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Beyond quantitative metrics in urban acoustic design

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Exposure to noise has become one of the biggest problems posed by urban growth as noise pollution affects the health, work performance and everyday well-being of the inhabitants. Noise reduction in cities has therefore become a focus subject, both regarding indoor and outdoor spaces. A city is in many ways defined by its various outdoor areas. Vibrant public spaces, busy streets and hidden backyards are an important part of the urban experience. The different types of spaces provide different atmospheres and the quality of those spaces does not only depend on the architectural configuration, but also on how the users perceive the different futures of the space and what they expect in each situation. The same applies for the acoustic quality. It is therefore insufficient to describe the acoustic quality of outdoor areas with quantitative measures as the noise level alone. The use of a more holistic approach, using non-standardized methods for the assessment of acoustic environments has been growing in influence and several methods have been developed. The methods take into account various factors regarding the type of sound sources and composition of sound in combination with the perceptional factors of the surroundings. As of now, the challenge is to apply those methods in the design process as efficiently as e.g. noise mapping. The paper presents a mapping of the different methods and the possibility of applying the respective qualitative parameters in urban planning- and design processes.

1 Introduction

Traditionally, the quality of urban acoustic environments is measured with the A-weighted sound pressure level. Guidelines use the A-weighted sound pressure level and other levels derived here from to indicate maximum noise levels, mainly from noise generated by traffic or industry, in different areas. The focus on the control of noise levels is in accordance with documentation relating several health implications and disturbances to long term exposure to high noise levels [1]. In order to prevent health problems caused by noise pollution, the Environmental Noise Directive has defined two values, the day-evening-night equivalent level L_{den} and the night equivalent level L_{night} as noise indicators [2]. Although the noise indicators represent outdoor noise levels, the primary focus is to prevent long term exposure to high noise levels in dwellings, workplaces and institutions as a consequence of the outdoor levels. The indicators are therefore not necessarily descriptive for the acoustic quality in urban spaces.

When improving acoustic quality in the urban environment, noise reduction is not always the primary factor. When considering noise levels up to 70 dB(A), it is more the composition of sounds than the sound pressure level alone that is of importance [3,4]. The perception of the acoustic environment is also very much dependent on the function and context of a given location, what is preferred in one situation might not be fitting in another context [5]. Different individuals can also perceive the same acoustic environment in different ways, dependent on previous experiences and their expectations [6].

The quality of the urban acoustic environment does therefore depend on a range of factors, which makes it difficult to evaluate the quality of the urban acoustic environment with quantitative measures from noise mapping alone. Several methods have been developed to make a more comprehensive evaluation of the urban acoustic environment. The best known is probably the Soundscape method which now is being standardized, the first part of the standard ISO 12913-1 was published in 2014. The European Environment Agency (EEA) also suggests using a combination of subjective and objective methods when analyzing areas with good environmental sound quality [7]. It is therefore obvious that a method that includes both quantitative and qualitative parameters is in its place. The challenge is that the applicability

of the methods is not the same as for noise mapping, which is an effective and relatively inexpensive method to assess noise data. The presentation of data in a colored noise map is easy to interpret and identification and communication of problematic areas is therefore made simple, also for non-specialists [8]. Noise mapping does therefore have a potential as an efficient planning tool, not least because of how the simple visual presentation can easily be communicated between different stakeholders. The drawback is as mentioned before, that the method is lacking a layer of qualitative objectives necessary for a more holistic evaluation.

Another important factor for the design of urban acoustic areas is the scale. Three different scales for urban sound planning; *macro*, *meso* and *micro*, are defined by the Sonorus project [9]. The macroscale is the masterplan scale, where an overall sound for a city is defined. The mesoscale is the neighborhood scale, where a strategic plan is made for the main traffic network and sound emission therefrom. The microscale is the local scale, where the acoustic environment in smaller urban areas is considered. Noise mapping is primarily a tool applicable at the macro- and meso scale from the earliest planning and design stages, while focus on the local areas, the macroscale, is missing.

