action on Soundscape

An EU COST Action on Soundscape of European Cities and Landscapes (http://soundscape-cost.org/) started in May 2009. The main aim of the Action is to provide the underpinning science for soundscape research and make the field go significantly beyond the current state-of-the-art, through coordinated international and interdisciplinary efforts. There are five workpackages, including understanding and exchanging, collecting and documenting, harmonising, creating and designing, and outreaching and training. The Action is working on an integrated database of laboratory/field studies, harmonised/standardised soundscape assessment and indicators, academic and practical publications, and tools to support designers and decision makers in planning and reshaping urban/rural spaces. It will promote soundscape into current legislations, policies and practice, for improving/preserving our sonic environment [Kang and MC, 2008].

Recent activities include:

- Workshop on Hot Topics in Soundscapes, Edinburgh, UK, 2009.
- Workshop on Soundscape Contributions to Standardisation, Berlin, Germany, 2010.
- Workshop on Understanding, Modelling and Measuring Soundscapes, Gent, Belgium, 2010.
- Conference on Soundscape Support to Sustainable Development, Stockholm, Sweden, 2010.
- Training School on Soundscape, Lubljana, Slovenia.

3.3. ISO

A working group ISO/TC43/SC1/WG54 was formed in 2008 on the perceptual assessment of soundscape quality. The scope of the Standard is to provide specifications for questionnaire studies. The Standard is primarily intended for researchers to assess perceived soundscape quality, and for public users to evaluate soundscape quality in existing outdoor areas. The Standard will specify a questionnaire protocol, which includes questions on sound source identification and perceived quality of the soundscape, as well as reporting core information [Axelsson and WG, 2009].

In 2009 three project meetings were hold, in Berlin, Ottawa, and Seoul, respectively. The main themes were reaching a common understanding of the scope of the proposed standard.

3.4. Research Projects

The importance of soundscape research has been recognised by governmental organisations and national funding bodies in Europe, and a number of national research projects relating to this field have been, and are being, carried out in Europe, such as two UK Noisefutures Network associated soundscape projects, namely ‘Automated Soundscape Identification’ and ‘Positive Soundscapes Project’ (www.positivesoundscapes.org/); a number of soundscape projects supported by the Royal Society, British Academy and British Council (www.sheffield.ac.uk/acoustics); the ‘Soundscape Support to Health’ project funded by the Swedish Foundation for Strategic Environmental Research; the “Eyer-Hear Project - Qualitative Sound Maps for Visualization of the Urban Soundscapes” funded by the Portuguese Science and Technology Foundation; and a series of soundscape

projects funded by the French Ministry of Town Planning, Housing and Construction, as well as the PREDIT program (National Research Program on Innovation in Transport).

At the EU level, in the SILENCE (Quieter Surface Transport in Urban Areas) and the QCity (Quiet City Transport) projects, some sub-tasks relevant to soundscape, perception, acceptance and expectation have been included, although the subjective evaluation has been limited mainly to annoyance perception. In the CALM (Coordination of European Research for Advanced Transport Noise Mitigation) network, the need for perception related research for identifying indicators and parameters for quiet areas has been indicated. The RANCH (Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health: Exposure-Effect Relationships and Combined Effects) project has considered the potential benefits of a restorative soundscape at home on children's cognition, although the study mainly concerns the acoustic environment at home which is only a small part of the whole soundscape picture. The MINET (Measuring the Impossible' Network) aims at supporting the development of new methods and investigative techniques for the measurement of complex phenomena that are dependent on human perception and/or interpretation, with sound as one dimension. The ENNAH (European Network on Noise and Health) aims to produce information that is useful for the further development of the END [EU, 2002] by examining whether existing noise maps can be used to establish any adverse effects of noise on health.

In other parts of the world including Australia, Canada, USA, Japan, China, Hong Kong and Korea, considerable attention has also been paid to soundscape research.

3.5. Policies and Practice

There have also been increasing interests in the practice and policy sectors. For example, the Greater London Authority is actively promoting several practical exemplar soundscape projects [Memoli et al, 2008] and the GLA has also hosted a number of conferences/workshops relating to soundscape. The City of Berlin is promoting the soundscape research with regard to its application concerning action plans and public places, and a successful project has been completed [Schulte-Fortkamp et al, 2008a; 2008b; Schulte-Fortkamp, 2009]. The City of Antwerp is using a soundscape approach to improve the acoustic environment in a new development area [De Coensel et al, 2010]. Stockholm is also promoting soundscape by hosting a Conference on Soundscape Support to Sustainable Development (http://soundscape-cost.org/). The above activities are closely related to the END in terms of creating quiet areas.

Soundscape approach has also been applied in preserving and restoring archaeological places of great importance such as Pompeii in which the tourist sensation shall be globally connected to the atmosphere of the historical site [Brambilla et al, 2007].

