Analysis of soundscape of selected urban public places and its impact on their assessment by users

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ABSTRACT

This paper describes an ongoing research project concerning the soundscape of urban public spaces and the relevance to architectural quality of particular public spaces and their overall assessment by users. Described here is the methodology of data gathering and analysis that was carried out last year in Prague, Split and Ljubljana. In addition, partial and expected results and possible further applications will be discussed. The topic of the research is the effect of sound environment on perceived quality of a given public space by the inhabitants and the dependant factors that influence these relations. The research is focused on selected public spaces representing different typological categories in cities of different geographical location and their users' cultural background. Examined cities will represent regions of central Europe, south Europe and north east Australia.

Keywords: Soundscape, Soundwalk, Urban design, Public places, Assessment, Evaluation
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1. INTRODUCTION

Recent and past research shows (1-4)that soundscape has an important role in the overall architectural atmospheres (ambiances) of public space design. Since the last decade of last century, there has been a clear shift of interest in the field of architecture and urban design worldwide from grand scale planning to urban public spaces and human scale, which is condensed in the works of Gehl(5). Leaving the urban space neglecting behind, the public space renaissance is evident among Czech and Slovak architects and planners as well. In his work about experiencing architectural properties of (architectural) spaces by one's sences, Rasmussen (6) suggests that the only true approach to assess architecture is by experiencing it in its totality. He regards sound as a property that sets architecture apart from other forms of art. Acoustics of the designed space, whether it is interior architecture or urban exteriors of public space, decisively influence their soundscape. Architects today do not usually take the aural properties of their (public space) designs into account during the conceptual phase. Research described in this paper is a part of doctoral thesis that will challenge traditional approaches of design to include notion of soundscape and acoustic design into architectural design paradigm, focusing on the case of urban public places (UPPs) design.

For meaningful implementation of findings for the designer (architect), urban elements, entities and factors influencing sound propagation and soundscape must be identified and described. This requires a development of a set of descriptors and metrics to quantify the soundscape and demonstrate its impact on the users' response to related UPP. The concept of soundscape itself is too broad to address the acoustical situations and qualities in detail. Past research has proven that standard psychoacoustic metrics like loudness are inappropriate as descriptors for soundscape assessment by inhabitants. Increased interest in the soundscape as a specific phenomenon and environmental factor of UPP can be observed recently across different scientific fields. One group of research focuses on objective acoustical parameters used to categorize soundscapes, like Rychtarikova and Vermeir(7). Other group of researchers concentrates on subjective evaluation, perception and holistic modeling of soundscape. Emerging from this research and experiments are several descriptive models of soundscape and its perception; some of them may be considered overlapping each other. However, no standardized approach exists to-date, as summed up by Kang(8, 9) and Davies(1).

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Therefore, in this research, the Theory of Sonic Effect (10), developed at Cresson institute is proposed as a tool by which sound elements forming soundscape of a particular UPP can be grasped and examined as mediator between objective and subjective description of soundscape. In addition, for qualitative evaluation by UPP users, experiential emotional categories proposed by Rihacek (11, 12) are implemented to describe cognitive semantic assessment of a soundscape.

2. RELATED RESEARCH PROJECT

2.1 Outline

The above mentioned trend is followed by the ongoing wide-scoped research project "Changes in the usage of territory and concomitant negative effects II" under the internal research grant of Czech Technical University. Project encompasses several research groups that lead own research around the topics from Urban design and planning field.

2.2 Project's objectives related to described analysis

The primary objective of the research discussed is to determine whether the soundscape can be considered relevant 'and to what extent' a critical agent in the spatial, functional and qualitative shaping of urban spaces and their assessment by users. The secondary objectives are to identify those architectural elements or compositions of urban public space that contribute to the shape and character of its soundscape, and determine if there is a correspondence between soundscape appretiation and typological form of given urban space. Current research attempts to tests three hypotheses:

First is that soundscape perception is relevant factor in the appreciation and usability of any given urban space by its community. Early research indicates there is some correlation between perceived soundscape quality and regarded urban place quality. That suggests the character and composition of soundscape influences livability and success of any urban public space.