Jan Gehl [10] considers urban planning in three similar scales or perspectives, the largest being the aerial perspective, the middle scale the helicopter perspective and the smallest one the human perspective, or the human scale. As within urban sound planning, the smallest scale, the human scale, is often neglected in urban planning in general. According to Gehl, cities are therefore rarely designed for the actual users, for the eye level. The same could apply for the ear level.

The biggest challenge might be that the qualities at eye- and ear level are considered too late in the design process, where the task often becomes to ‘fix’ what has gone wrong instead of ‘optimizing’ from the earliest stages. Unfortunately everything cannot be fixed. There are many factors as scale, choice of forms and materials, openings, vegetation, function and etc., which affect both quantitative acoustic parameters and the visual and acoustic perception of the space, many of whom are resolved at the earliest design stages. It is therefore essential to consider all the three scales in relation to each other from the beginning of the planning process

This paper presents a literature review of qualitative assessment methods for the urban acoustic environment. The review examines the objectives of the methods and their applicability at different urban scales in an iterative urban design process. The results of the review are presented in graphical maps, which form the basis for a synthesis and discussion in the final chapter.

2 Methodology

Five assessment methods for the urban acoustic environment are evaluated through a literature review. Four methods are chosen because of their more qualitative approach to the evaluation of the urban acoustic environment and noise mapping is included for comparison. The aim of the literature review is to examine the main *objectives* of the methods and their *applicability* in relation to urban planning *process* and the urban planning *scale*.

Objective - The objective is the design goal, which the design outcome can be concluded on. The objective can be measured with either quantitative or qualitative metrics or the combination of both, depending on which design parameters are considered.

Applicability - The applicability addresses the *complexity* and *use of resources*. The complexity is determined by e.g. the amount of parameters and the intricacy in relations between them. The use of resources depends on the amount of data, ‘labor’, time and calculations needed. The applicability is then assessed in relation to the design process, that if the method is eligible as a design tool that can inform decisions in an iterative design process. High applicability does therefore indicate that the tool can easily be ‘operated’.

Process – The process refers to the planning and design process. Here, three different stages are considered; *early design, development and implementation*.

1. Early design – ranges from the initial planning and programming to the end of the schematic design face where the general scope and conceptual development of the design is finalized.
2. Development – where design concepts are developed, including technical details, and the design is finalized.
3. Implementation – ranges from the design is finalized, through the construction face and while the area is being used and design outcome evaluated.

Scale – The scale refers to the three different scales for urban planning, or urban sound planning, as described in the introduction. Here, the scales are introduced as the *city-*, *neighborhood- and local-scale* and the objective of the different methods is related to the respective scale.

In Chapter 3, the outcome of the literature review is presented in graphical mapping of each of the methods, see Figures 1-5. The maps represent the four parameters; objective, applicability, process and scale. In Chapter 4 a synthesis of the methods is presented and discussed.

3 Mapping

3.1 Noise mapping

Noise mapping is the most common way of graphically representing the distribution of noise levels in urban areas. Noise mapping is widely used and remains the main method for assessing acoustic quality in urban areas. Normally, the map represents the A-weighted long term average sound level, LA_{eq}, in different colors and contour lines. The noise levels shown can be from measurements but are normally based on mathematical models where noise levels from different sources are calculated. Noise mapping can be used as both a planning tool and as a method for 'monitoring' changes in existing areas, e.g. in strategies for preserving quiet areas.

The European Noise Directive (END) has presented strategic noise mapping as a primary method in the attempt to reduce exposure to harmful noise levels. The strategic noise maps are used '*for the global assessment of noise exposure in a given area due to different noise sources for overall predictions for such an area'* [11] and do therefore combine the assessment of exposure with traditional noise mapping [12].

The main objective of noise mapping is to ensure that noise levels are in accordance with current regulations and to see how planning of new infrastructure and industry or changes in traffic behavior affect the noise levels in different zones or areas. In strategic noise maps the noise level data is related to the inhabitants and how many of them are exposed to long term noise levels that can result in different effects on behavior or health.

As implied in the introduction, noise mapping is an effective and relatively inexpensive method to assess noise data, which can be used to both predict and assess changes in urban environments.

