Urban Sound Planning

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Background

Rapid urbanisation accompanied by insufficient access to affordable housing as well as increased demand on mobility are key issues of any bigger city in Europe and around the world. Adding to these questions the problems of climate change it is easy to see the risk that we loose sight of other qualities appearing less urgent but nevertheless highly relevant for a sustainable development of our cities.

One of those qualities is the acoustic environment in our cities. It typically appears very late on the agenda, often first when realised that relevant regulations with respect to noise are not met. Consequently regulations are often also experienced as hinders for an economically efficient urban development.

We as acousticians might partly be responsible for this situation. In our ambition to protect people from the negative consequences we strongly focused on regulations. However regulations have shown to be an insufficient driving force to motivate relevant actors such as architects or city planners to include urban sound as one part in the quality of the "product" they are creating.

Training network SONORUS

SONORUS is the name of an Innovative Training Network (ITN) funded by the European Community inside the Marie Skłodowska-Curie Actions. Such programmes offer young researchers the opportunity to improve their research skills, join established research teams and enhance their career prospects. The Latin word "sonorus" which means sounding, sonorus, has been chosen to describe a professional vision. Following the symbolic meaning of "aquarius" to specify a water expert, "sonorus" has been given the meaning of a sound expert, a skilled person with full expertise in all matters of (urban) sounds and soundings. The consortium comprised nine partners from seven European countries, five universities, three research institutes and an acoustic engineering company. Besides these partners, associated partners in the form of the cities Antwerp, Brighton, Gothenburg and Rome were involved in the project. From year 2013 to 2016 fourteen young researchers with different educational backgrounds in acoustics, architecture and city planning contributed to the development of approaches, methods and tools for urban sound planning. The overarching goal of SONORUS was to educate people being able to implement a holistic approach in urban sound planning by mastering relevant areas in acoustics (prediction methods including auralisation, noise control engineering and soundscaping approach) in the context of urban planning. The four cities provided for this test sites which allowed training in its very best way, i.e. training by doing. The results of the project are summarised in the SONORUS booklet [1] and are briefly presented in the following text.

The Need for Acoustic Design of Urban Space

Sound and vibration are a fundamental part of our daily life. Visual and auditory stimuli deliver our main stream of information from the outer world. Therefore it is to no surprise that sound and vibration properties are critical for the experienced quality of environments or products.

For products such as high speed trains, automotive vehicles or machinery, sound often takes a much higher priority in consumers' decision than would be expected purely from consideration of function [2]. Sound is a key issue in brand differentiation and therefore in sales. Product sound quality has been defined as "the adequacy of a sound in the context of the specific technical goal and/or task" [3]. There is a general agreement that product sound quality evaluation has to begin at the very early stage of design. It has to be guided by the expectations of the customer in relation to the product. Consequently the process of virtual prototyping starts with the definition of the product sound and ends with the evaluation of the resulting sound [4]. The ambition level in this process is deliberately chosen as part of the overall product strategy. This clearly differs from the work to fulfil imposed regulations by products. From an economical perspective it is understandable that, in this case, effort is limited to just passing the regulations.

When it comes to the sound environment in the urban space, decision makers' commitment solely concerns the fulfilment of regulations at the best and even this seems to be difficult and often failing. Very little effort, if any, is focused on "product" sound quality. Reformulating the definition in [3] to "the adequacy of a sound in the context of the specific function and/or task of urban space" would mean that insufficient or absence of "product" sound quality is equivalent to a dysfunctional urban space. This should alarm and highly motivate architects and planners to make deliberate decisions on the intended sound environment in the very early phase of projects. Such decisions are hardly made today and the question has to be raised what makes the urban space so different from industrial products that sound design has not really found its legitimate position in the planning process.

The "Product" Urban Space and Sound

Technically one might assume the acoustic design of urban space as a task to be similar to the acoustic design of any other product. However there are tremendous differences due to the inherent properties of urban space characterised by form, scale and time [5]. The form is represented by its buildings, the open spaces, plot-lots and streets. The scale or resolution of the city reaches from the building/lot to the street/block, the city, and the region. Finally there is the aspect of time, where the built environment is under constant evolution, subject to socio-cultural, but also socio-technical, and environmental forces that transform and adapt the elements composing the city. To this adds that customer and sound sources are hard to separate as we as users of urban space are also determining its acoustic environment due to our needs for mobility, leisure and social life.