The second, at micro-scale, examines the quantitative acoustical descriptors (L_{AeqT} and L_{Amax}), these values are standard in regulating health protection noise limits, but are inadequate to describe the real perceived sound environment of a given urban space by its users. These descriptors, along with indicators imposed by the EU directive[2] and other legislations[3] (L_d, L_e, L_n, L_{den}), deal with acoustical energy distribution and its effects on human health. Being objective quantitative measurements of sound pressure, these parameters do not carry qualitative information about meaning of sounds perceived and their interrelations to context. It is expected that there will not be correlation between noise levels and perceived quality of soundscape and urban place. As shown by past research works (1, 4, 13)and noted by Kull(14). Mentioned descriptors can then be regarded as misleading values that flattens the understanding of soundscape and its effective use in architectural design of public urban spaces.

Third hypothesis is that each typological form of urban public space is associated with a soundscape containing specific sounds, that inhabitants expect them to be present, thus creating a predetermined 'acoustic scenario' as proposed in research by Rychtarikova and Vermeir(7).

Based on already gathered data, research assumes that regional factors and cultural distinctiveness have bias on importance and valence of various soundscape elements and their impact on urban places perceived quality and ultimately, on urban public space success.

2.3 Focus of research

2.3.1 Soundscape

In multidisciplinary research, the dynamic sound environment of a place regarded by humans. It can be seen as a whole system of all sounds audible at some point of a place in given time. According to Shaffer (15), it is parallel to the visual country. The sound sources within studied space are contributing to creation of place's soundscape and constitute a metabolic environment[4]. There are no agreed definite models by which to describe the soundscape, as the original model proposed by Shaffer(15) is considered inaccurate. Currently, the ISO WG54 working group develops a standardised

[2] EU directive on environmental noise 2002/49/EC; 2002.

[3] OECD guidelines for multinational enterprises; 2008 and WHO quidelines for community noise; 1999

[4] Structural and perceptual concept, regards sound environment that is stable over time, while the individual sounds creating it are perceived as fluctuating, therefore impossible to perceive individually. Homogenous soundscape composed by numerous heterogenous transitory sound. See also:

definition. Research on conscious perception, informational quality quantification and valid qualitative descriptors is still underway. This project follows the holistic approach to soundscape of The Positive Soundscapce Project(1) and Dubois(16), works of Kang(17, 18), Rihacek[5] (11) and Augoyard and Torgue[6] (10). The model used considers soundscape consisting of Aural dominant, Foreground, Horizon and Urban space, as proposed by Rihacek. Each of selected public space are regarded having their own soundscape, background of which are soundscapes of different urban spaces.

2.3.2 Urban public spaces

Set of typologically distinct spaces (UPPs) accessible for general public within the central areas of conurbations are selected. In contrast with similar research of Rychtarikova and Vermeir(7), these spaces are devised to groups based on their use, hierarchical status within network and prevalent traffic. Settlements from which urban places are selected are generally of the same size, development level or importance relative to their region. Cities included to-date are Prague, Ljubljana and Split.

2.3.3 Urban traffic

Transportation is a common structural feature in every settlement or urban structure. Traffic shapes and impacts the UPPs. Because of its ubiquity, it can be regarded as an environmental factor that contributes to acoustical situations in any UPP in a wide scale – as a dominant sound source on one hand. Traffic contributes to the soundscape of any given public urban space. According to several studies and research projects, traffic is either a dominant figure or feeble acoustical backdrop on the other hand (11, 15, 19).

3. Methodology

The analysis of soundscape and selected regional factors are intended to be carried out in the form of four case studies in the public urban areas of Prague, Ljubljana, Split and Brisbane. In the future, urban spaces from a city in Nordic regions will be included. These cities represent culturally and geographically different regions in European Union and Australia. The common denominator is the quality and identity of public space. European public urban spaces were chosen because of their uniqueness, diversity and high cultural value. The research bases its methods and actions on experience from past research of soundscape evaluation and description. The basis of methodology raises from techniques used by Kang et al.(17), Dubois et al.(16), different levels of listening attention and their implications to sound environment characterization as described by Amphoux (20) are acknowledged, sound sources qualification proposed by Léobon(21) is applied[7], the clustering method by objective acoustical parameters proposed by Rychtarikova and Vermeir(7) is taken into consideration and the past ASTUCE research at Cresson institute (22), that were modified. These methods of looking at and describing soundscape are preferable, because of their holistic approach. Soundscape is not regarded as an object with given attributes that can be quantifiable in the same way as acoustical indicator s in the 'traditional' noise annoyance model.