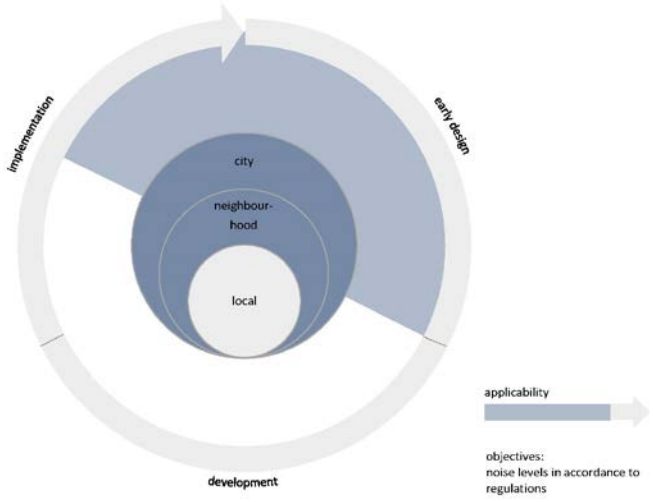

Figure 1: Applicability and main objective of noise mapping in relation to the city scale and design process

3.2 Soundscapes

The term soundscape was originally introduced by Murray Schafer. A definition of and conceptual framework for soundscapes was standardised in the first part of the soundscape standard, ISO 12913-1, where the soundscape is defined as being the '*acoustic environment as perceived or experienced and/or understood by a person or people, in context'*. The emphasis is therefore on how the acoustic environment is perceived in a certain context. Research within the soundscape method addresses the relationship between the different components [sound sources, objective acoustic parameters, contextual parameters] of soundscapes and how this relation affects the perception of the soundscape. Traditionally, soundwalks are performed to get a subjective evaluation of certain acoustic environments. The subjective information is often compared with recordings and measurements from the respective areas, which enables categorisation of the subjective data in relation to objective parameters [13].

The main objective is therefore to define and categorize the characteristics of soundscapes within different contexts.

Some models or frameworks have been introduced for the integration of soundscape studies in urban design [14]. Here, the focus often lies in the application of soundwalks and soundscape analysis when assessing the respective area as a part of the initial analysis. The assessment identifies problematic features and suggestions can be made regarding the improvement of those features. There has not been developed an explicit design tool from the models or frameworks.

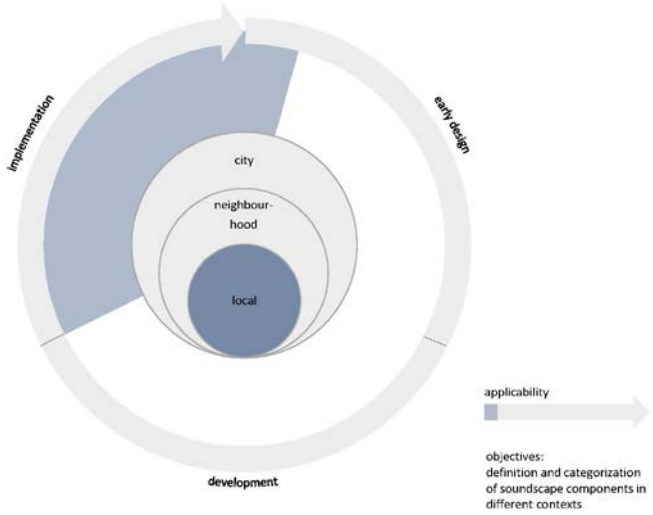

Figure 2: Applicability and main objective of the soundscape method in relation to the city scale and design process

3.3 Sound effect

The centre for Research on Sonic Space and Urban Environment (Cresson) at the National school of Architecture in Grenoble was founded in 1979. The primarily reason was to develop qualitative tools for the analysis of acoustic spaces. This led to the development of a conceptual tool, sound effect, to be used in the architectural design process. The sound effects are defined through spatial observations, architectural descriptions and characterisation of the built environment and link sonic phenomenon in urban spaces to a context and its effect on individuals. It can therefore be defined as '*an interdisciplinary tool with which one may conceptualise and create sonic criteria with regard to the built environment and perceiver space*' [15].