Today, when we as acousticians work with noise or sound projects in urban context, we mainly work locally in all aspects. We work with a single or few buildings (limited form), in a small area (micro or meso scale) and with a short time perspective (now or in the very near future). In this case acoustic design of the "product" urban space might be similar to the acoustic design of any other technical product.

However there are also similarities, as the acoustic properties of technical products as well as of urban space cannot be handled isolated but are strongly interweaved in a wider context of demands, policies, strategies and technical settings. What differs is the immense complexity the work with urban space entails.

The Complexity of Urban Sound Planning in a Multi-Facetted Perspective

Urban Sound Planning is about relationships and perspectives, as any other aspect in urban planning. The complexity to approach it from a multifaceted view is intrinsic to it. In [6] one of the authors made the attempt to address the most relevant perspectives (see Figure 1).

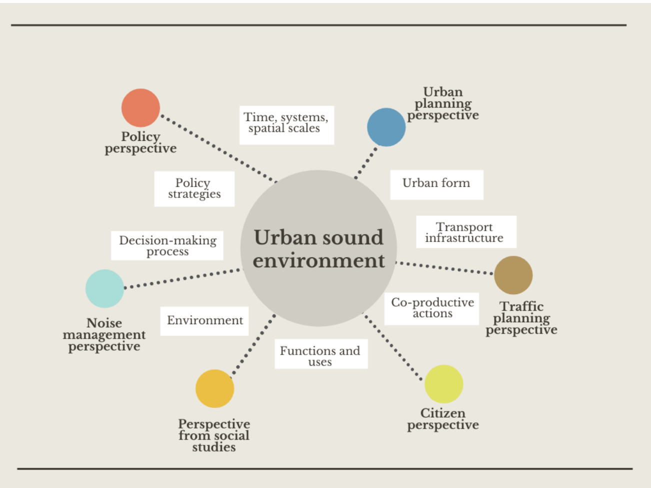

Figure 1: Different perspectives relevant to urban sound planning.

From this work it becomes clear that the challenge to address urban sound planning by including the multitude of perspectives is enormous. At the same time neglecting perspectives can easily be identified as reason for unbalancing the way city planning is carried out. Focusing mainly on the concept, the building design or the traffic planning, means neglecting other perspectives with all its consequences. Urban sound planning therefore means to accept the multi-perspective complexity of planning. However, it also means to be prepared to contribute as acoustician with appropriate tools and methods beyond "the usual business". The latter is not easy and needs mastering of the whole variety of tools, methods and approaches.

Tools for Urban Sound Planning

A main objective inside SONORUS was therefore to educate young researchers to master the wide range of tools needed inside urban sound planning. Beside courses and workshops this education was carried out as individual research. Inside the research projects methodologies and tools have been developed. In the following some of the results from this work is highlighted. With respect to the limited space of this paper, the presentation is far from covering all work made in SONORUS.

When it comes to urban sound planning it is important to be able to approach it from a micro-, meso- and macro-scale level. However, we should have in mind that these scales are interacting.

At the ***microscale***, one can for instance study the control of the sound environment by ***local architectural elements, building façade design, balconies and small barriers***. The idea could also be to protect pedestrians. One of the projects utilised Finite-Difference Time-Domain (FDTD) calculations [7]. In the study different façade geometries have been investigated (see e.g. Figure 2) with respect to the reduction of sound for pedestrians and at the façade at different heights. The work showed that shaping the urban canyon has an important influence on road traffic noise levels for pedestrians. Redirecting the first noise reflections upwards by inclination of geometries at the facades and close to the sources can make substantial differences (easily 10 dB for people at higher floors in the building, at least in 2D modelling). To make use of such rather small design changes (e.g. modifications of balconies in the proper way) should be a natural part in architectural design.