3.1 Research and data gathering approach

Approach in gathering data of the different factors of urban spaces environment was governed by several facts: different repertoires of attributes for each factor, difference in amount of data and the future analysis intended.

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[5] In his thesis from psychology field, Rihacek develops 35 distinct categories of emotional experiences by soundscape listeners that describe meaning and polarity (positive-neutral-negative) of subjective assessment of soundscape. Additionally, he proposes descriptive model for soundscape that consists of Dominant, Foreground, Horizon and Space (built environment), a modification of Shaffer's model.

[6] In their novel contribution to soundscape studies, Grenoble's CRESSON institute proposes vocabulary of terms that conceptualise a give common sense to the physical and human dimension of sound phenomena in soundscape. This terms are called 'Sonic effects' and are categorised according to their nature. After 15 years of interdisciplinary studies a set of 82 hierarchically organised 'effects' where identified that can be used as an aural parallel to morpho-typological classification of architectural elements. The set consists of 16 major and 66 minor Sonic effects each described from point of view of 6 different domains of knowledge (acoustics, architecture, psycho-physiology, sociology, musicology and media-linguistics).

[7] Taxonomy derived from the principle of variation of sound source within a triangle of three sound groups representing the extremes of urban space use / activity (mechanical, human activities, human or natural presence sounds) allows for description using color spectra. This is found most practical and straightforward for mapping.

3.1.1 Types of data

Two groups of data is collected in-situ and in laboratory.

Objective data include calculated noise levels from noise maps, traditional acoustical descriptors (L_{AeqT}, L_{Amax}, SEL, Loudness, Sharpness, Roughness, Spectral profile in 1/3 octave bands), architectural composition and proportions, hierarchical significance and type of traffic in given UPP.

Subjective data include UPP quality and satisfaction assessment by users, frequency of visiting of particular place, opinion on acoustical appropriateness of place, rating of satisfaction with soundscape and emotional experiential categorization.

Additionally, emergence of Sonic effects in each recorded soundscape and sound source composition will be identified during laboratory listening and analysis of activities in UPP.

3.1.2 Data acquisition

Activities can be sorted into three groups: In-situ measurements and survey, geospatial data extraction and Laboratory evaluations. Based on the aims of research, different phases of data acquisition were designed.

In-situ measurements are carried out by a short questionnaire to users and passersby with closed answers, recordings of sound environment using binaural microphones and high fidelity linear PCM recorder, acoustical measurements of sound pressure levels and spectral composition with sound analyzer in 'fast' mode 125 ms sampling, photographing human activities and architectural elements and drawings of the build environment. Recordings and questionnaire interviews are carried out simultaneously to ensure maximum coherence and validity of data. Among demographic information, the questionnaire survey also gathers data about level of appreciation of current urban space on a scale, emotional experiences of sound environment by categories developed by Rihacek (11), acceptation of perceived noise, general assessment of quality of urban space on a scale.

Geospatial data extraction will be carried out by ArcGIS software. Relevant GIS databases will be provided by universities in the related cities. Spatial, land-sue, acoustical and traffic data, will be extracted.

Laboratory evaluations are be carried out by commented "virtual soundwalks". A selected group of listeners will listen to the recordings made earlier in the In-situ measurements. Listening should be carried out twice – once through headphones and once through stereo loudspeakers in acoustically isolated room. No visual reference will be provided. This will constitute a "verification group" to compare with results of the questionnaire poll. Additionally, attentive listening will be used for describing the soundscape according to Leobon (21) and identification of Sound effects (10). Listeners will be divided in to subgroups according to their home region. All of the subgroups will be listening and describing to all of the recorded sound environments.

3.2 Collection of urban spaces

Urban spaces, from which the acoustical, audio, survey, spatial and traffic data will be extracted, are selected in cities by a matrix of several criteria:

Urban typology of spaces, contrast in usage, location within the core of the urban structure and type of traffic that occurs in the given space.

Following urban space categories emerge:

A – longitudal streets, subdivided to groups by primary use to 1: Busy traffic streets, 2: Streets in pedestrian zones of centre, 3: Residential streets.