3.6. Publications

In the last decade or so there have been a growing number of publications in the field. In the major international conferences including the International Congress on Noise Control Engineering (internoise), the International Congress on Acoustics (ICA), the International Congress on Noise as a Public Health Problem, the European Conference on Noise Control (euronoise), the International Congress on Sound and Vibration (ICSV), as well as various national conferences such as the Acoustical Society of America (ASA) meetings, the UK Institute of Acoustics meetings, a number of special sessions on soundscape have been organised, from a range of viewpoints including acoustical, social, psychological, physiological, linguistical, historical and architectural aspects. In Fig. 2 is shown the number of papers relating to soundscape research and practice in internoise in recent years.

In 2006 a special issue of Acta Acustica united with Acustica (AAA) (the Journal of the European Acoustics Association) was produced on soundscape. A number of special issues relating to the

soundscape area are also being planned in other journals, including Noise Control Engineering Journal (NCEJ), AAA, International Journal of Environmental Research and Public Health, Applied Acoustics, and the Open Transportation Journal (OTJ) [Kang, 2010].

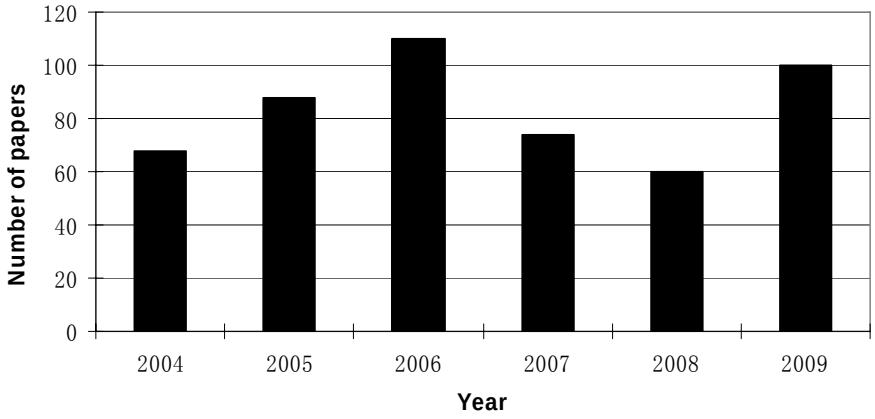

Fig. 2. Number of internoise papers relating to soundscape in recent years.

4. A SYSTEMATIC REVIEW OF THE RESEARCH AND PRACTICE PROGRESS

A database has been established based on a number of main conferences, including:

- International Congress on Noise Control Engineering (internoise), 2004-09
- International Congress on Acoustics (ICA), 2001, 2004, 2007
- European Conference on Noise Control (euronoise), 2003, 2008, 2009
- International Congress on Sound and Vibration (ICSV), 2001-09
- UK Institute of Acoustics meetings, 2002-08 (part)

The database, currently with 1534 papers in total, was established by selecting papers from the above conference proceedings in the following three categories [Kang et al, 2010]:

- Soundscape (currently 663 papers)
- Sound quality (currently 280 papers)
- Others, mainly in community noise, noise annoyance and noise sources (currently 591 papers)

More papers are being put in the database from a range of sources including journals, reports and other conferences. The reason for using conference papers is that soundscape covers both research and practice sectors, and conference papers would reflect the whole picture in the field. Moreover, the number of journal papers is still rather limited.

In this section, a systematic review is made based on the current database, as well as other literature wherever appropriate, in terms of the five facets discussed in Section 2.

4.1. Understanding and Exchanging

4.1.1. Definition

Depending on the field, soundscape has been defined from different points of view, such as ecology, arts, design and psychology. The mostly commonly recognised definition is the one listed in the “Handbook for Acoustic Ecology” published in 1978 [Truax, 1999]: *An environment of sound*

with emphasis on the way it is perceived and understood by the individual, or by a society. It thus depends on the relationship between the individual and any such environment. The term may refer to actual environments, or to abstract constructions such as musical compositions and tape montages, particularly when considered as an artificial environment.

Based on intensive discussion of the ISO/TC43/SC1/WG54 working group and the COST network, at least in the context of the proposed Standard, soundscape is defined as [Kang and MC, 2009]: *The perceived sound environment in context by an individual, a group, or a society*.

4.1.2. Evaluation

A key part of soundscape research is to understand how the soundscape within its proper context affects its users. With a wide range of multi- and interdisciplinary research, much work in this aspect has been carried out, both under field and laboratory conditions, considering a range of spaces and locations, sound sources and people [Kang et al, 2010]:

- Spaces/functions: urban streets, urban open public spaces, parks, schools, bus stations, theme streets, cycle path, outdoor concert, racing games, archaeological sites, covered spaces, underground shopping streets, as well as a range of indoor spaces. The spaces are widely distributed across the world, although the work in Europe is considerably more than that in other countries.
- Sound sources: from noise sources including industry noise, aircraft noise, road noise, wind turbines, amplified music; to positive sounds including natural sounds; to infant cry. The effects of a number of sound source characteristics, such as low frequency components and tonal and impulsive features, have been examined.
- People: the social and demographical characteristics have been considered for various users, also for specific groups such as children, deaf, hearing impaired and blind people.