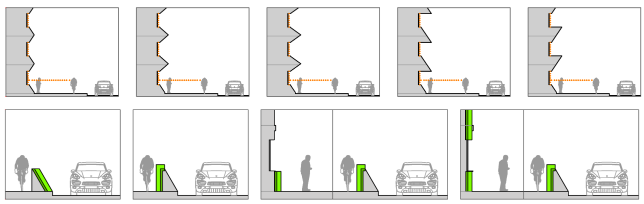

Figure 2: Examples of façade and street design presented in [7].

The ***concept of quiet side*** in inner yards has become a powerful tool for the development of new urban areas, especially when densification of consolidated cities is pursued. Quiet sides are typically defined as areas where sound-pressure levels do not exceed a certain magnitude. They are considered as restorative places. However the concept is strongly linked to the quality of those spaces. The way we perceive our environment strongly affects the way we behave and how we feel. To make these areas attractive, attaining a low noise level is not sufficient. Other spatial qualities might influence the human response, such as vegetation, diversity, privacy, aesthetics, sense of community, thermal comfort, etc.

To predict the sound environment in shielded areas like inner yards is not simple, however. Typical noise mapping software do not work in this case as only a few reflections are taken in to account at the best. The consequences are differences in up to 15 dB between predictions in realistic cases. In [6] an implementation is presented of a Qside model which improves this situation substantially (see Figure 3).

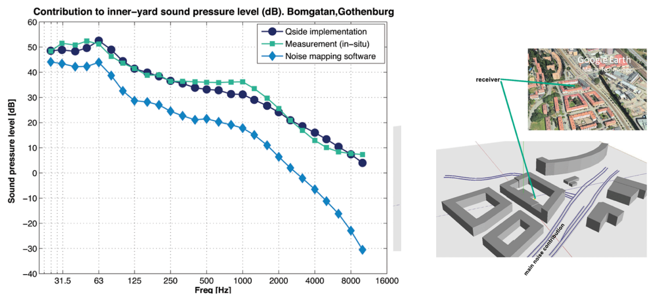

Figure 3: Contribution to the inner-yard noise level. Differences between measurements, *Qside* implementation and noise mapping software.

The concept has tremendous capacity to influence the urban decision-making process and with this having an impact at all urban scales.

For working on the meso-scale a tool has been developed to improve the city decision-making processes in terms of road traffic and noise emission. For this an assessment tool consisting of a series of microscopic traffic simulations including vehicles kinematics has been implemented (see e.g. [8]). Combining this with the road emission model of the Common Noise Assessment Method in Europe (CNOSSOS-EU) dynamic *noise contribution maps* can be calculated, i.e. the respective contribution from each road segment to a selected receiver, as well as sound pressure time patterns enabling to study the effects of vehicle kinematics.

For a development area in Gothenburg eight different strategies were tested, whereof a few are pointed out here: (1) base-scenario for the future plan, (2) remove a road and move its traffic towards other adjacent roads, (5) reduce speed in the highway located near the area, (8) remove medium-heavy and heavy vehicles, and (9) neglect the effect of acceleration. The equivalent sound pressure level and the number of events above 60 dB(A) are plotted for the selected scenarios for different study points (see Figure 4).

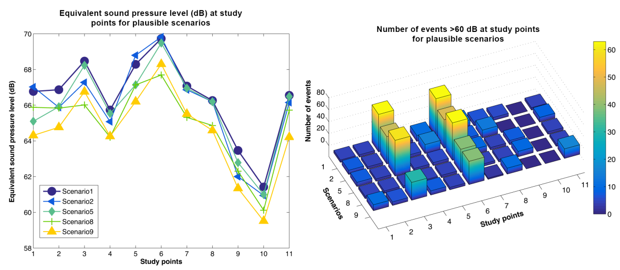

Figure 4: Sound pressure level (left) and number of events above 60 dB (right) for the study points and scenarios

In case the heavy and medium-heavy vehicles are removed from the network (8), equivalent sound pressure level (LAeq) reductions at the selected points are between 1 and 3 dB. Similar reductions are achieved if acceleration noise is omitted (9). With this type of tool, we can study time patterns in any form of indicator depending on noise level. In our real case study, the number of noisy events above 60 dB(A), are drastically reduced in the scenario without heavy vehicles (scenario 8) for the majority of the points (up to 60% less noise events at several points), see Figure 4 (right).