B – polygonal areas (squares), subdivided to groups by primary use to 1: Heavy traffic, 2: Pedestrian zones

C – Riverbanks, subdivided into groups : 1: heavy traffic, 2: pedestrian

D – Passages (Laneways), subdivided into groups by connection importance: 1: connecting main roads, 2: connecting back alleys

E – Parks and green areas with prominent significance.

3.3 Sound environment data recording and survey

The physical description of sound by using physical properties for objective evaluation of subjective impressions from stimuli has serious limitations (16, 23). Following the work of many researchers of CRESSON in the multidisciplinary fields dealing with soundscape studies and acoustical communication (22) , gathering of acoustical data has been derived into two contexts. First context is the cognitive approach. The developing soundscape concept implies the use of psycholinguistic semantic categories for describing the subjective impressions of the sound

environment in given space for given time (2, 10, 16). For our research, the categories developed in the work of Rihacek (11)will be used for describing the sound environment. The context that has been shown to be important for users to give meaning to perceived sound, thus assessing it, will be mapped. In addition, overall satisfaction and acceptation of given urban space will be mapped. To capture the soundscape of the place, recordings of the places take approximately 10 – 15mins together with acoustical measurement. Second context is the quantitative or "noise annoyance" approach. This requires additional simultaneous acoustical measurement of each surveyed area. Equivalent sound pressure level (L_{AeqT}) is the main descriptor for objectively quantifying acoustical situation in a space for a given time. The duration of acoustical measurement is synchronous with the audio binaural recording. The recording microphones have two positions: Stationary is located in the center of examined space; mobile microphone measures levels along the audio recording route. Thus material for examining correlation and quality control is obtained.

3.4 Urban space morphology and use

The urban space forming the context for the recordings are captioned by photographs of facades and pavements. Composition, size of space, the ratio of building height of building to width of street, openness / closeness of the space is considered. Human activities along the soundwalk routes are documented as well by photographs taken. Understanding the overall meaning and popularity among users of each space also adds to context. This information should be discretesized in some way.

3.5 Urban traffic data

For purposes of the project, traffic will be described by scale of intensity and percentile of traffic areas from the overall used area of public space. Data will be collected by extracting and analyzing the appropriate layers from GIS databases. Since it is not studied how traffic contributes to overall noise levels, no on-site counting of traffic will be carried out. Only statistical and available geospatial data will be used. Where there is no data available, general characteristic of the traffic load is derived from the photographs and observation[8].

3.6 Fundamental condition for obtaining valid data

Dry weather without precipitation or high winds and moderate with everyday use of examined public space by inhabitants. Measurements will be conducted on weekdays in similar seasons of year (May, September and vice-versa in Australia).

4. EXPECTED RESULTS

Data are primarily divided into collections according to the public urban space category from which they originated. Results according to the project's object of research will be obtained:

4.1 Soundscape assessment

Sets of temporally coherent data are obtained:

Soundwalks – psychoacoustic and phenomenological description of the sound environment. Perceived loudness parameter and psycholinguistic experiential categories for each discretized section of the soundwalk trajectory.

Traditional acoustical descriptors - objective quantification of characteristics of sound using L_{Aeq} and L_{Amax} descriptors. Additionally, spectral profile (sonograph) of each soundwalk will be studied. Noise map of calculated sound pressure levels in the given, extracted from the provided GIS databases area will be used as a reference.

Soundscape phonography composition map – sound environment of each public urban space will be described according to analysis of sonic signatures. These will be represented by types of activity (events) that constitute the sound sources, normalized into descriptive items according to the study of Leobon (21). This qualitative inventory of sounds will be fed with results of Laboratory evaluations of soundwalks for each of the urban places soundscape.

Datasets will be colorized in tables and maps for further analysis and correlation. The comparison between studied indicators may confirm the stated hypothesis.

[8] Intensity of traffic will be described on two scales "scarce – moderate – frequent – constant flow" for mainly cars and mixed cars / trucks.

4.2 Urban public space assessment

Data obtained from surveys will provide a picture of the overall quality and attractiveness of each public space, perceived by the users. This is expected to coincide to some degree with the assessments of appropriateness and quality of soundscape.