While the majority of the soundscape evaluation research has been based on social and psychological approaches, limited physiological studies have also been conducted, including the use of fMRI techniques to investigate the perception of tranquillity [Watts et al, 2009], and listeners' reaction to different urban soundscapes [Irwn et al, 2009]. In a study by Hume and Ahtamad [2009], the effects of individual soundscape elements on the subjective assessment of pleasantness and arousal were compared with associated physiological responses including heart rate (HR), respiratory rate (RR) and forehead electromyography (EMG) levels, and some correlations have been shown preliminarily.

The interaction between acoustic and other physical environments is an essential consideration, and of various physical conditions the aural-visual interactions have been intensively studied. Significant correlations have been found between landscape and acoustic satisfaction, between visual and acoustic satisfaction, as well as between view and quietness in choosing a living environment [Kang, 2006; Kang et al, 2010].

Linguistic analyses could be made of the semantics of the vocabularies and of discourses encountered in the diversity of studies concerned with soundscapes using verbal responses. The case of linguistic analyses of verbal content is further mandatory because of the diversity of languages in Europe. This could also reflect the cultural variations in conceptualisations and subjective responses to noise and their relations to acoustic parameters. Dubois and Catherine [2007] indicated that cognitive evaluation in the first place as a 'pre-filter' can be used to decrease the complexity in relevant category sound identification. Payne [2008] suggested that the context, the exact situation and the perceivers' interpretation of sound events played a significant role in sound classification; therefore, new affectively termed categories which allow variations in the perception of sounds and context were created alongside the affective evaluation carried out by semantic different scales.

Although considerable work has been carried out in the soundscape evaluation, as discussed above, there are still recognised needs for further work [Kang and MC, 2008]:

- Detailed knowledge on sensory perception is needed to identify features that are distinguishable by the human sensory system. Not only classical psychophysics can be useful in this respect but also recent results obtained from brain imaging.
- The way the sensory perception is organised in objects and streams and how this depends on personal characteristics, and how attention affects the external environment is shaped internally, are important research topics.
- To discover how meaning is attached to the objects and streams formed in the human mind, within a cultural and social context, is a tremendous challenge. It relates strongly to the spearhead research on the mechanisms of thought and the working of the human mind.
- Somewhat in parallel to the above, the effect that a stressed or harmonised human-environment relationship can have on mental health needs further investigation.
- To optimally use the results obtained by cognitive science, brain imaging/neural imaging/neuro-informatics, and research on auditory perception, the knowledge embedded in these research communities needs to be made reachable to the community of soundscape researchers.

4.1.3. Description

Relating to soundscape evaluation, it is of great significance to describe soundscapes systematically, taking into account various facets in terms of space, source, people and context/environment. Fig. 3 is a possible taxonomy of the acoustic environment [Brown et al, 2009], for sound sources. It has been constructed in terms of categories of places—indoor, outdoor—and within the outdoor environment urban, rural, wilderness and underwater.

To investigate an existing soundscape or to design a new soundscape, it is essential to describe it in terms of designable factors. As an example, for urban open public spaces such a system/framework is proposed, as shown in Fig. 4, where four facets are considered, namely characteristics of each sound, acoustic effects of the space, social/demographic aspect of the users, and other aspects of the physical/environmental conditions [Zhang and Kang, 2007].

Within the ISO/TC43/SC1/WG54 working group, a subgroup, called ‘box group’, has been formed [Axelsson and WG, 2009] to establish the relationships between various facets of soundscape, including contexts, physical soundscape, soundscape perception process (psychological and physiological), coping behaviour and outcomes [Schomer et al, 2010].

4.1.4. Modelling

Modelling and simulation are strong tools for helping to understand how complex systems work. A range of models are relevant here, from perception modelling, to the modelling of physical soundscape, as well as the human-soundscape interactions. Simulation tools could include computational auditory scene analysis tools, numerical ear models, saliency detection modules, cognitive mapping tools, etc. Closely relating to the soundscape modelling is sound source recognition. It is a very detailed yet extremely important facet of understanding how soundscapes are perceived and how they affect the user. There are different angles to this problem: in a physical sense there may be an advantage in recognising the source of the sounds as accurately as possible, but it is equally important to identify what a human listener will detect and think to recognise when exposed to the sound mixture. It is the latter that is essential as a starting point for soundscape perception modelling.