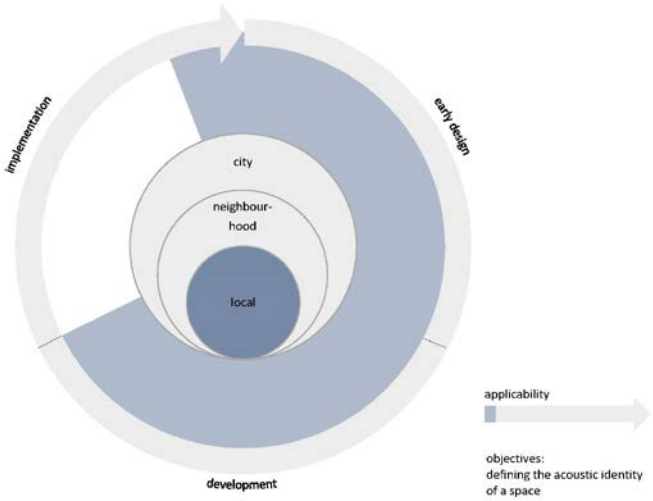

Figure 3: Applicability and main objective of sound effect in relation to the city scale and design process

The main objective the sound effects is to understand how an architectural form affects the acoustic configuration and perception of space with a certain cultural and social context; the acoustic identity of the space.

The defined effects can serve as a criteria for the synthesis of the characteristics of existing areas and as a design tool, predicting the identity of a space by relating physical properties and context to the perception qualities. The application of sound effect requires that the practitioner has knowledge of the theory behind the defined effects [15]. The sound effect can therefore be seen as a toolkit or a paradigm rather than an explicit design method that can be applied in an interdisciplinary design process. The sonic effect can on the other hand serve as a framework for the development of tools for the evaluation and design of urban acoustic spaces [16].

3.4 Sound expert walk

Soundwalks are traditionally related to the soundscape method where it was originally introduced as a listening practice method [17]. The soundwalk has since then been applied in various ways for the investigation of soundscapes. Here, soundwalks are particularly performed in groups of various people, where the group is led through a certain route. The soundwalk is often followed by interviews or questioners where participants share their subjective experiences [18]. A soundwalk, not related to the soundscape method, can also be referred to as a performance sound walk, where people are led to a series of installations or happenings. A third type of soundwalk, and the one that forms a part of this review, is a sound expert walk which can be seen as a tool that supports the design process of urban acoustic areas. A sound expert walk might be performed by sound experts solely or with a sound expert as a guide, which allows for local inhabitants to be involved. The quality of the acoustic environment is evaluated in the given context and the experts try to identify which elements in the area can be identified as having positive or negative influence on the acoustic environment, including architectural parameters, natural elements and the composition of sound.

The main objective of sound expert walk is therefore to give an immediate idea about problematic areas and to identify key parameters for improving the quality.

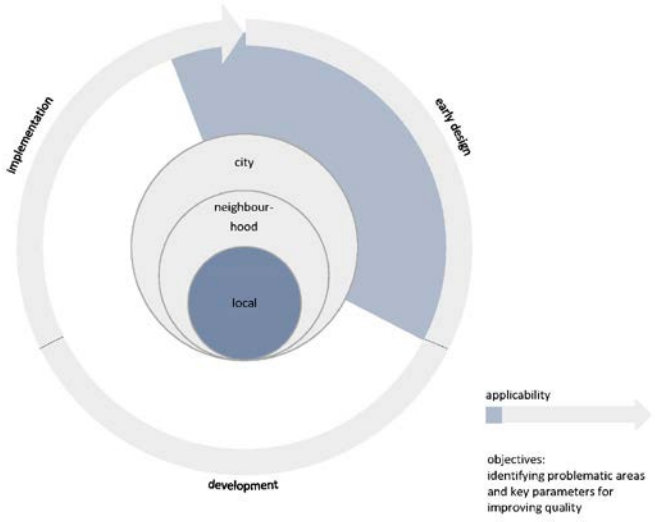

Figure 4: Applicability and main objective of sound expert walks in relation to the city scale and design process

The sound expert walks is not a defined tool but a method, which supports a dialog between different experts and locals involved and can be used to complement the design process. The optimal use of sound export walks is used to assess existing areas or the ‘result’ of newly developed areas, but the method can also be used to evaluate mock ups of design proposals that are under development [19] and thereby influence an iterative design process.