To work with urban sound planning also means to characterize of the sound environment. Inside SONORUS this has for instance been made by integrating a detailed traditional noise mapping and soundscape maps through the perception evaluation of the sonic environment appropriateness. Assessments showed that this integration can be an effective methodology in the analysis stage, supporting city planners with adequate information and strategies to plan future urban interventions on the ***meso-scale***. The approach has been applied to the Valley Gardens site, a green area located in the city centre of Brighton & Hove, which stretches from the seafront roundabout (Brighton Pier) to approximately 1.5 km into the city [9] (Figure 5).

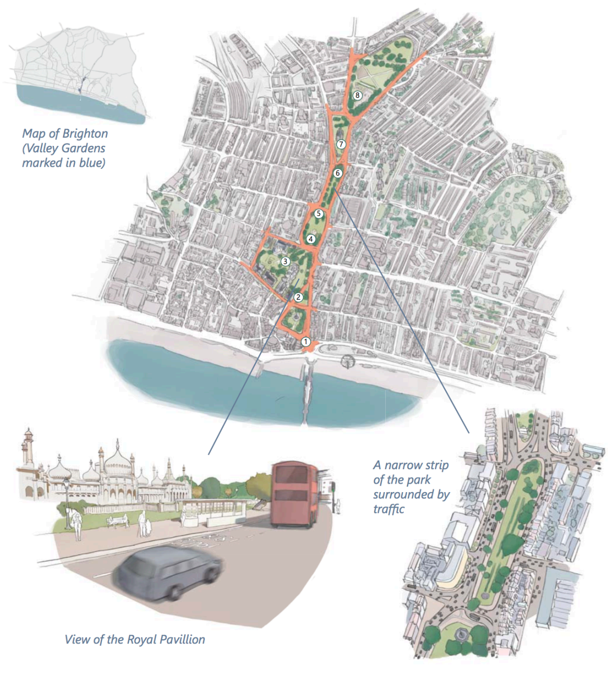

Figure 5: The test side Garden Valleys, Brighton & Hove.

A noise survey and a soundwalk campaign were carried out at eight selected locations close to and within the Valley Gardens. The results showed that only two of the selected locations had high scores both on the overall sound environment quality and appropriateness of the sound environment to the place: The Royal Pavilion and The Level. This is likely due to the fact that those are the only two sites that are not directly exposed to road traffic noise, which has been found to be the main cause of noise annoyance in the investigated area. A “sound sources dominance map” confirmed this. Based on these findings a combination of soundscape approach and noise reduction measures were proposed to the city.

On the ***macro-scale*** methods have been developed enabling planners but also politicians to deliberately defining sound qualities in the urban space. One of the most important instruments in this context is auralisation and soundwalks as they allow even a non-acoustician to judge the quality of an urban space with respect to acoustics. Tools have been developed for the auralisation of different sources in a variety of environments. In [10] a model approach for prediction of aircraft sound in the presence of atmospheric turbulence is presented. A method for auralisation of background road traffic has been developed, with the aim to concentrate computational power to foreground events, e.g. a car passing by on a local road where the listener is located. The approach uses modulation transfer functions, i.e. rippled noise spectra that shift with time, which appears to be a compact and promising way to model a time varying noise event (see e.g. [11] and [12]). To create auralisation of the sound environment in the urban space – maybe even compared with visual information – can be considered as an important tool enabling planners and architects to learn to listen to the consequences of the urban design over the whole spatial scales as well as including anticipated transformation process over time.