While most research relates soundscape descriptors to perception in a fashion strongly related to epidemiologic research, a bottom-up approach has been used by De Coensel and Botteldooren [2007; 2008]. The individual sensory, cognitive and emotional mechanisms that play a role in soundscape perception are discerned, and a human mimicking software model was proposed. In particular, such a model is able to reproduce and explain, in a qualitative way, trends as observed in epidemiological research on soundscapes [De Coensel et al, 2005]. Since human listeners process sound as meaningful events, Niessen et al [2009] developed a model to identify components in a

soundscape that are the basis of these meaningful events. First, they selected structures from the sound signal that are likely to stem from a single source. Subsequently, they used a model of human memory to predict the location at which a sound is recorded, and to identify the most likely events that constitute the components in the sound given the location. Accepted or corrected annotations can be used to improve the classification further. This speeds up the annotation process and makes it possible to annotate complex soundscapes both quickly and in considerable details [Krijnders et al, 2009]. Another approach is the use of artificial neural networks, with which models have been developed to predict soundscape perception [Yu and Kang, 2009].

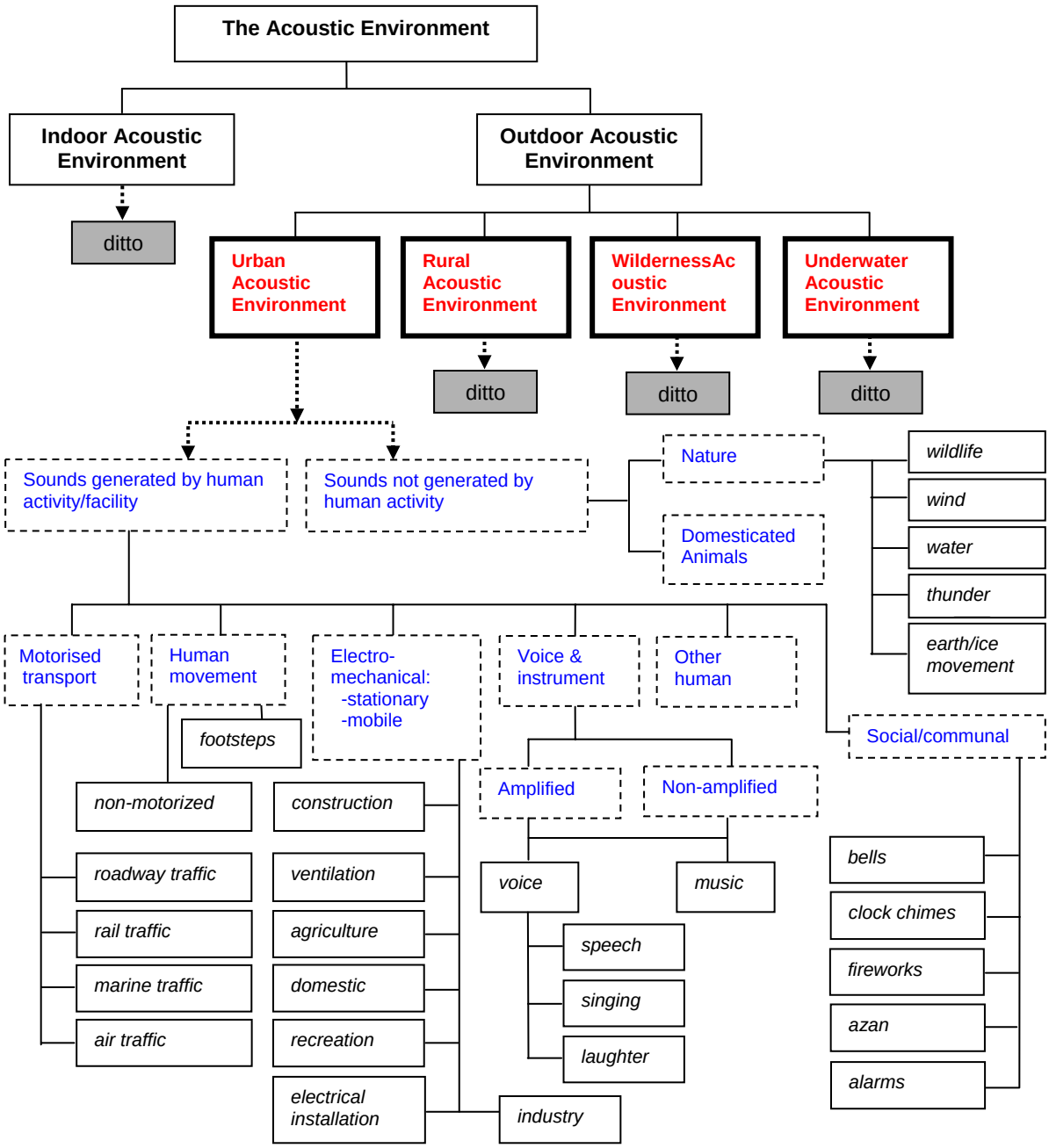

Fig. 3. A taxonomy of the acoustic environment for soundscape studies, showing categories of places (letters in red in boxes in bold lines), categories of sound sources (letters in blue in boxes with dashed lines), and sound sources [Brown et al, 2009].