3.5 SONORUS

The European Training Network SONORUS was established to bring together different actors within the urban acoustic environment and develop skills within the planning process of urban acoustic environments. SONORUS addresses three scales as described in the introduction to this paper, the macro-, meso- and micro scale and remarks that all scales

influence each other, addressing the importance of a transdisciplinary approach at the various scales. SONORUS has not developed one final tool or method for urban planning but presents several different tools for the assessment and prediction of the acoustic environment. The majority of those tools are based on calculations and assess the objective parameters related to traffic planning and the propagation of sound. At the micro scale, soundscape studies and multisensory perception tools are applied in combination with objective models.

The main objective of SONORUS is therefore an approach to the urban sound planning, where various tools are use at different scales in an interdisciplinary process to reach a holistic solution.

According to the SONORUS project it should be seen as the start of a paradigm shift towards a holistic approach to urban sound planning and as a framework basis for future development. The tools presented include numerical methods and other computational models which demand a somewhat extensive amount of data and a time consuming process. The combination of various methods and collaboration between different practitioners complicates the use in an iterative design process [9].

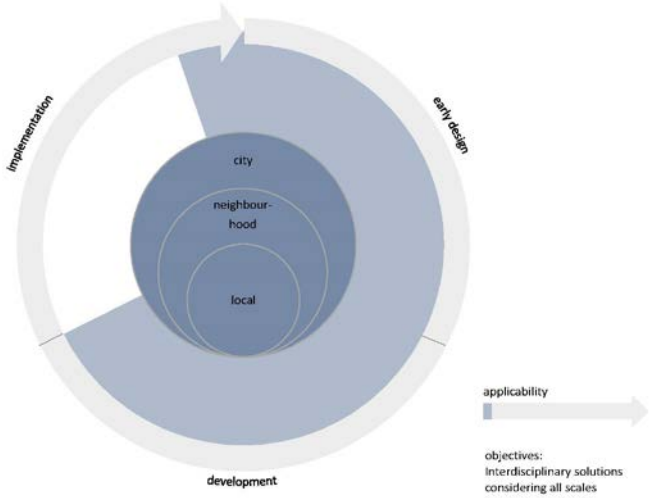

Figure 5: Applicability and main objective of the sonorous project in relation to the city scale and design process

4 Findings and discussion

In Chapter 3, a review of five methods or frameworks for the assessment of the urban acoustic environment was presented in several diagrams. The diagrams illustrate the main objectives of the methods and their applicability in relation to the design process and an urban planning scale.

When looking at the four methods with a qualitative approach there are some differences in the main objectives. The soundscape method, sound effects and sound expert walks have emphasis on the relationship between the sound, contextual parameters and the perception of the acoustic environment. The ‘quality’ presented by the SONORUS project lies in the interdisciplinary approach and consideration of all scales, while the tools presented are mainly based on quantitative assessment.

The soundscape method and sound expert walks are methods, which are optimal for initial analysis or for the ongoing assessment of existing areas while a design support further in the design process is complex without a defined framework. The design ‘paradigm’ of sound effect and SONORUS can be applied from the initial analysis and through the design development but as for the other methods a more explicit design tool would make the methods more eligible for design support in an iterative design process.

The soundscape method, sound expert walks and sound effect have focus on the perception at ear level. The SONORUS project emphasises the importance of considering all scales in relation to each other. All the qualitative methods do therefore address the scale or level which often is neglected, the local scale and the ear level.

As implied in the introduction, the greatest challenge is the application of the qualitative methods in the early design stages. In order to be relevant as design support tools, the methods should match the extent and detail of data available

at the early design stage and the operation must be relatively simple. This would enable the exploration of different design solutions in an iterative process. As illustrated in the synthesis in Figure 6, the qualitative methods address all scales and the whole design process. The objectives of the methods do also include a wide range of both subjective and objective considerations, including architectural, perceptional, contextual and noise-related parameters. It is only the applicability that is lacking.