The last tool presented here aims back on the functionality of our urban spaces and the influence of the sound environment. As written in the introduction, urban sound planning is not about silence but about to ensure the individual functions of urban space. In [13] an approach is presented to investigate the use of common space by identifying how the sound environment affects the functions of space and the interaction with other environmental and spatial variables. In situ evaluations with regular users were collected in nine common spaces in Gothenburg, Sweden, conducting sound recordings and questionnaires. The combination of resources as noise maps and sociotope maps, together with the development of tools (questionnaires evaluating quality judgements, particular sound quality attributes and suitability of activities) and sound recordings plus indicators, can help us to further understand the relevance of the outdoor sound environment in the spatial production and the functions of those spaces. As we have already mentioned, this is a further step in the attempt to evaluate the urban sound environment through a multifaceted perspective.

Conclusions

Through the urban design, we give form and structure to our society and to the quality of places. Concerning this, the built environment is an extension of us, which allows such liveability.

Urban sound planning is about health and wellbeing of the people which is of course essential. However to overcome the situation where designing the sound environment is reduced to the fulfilment of regulations, we have to be more persistent with that urban sound planning is also about creating and preserving functionality of the urban space. Finally it is also a possibility to add uniqueness and recognition to the urban space, something which could counterbalance the lack of visual uniqueness we observe today in architecture in many cases.

The idea of SONORUS was born out of the vision that it is possible to achieve a paradigm shift in the handling of sound environments in our cities. A shift to a holistic approach to sound environment planning, as a natural part of the overall planning of our cities from the very beginning, instead of traditional noise control applied late in the planning process. A project such as SONORUS alone can never achieve such a change during its limited lifetime. It can, however, be the beginning of that change.

References

[1] Kropp, W., Forssén, J., Estévez-Mauriz L., Urban Sound Planning – the SONORUS project, Chalmers University of Technology, 2013, www.ta.chalmers.se

[2] Lindstrom, M., Buyology: truth and lies about why we buy, Doubleday 2008

[3] Blauert, J., & Jekosch, U. (1997). Sound quality evaluation - A multi layered problem. *Acta Acustica united with Acustica 83*(5), 747 – 753

[4] Lyon, R.H. Designing for Product Sound Quality (Mechanical Engineering), CRC Press; 1 edition (2000)

[5] Moudon, A. V. , “Getting to know the built landscape: typomorphology,” in ordering space: types in architecture an design (K. A. Franck and L. H. Schneekloth, eds.), ch. Getting to know the built landscape: typomorphology, pp. 289–311, New York: Van Norstran Reinhold, 1994.

[6] Estévez-Mauriz L., Urban Sound Planning – An attempt to bridge the gap, PhD thesis, Chalmers University of Technology, 2020.

[7] G. M. Echevarría Sánchez, T. Van Renterghem, P. Thomas, and D. Botteldooren, “The effect of street canyon design on traffic noise exposure along roads,” *BUILDING AND ENVIRONMENT*, vol. 97, pp. 96–110, 2016.

[8] Estévez-Mauriz L. and Forssén, J., “Dynamic traffic noise assessment tool: A comparative study between a roundabout and a signalised intersection”, Applied Acoustics, vol. 130, pp.71–86, 2018.

[9] Aletta, F., Kang, J. (2015). Soundscape approach integrating noise mapping techniques: a case study in Brighton, UK. Noise Mapping, 2(1), 1-12.

[10] Rietdijk, F., Heutschi, k., Forssén, J., Modelling sound propagation in the presence of atmospheric turbulence for the auralization of aircraft noise , The Journal of the Acoustical Society of America 136:4, 2286-2286

[11] Zachos, G. Forssén, J. Kropp, W. Estévez-Mauriz, L. Background traffic noise synthesis. In. Proc. Internoise 2016, August 21-24, 2016. Hamburg, Germany.

[12] Zachos, G. Forssén, J. Kropp, W. Estévez-Mauriz, L. Auralisation methods as tools for urban traffic noise assessment. In. Proc. Internoise 2016, August 21-24, 2016. Hamburg, Germany.

[13] Estévez-Mauriz, L., Forssén, J. and Dohmen, M.E., “Is the sound environment relevant for how people use common spaces?”, Building Acoustics, vol. 25(4), pp. 307– 337, 2018.