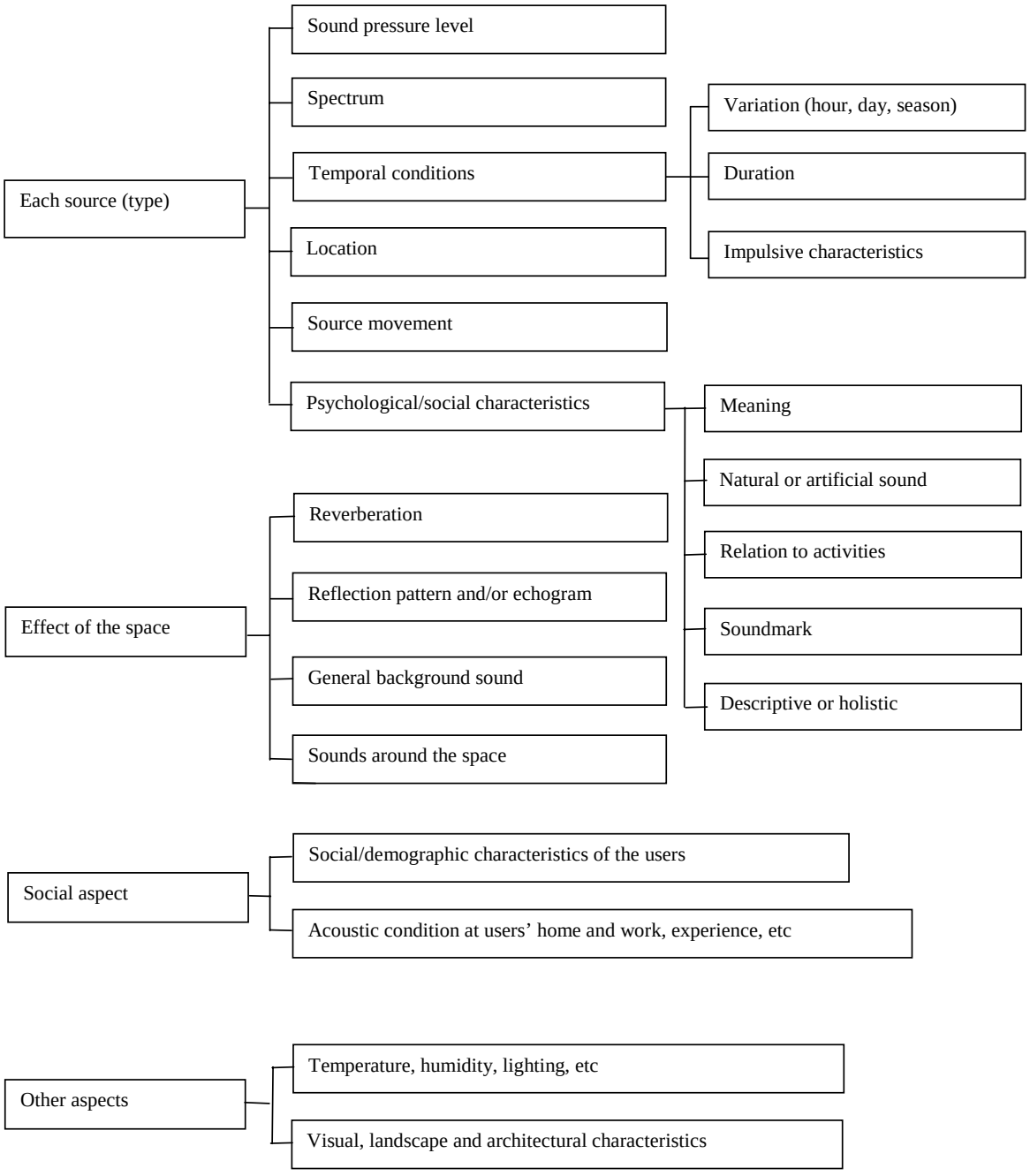

Fig. 4. A system/framework of designable factors for the soundscape in urban open public spaces [Zhang and Kang, 2007].

In terms of modelling techniques for physical soundscapes and sound environments, much work has been carried out [Botteldooren and Van Renterghem, 2009; Kang 2006; Attenborough et al, 2006], considering the effects of various factors such as meteorological/atmospheric conditions and the effects of urban elements. With artificial neural networks, models have been developed to predict the level and the temporal and spectral composition of the sound pressure in urban soundscapes [Torija et al, 2009].