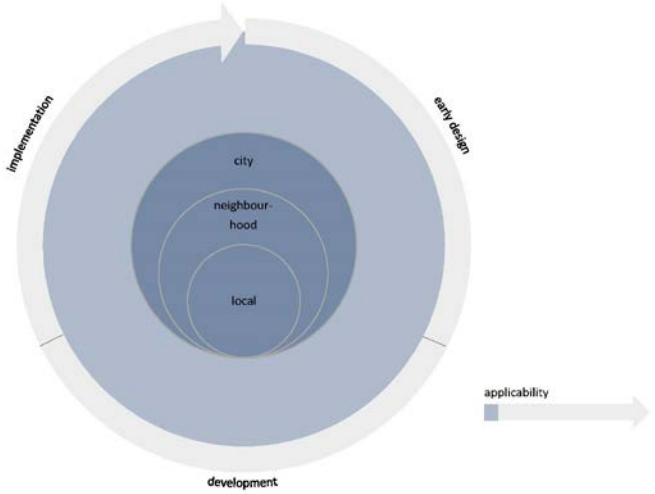

Figure 6: City scales and design stages covered by the four qualitative methods

The further development of the frameworks or methods should therefore focus on the applicability. Here, a 'compromise' might be necessary when considering the degree of detail and precision of the results. It can be discussed how a design tool should inform the design process but at the early design stages the awareness of the effect of different design decisions and an indication the acoustic identity of the space might be sufficient.

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References

[1] WHO. Guidelines for community noise. WHO, Geneva 1999.

[2] EEA EEA. Noise in Europe, EEA Report No 10/201. : EEA; 2014.

[3] Zhang M, Kang J. Towards the evaluation, description, and creation of soundscapes in urban open spaces. Environment and Planning B: Planning and Design 2007;34[1]:68-86.

[4] Yang W, Kang J. Acoustic comfort evaluation in urban open public spaces. Appl Acoust 2005;66[2]:211-229.

[5] Brown A, Kang J, Gjestland T. Towards standardization in soundscape preference assessment. Appl Acoust 2011;72[6]:387-392.

[6] Bruce NS, Davies WJ. The effects of expectation on the perception of soundscapes. Appl Acoust 2014;85:1-11.

[7] EEA EEA. Good practice guide on quiet areas. European Environmental Agency, EAA Technical Report 2014[4]:2014.

[8] EU Commission and others. The Green Paper on Future Noise Policy. COM [96] 1996;540.

[9] Kropp W, Forssén J, Estéevez-Mauriz L. Urban Sound Planning: The Sonorus Project. : Chalmers University of Technology, Division of Applied Acoustics; 2016.

[10] Gehl J. Cities for people. : Island press; 2013.

[11] EU Directive. Directive 2002/49/EC of the European parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise. Official Journal of the European Communities, L 2002;189[18.07]:2002.

[12] King EA, Murphy E, Rice HJ. Implementation of the EU environmental noise directive: Lessons from the first phase of strategic noise mapping and action planning in Ireland. J Environ Manage 2011;92[3]:756-764.

[13] Holistic design method for the urban acoustic environment. INTER-NOISE and NOISE-CON Congress and Conference Proceedings: Institute of Noise Control Engineering; 2017.

[14] Adams M, Davies W, Bruce N. Soundscapes: an urban planning process map. 2009.

[15] Björn Hellström. Noise design: Architectural Modelling and the Aesthetics of Urban Acoustic Spase. Institutionen för arkitektur; 2003.

[16] Maag T. Cultivating Urban Sound Unknown Potentials for Urbanism. Oslo: Oslo School of Architecture and Design 2013.

[17] Schafer RM. The tuning of the world. : Alfred A. Knopf; 1977.

[18] Yong Jeon J, Young Hong J, Jik Lee P. Soundwalk approach to identify urban soundscapes individually. J Acoust Soc Am 2013;134[1]:803-812.

[19] The sonic public realm-Chances for improving the sound quality of the everyday city. INTER-NOISE and NOISE-CON Congress and Conference Proceedings: Institute of Noise Control Engineering; 2016.