4.2. Collecting and Documenting

4.2.1. Sounds

In the Soundscape category of the database, by using keywords ‘sound database’ and ‘database of sound(s)’ 4 papers were found. With ‘sound recording(s)’ and ‘recording(s) of sound(s)’ as keywords, 48 papers were found. After reviewing those papers, it was found that 34 of them were related to, directly or indirectly, sound database/recordings, and among those, 4 papers mentioned the need for creating sound databases [Drever, 2005; Fonterrada and Filho, 2005; McGinley, 2005; Berglund et al, 2004]. Sound recordings were used as one of the research methods in 30 papers. The environmental sounds of the Amazon in Brazil were recorded and proposed to be divided into three main categories: natural, technological and anthropic environment, which could contribute to the local soundscape as well as the expression of local culture [Fonterrada and Filho, 2005]. Lemke [2008] stated that due to the absence of the visualisation of the events, recording a sound from its source, which transited the ‘real thing’ into electronically created signals, changed the physicality of the sound and made it difficult to identify. Therefore he collected and archived sounds by means of drawing, writing and photography and sound recording. Brambilla et al [2008] employed both site binaural recordings and photos to collect the data of 12 sites, and confirmed the important roles of auditory perception and visual information on the assessment of a site through the laboratory listening tests. Overall, although some initial databases have been, and are being established, and discussion has been made about the ways of establishing sound archives in soundscape research [Clouter, 2008], more systematic work is still needed.

4.2.2. Questionnaires

Questionnaire survey is a commonly used method in soundscape research and a considerable number of questionnaires have been developed in different studies [Kang, 2006] and correspondingly, a large amount of survey data has been collected. In an EU study over 10,000 questionnaires have been distributed with simultaneously measured sound level, and correspondingly, acoustic models for micro-scale urban areas have been developed to obtain sound map data of the case study sites. In Italy, experimental studies have been carried out using sound measurements, binaural recordings and interviews, in a range of sonic environments including 9 urban parks, a rural area, 12 squares, and the outdoor archaeological area of Pompeii. There have been three Flemish noise surveys at home on annoyance, each with 3000-5000 samples, where an advantage is that many data are geographically referenced and many GIS layers are coupled. The "Maglev field experiment" was conducted in a house with traffic sound playback. A series of studies in Berlin generated soundscape data combining physical, psychoacoustic and perceptive measurements in different residential areas. Macro- and microscopic approaches were chosen for sound walks, environmental screening, acoustic measurements and narrative interviews. The data collection is available in raw data and triangulated data concerning the combined approach. In France and other countries, a large number of urban squares have been surveyed, with questionnaires and aural-visual recordings [Kang and MC, 2008].

4.2.3. Case studies

A number of practical soundscape projects have been carried out, as also discussed in Section 3.5. In the case of Alcântara bridge in Lisbon, a noisy urban place, the soundscape approach was applied as an alternative solution for simple noise reduction, through the use of masking effects of the natural soundscape and an electro-acoustic system that reinforces the natural soundscape. [Bouzebaria et al, 2009]. In Korea, the soundscape was designed for a memorial space with a seaside view [Shin et al, 2004].

4.2.4. Needs for collecting and documenting

Overall, the amount of soundscape data and the number of case studies using the soundscape concept for improving the living environment is steadily growing. However, ongoing soundscape

researches have different approaches. In the same time, new techniques for assessing soundscape quality and new theories are being designed and invented. It remains however rather difficult to test new theories on available data. It is therefore important to make the body of existing data available to all researchers in the field, preferably in comparable formats, for testing their theories and ideas. It is expected such databases will stimulate researchers to start meta-analyses on the collected materials, which will strongly increase the statistical strength of the resulting conclusions.

For establishing such databases, it is important to determine what data should be included. The data could take very different forms: audio-visual recordings, interviews, tables obtained from social surveys, acoustic measurements with different equipment and procedures, etc. It is also useful to explore the synergies and differences [Kang and MC, 2008]:

- between cities and landscapes, given their considerable differences, for example, aural-visual interactions would be rather different in the two settings;
- between field studies and experimental settings, given that in the latter many other sensory factors are not included;
- between verbal data collection and analysis and physical measures, which have been paid different attention by researchers in different disciplines.

4.3. Harmonising and Standardising

4.3.1. Indicators

Efforts have been made to derive certain indicators, in a number of rather different ways, for the evaluation and design of soundscapes. Raimbault et al [2001] explored common factors in the identification of urban soundscapes through pilot studies in two French cities. Botteldooren [2001] proposed to use fuzzy noise limits. Pheasant et al [2009b] derived formulae to calculate tranquillity rating, which depends on the sound pressure level and the percentage of natural features contained within a scene [Pheasant et al, 2009a]. Davies et al [2009a] suggested to measure and map soundscape speech intelligibility. Woloszyn et al [2009] used geospatial knowledge modelling and representation techniques, leading to a methodology for semantic integration of the urban ambient soundscape model, namely integrating psychophysical information into a powerful geocomputational basis for pedestrian acoustic exploration of a city. Hiramatsu et al [2001] explored environment similarity index concerning sonic environment towards the evaluation of sonic environment. Licitra and Memoli [2005] proposed noise Indicators and hierarchical clustering in soundscapes.

However, there is still a need to derive/examine/harmonise soundscape indicators, based on multi-disciplinary analysis of various physical, psychological, social and physiological parameters, by coupling physical parameters with, for example, semantic analysis of verbal data collected from a diversity of techniques. These parameters could be integrated into indicators through statistical methods as well as cognitive modelling using artificial neural networks [Yu and Kang, 2009] or symbolic representations developed in sound recognition research. It is important to seek the synergies of different definition/understanding of soundscape from different disciplines/sectors, defining a “common language”. Indeed, multi-sectoral environmental health impact assessment [Lercher, 2007], preservation of quiet areas, and the design of ‘supportive environments’ require new insights into the existing annoyance data and new integrative research strategies. Within this context the appropriateness of health and Quality of Life outcome indicators should be assessed and summarised and a required set of moderator/mediator variables should be proposed [Kang and MC, 2008]. In the above, the acoustic properties of environmental noise have to be considered and combined with the empirical data. Soundscape indicators could take the form of a single index, or a set of indices, corresponding to different facets of soundscapes.

4.3.2. Protocols

Corresponding to the soundscape indicators, it is important to develop standard protocols for describing and evaluating a soundscape, and also for assessing cross-cultural and cross-contextual

differences. Physical measure of soundscapes is another important dimension, for the application and calculation of soundscape indicators, for understanding the human-environment relationships, and for validating relevant simulation/modelling. It is important to deal with applicable measurement procedures with respect to a balance between scientific accuracy and practical applicability, also considering comparability and reproducibility [Kang and MC, 2008].

4.3.3. Standardisation

Along with the standard protocols is the standardisation. While it is argued that standardisation could restrict the creativity in designing soundscapes, from a planning point of view it is very useful to have standards. They are not necessarily used to rank different soundscapes, but at least they can provide a standard way of describing and integrating various key factors. The proposed standard on the perceptual assessment of soundscape quality would be a starting point on this [Axelsson and WG, 2009] (also see Section 3.3).

4.4. Creating and Designing

4.4.1. Design guidance

The development of design guidelines and good practice guidance would be vital for the implementation of soundscape research. In the Soundscape category of the database, by using keywords ‘design guideline’ and ‘design guidance’, 8 papers were found, although only 4 were actually relevant [Choy and Lui, 2009; Bouzebari et al, 2009; Kang, 2007; 2008]. Based on the investigation of the physical acoustic parameters and human perception in the landscape which is exposed to the traffic noise in Hong Kong, it was indicated that the results could be useful for the design of recreational parks in terms of soundscape design guidance [Choy and Lui, 2009]. Kang [2007; 2008] demonstrated the design potentials considering four key components, namely sound, space, people and environment, and introduced initial planning and design guidelines for urban open public spaces.

Overall, while currently soundscape is mainly a research subject, the practical implementation will need significant attention. There is still a need for a systematic examination of the effectiveness of design changes, in terms of planning, landscape, architectural elements, and sound components, on the creation and improvement of soundscapes, including not only the acoustic aspect but also people’s perception. Both urban and rural soundscapes need to be considered. Associated with the design guidelines, good examples of practical projects are needed.

While soundscape research has mainly been for outdoor spaces, the methods may also be applicable for enclosed spaces having a function similar to urban spaces such as commercial and entertainment areas, shopping malls, airports and train stations, where the acoustic comfort and sound quality cannot be dealt sufficiently only with noise parameters as is in the current practice. Although the acoustic comfort evaluation has been carried out in a range of architectural spaces, design guidelines in terms of acoustic comfort are still rather limited. Another important application of soundscape research is the acoustic preservation of architectural/landscape heritages.

4.4.2. Design tools

Efforts have been made in developing tools to aid design, from various points of view. Davies et al [2009b] suggested an evaluation tool, integrating perceptual results with outlines of what can be measured and how user behaviour can be characterised to supply the information that an urban design or planning team might need. Fiebig and Genuit [2009] proposed a synthesis tool to derive psychoacoustic maps, which could improve the planning reliability in the context of the redesign of cities and their road traffic situations. Bunting et al [2009] suggested an instrument which would be capable of characterising a sound field in terms of the relative contributions of different noise sources, along with the technological advancements in microelectronics and continuing research into signal characterisation and classification techniques. A design tool, Trans-Acousmatic Design,

with two main concepts of metabolic effect and acousmatics, was used in the research project of Acoustic Design Artefacts and Methods for Urban Soundscapes, and, a sound-art installation was proposed to be employed in the examination of the masking effect in this project in order to mask unwanted sounds in a park [Hellström, 2009].

Yu and Kang [2008] developed a tool to predict the subjective evaluation of soundscape quality by potential users, using known design conditions such as physical features of a space, acoustic variables, and characterises of the users. Models of predicting soundscape quality, including sound level and acoustic comfort evaluation, have been developed using artificial neural networks as well as the ordinal logistic regression (OLR) technique, respectively. Since there are considerable differences in soundscape evaluation between various case study sites in terms of the effects of various factors, it is necessary to classify urban open spaces into typical categories, and develop sub-models for each category. In another study, a neural network classifier as a design tool for city planners, architects and materials producers was utilised in a diagnosic system for soundscape certification, including green labelling of soundscapes, and a database was created from the sounds of four urban residential areas [Berglund et al, 2004].

To aid urban soundscape design as well as for public participation, it would be useful to present the 3D visual environment with an acoustic animation/auralisation tool, where considerations should be given to various urban sound sources, dynamic characteristics of the sources, and the movements of sources and receivers. The calculation speed should be reasonably fast, so that a designer can adjust the design and then immediately listen to the difference. A key issue of achieving fast acoustic animation/auralisation for urban soundscape is to simplify the simulation algorithms, whilst retaining reasonable accuracy [Kang, 2008]. Since human sensitivity to a particular sound source might be reduced within a complex sound environment with multiple and moving sources, to provide a fast urban acoustic animation/auralisation, simplifications of calculation parameters have been explored through a series of subjective experiments [Smyrnova and Kang, 2010].

Overall, although some initial tools and guidance have been developed, there is still a great need to improve them, based on the EU COST workshop on Hot Topics in Soundscapes, Edinburgh, 2009 [Kang and MC, 2009]. It was discussed that there are different needs for different users in terms of tools for soundscape design:

- Planners need different tools at different stages in the planning process, such as master plan, detailed plan for the development of an area, and the evaluation of results. For the master plan the planners need categories of soundscapes, organised according to the intended use of an area and the kind of sounds that may be heard. The categories may be used in a geographical information system (GIS) to provide an overview of a geographical region. In a detailed plan for the development of a local area the planners need a screening tool to see when and where soundscape can be of use. The planners need tools for determining the acoustic objectives for the area, and tools for design, namely what physical aspects to modify in order to meet the acoustic objectives.
- The consultants need high quality survey techniques, simulation tools (improved noise maps involving listening to simulated soundscapes), tools for measuring people's perceptions of soundscapes, reliable tools that describe what sounds people hear at a place, and models/tools to predict people's perceptions of planned soundscapes.

It was also clear from the workshop that there is no single recipe, there are several layers (inheritage, uses and purposes), and consideration should be given to the plurality of point of views (e.g. park is 'place' and the recreation area is 'use').

4.5. Outreaching

4.5.1. Policy makers

One of the major drivers for the recent intensive soundscape research and practice is the need to create quiet areas according to the END [EU, 2002; Shepherd and Grimwood, 2009]. Although much work has been carried out in terms of describing and evaluating soundscapes, there is still a

recognised need to integrate soundscape results into policy [Payne et al, 2009]. For this it is important to have a series of practical indicators and design guidance and tools, as discussed in Sections 4.3 and 4.4. More effort also needs to be made to disseminate the results to policy makers. Successful examples are required to underline significant points such as simplicity, reduction of social costs, and people's acceptance. Attention should be paid to a wide range of applications in terms of policy making, including preservation of heritage sites [Brambilla et al, 2007]. Indeed, while in the noise control sector a basic difficulty is that no single technological fix could solve the problems on emission and immission aspects [Kihlman, 2007], such multi-sectoral efforts are even more important in soundscape approaches. Noise maps, and further soundscape maps, could be powerful tools not only for disseminating the results of sound evaluation, but also for the decision making in sound environment policy [Sjölinder and Hallin, 2004; Bento Coelho and Alarcão, 2005; Park et al, 2009].

4.5.2. General public

With regards to policy making, there is also a need to disseminate the soundscape concept and benefits to the general public, based on much work in community noise sector [McDonald and Dobbyn 2009; Burgessa et al, 2008]. The general public would need to understand how to manage the soundscape more effectively and how to complain about a negative impact. Educational programs are also needed for the general public, for their benefits and for influencing the politicians. Tools are useful, to enable the users to structure their experiences of the soundscape in order to provide information to decision makers [Kang and MC, 2009]. Under the soundscape COST Action, an awareness day, on 'Listen your city', is planned to address the community.

5. CONCLUSIONS

Whilst there is a tendency from purely reducing noise level to overall soundscape design, the complexity as well as potentials of soundscape research and practice has been demonstrated through systematically examining the current situations in this paper. Although considerable work has been carried out, further research is still needed in more facets, and practical implementation of the research work is yet to start. The current research works in soundscape are still at the stage of describing and identifying the problems, and they tend to be fragmented and focused on only a few special cases, e.g. based on common sense categorisation of soundscapes and on local interests such as evaluation of soundscapes especially for residential areas. A number of issues need to be addressed, for example:

- While in the paradigm shift from noise control to soundscape design, a vital step will be the explicitation, comparison, and evaluation of methods and indicators from different scientific domains in order to model soundscapes in their globality, there is currently a lack of standardisation and explicitation in the categorisation and measurement procedures, and there are few tools.
- Relationships between subjectively assessed "acoustic quality of the environment" and perceived health-related quality of life and functional health are yet to be established.
- The importance of quiet areas within reach is recognised by the EU but no clear definition is given and there is no method by which "good" or "restorative" sound environments can be measured. For that great effort is still needed to integrate soundscape research into practice and policy making.

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