Activities – intensity of use of the space and diversity level of types of activities are regarded as success indicators for each UPP.

4.3 Overall output

Maps with data overlays based on ground plans of examined public spaces will be produced, alongside with statistical charts showing statistics and relations between main observed variables. Each public space will have a noise level map and spectral analysis attached to it, alongside with activities, traffic and use list.

5. DISCUSSION

The research extends and builds on findings and techniques of Rychtarikova and Vermeir(7) and Kang et al.(17). In comparison, approach to subjective data survey is different and smaller in scale, because the aim of the research focuses on meaning of soundscape assessment and its weight in overall subjective evaluation of given UPP, while studying the role of regional differences in this qualification. By using similar approach in using objective parameters for 'objective' soundscape classification, it can be regarded as extension of research of acoustical typology of UPPs by Rychtarikova.

It can be also compared to recent soundscape analysis of Bruce et. al.(24), that concentrates on impact of user expectation in perceiving soundscape of given space.

Field data gathering is time consuming and demanding. In-situ surveying provides authentic qualitative data but it also elevates questions about the level of bias and distortion of answers by external factors (haste, weather, presence of researcher…). The scope and amount of analysis is broader and time consuming than originally anticipated.

Referred research has not yet been implemented within CTU. At a National level one can find some parallels within research projects from the fields of psychology and sociology (11). Outcomes from this project might suggest ways of approaching environmental factors examined in paradigms of architectural and urban design. This project cannot produce definitive conclusions, but should identify trends and relationships for further studies. The results of the analysis from gathered field data will be useful source for future examination and study.

Suggested directions of research on this topic in the architects' professional conditions:

• Uncovering the links between sounds, sound situations and attractiveness of the urban public places. Is the difference between expected and actual situation of acoustic reality of given place reason for its rejection?

• Importance of soundscape as an envelope drawing mental boundaries and interfaces between UPP. What is the relation between mental projection of a UPP, its soundscape envelope and its importance in public space hierarchy?• The introduction of teaching of aural architecture and acoustic design of schools relating to the model of Virginia School of Architecture(25)

• Select appropriate methodology for qualitative description of the sound situation in the urban area.

• Legislative requirements to capture the public good in terms of space, which takes into account the concept of soundscape. A good example is the Charter of Linz – Linz Charter (26), albeit set from the noise mitigation perspective.

• Create awareness about the impact of architectural elements on the resulting sound levels in the proposed area

6. CONCLUSIONS

Categorization and comparative evaluation of obtained data will produce extensive database for further research into predicting the influence of morphology of studied urban public space to its sound environment and relevance of soundscape in assessing the quality of these spaces. This will add to other research in the area of soundscape influence on urban public space quality. The hypotheses stated by the project are able to be tested with the gathered data. Method of validation of results needs to be established. Preliminary examination of resulting datasets show variation of these features in different cultural regions of Europe, and also point to weak correlation between measured noise descriptors and

soundscape quality evaluations. The common denominator of the research should be the shift of opinion in the design process of urban spaces in favor of quality and identity. Architects should understand the design process not as (urban) space creation, but rather an environment for living, using and enjoying. This research should add to interdisciplinary insights for architects about placemaking and genius loci of public urban places.

By better understanding of relations between soundscape, morphology and design of urban public space, one can create an environment that will be better accepted by its inhabitants. User's identification with the given urban space will be reflected in increased interest in it. This will raise the attractiveness of public urban space and make it more used by general public, thus more successful.

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REFERENCES

1. Davies WJ, Adams MD, Bruce NS, Cain R, Carlyle A, Cusack P, et al. Perception of soundscapes: An interdisciplinary approach. Applied Acoustics. 2013;74(2):224-31. PubMed PMID: 82428783.
2. Hellström B. Noise design: architectural modelling and the aesthetics of urban acoustic space. Göteborg: Ejeby; 2003. 263 p.
3. Yang W, Kang J. Soundscape and Sound Preferences in Urban Squares: A Case Study in Sheffield. Journal of Urban Design. 2005;10(1):61-80.
4. Raimbault M, Dubois D. Urban soundscapes: Experiences and knowledge. Cities. 2005;22(5):339-50. English.
5. Gehl J. Život Mezi Budovami: Užívání Veřejných Prostranství. Brno: Nadace Partnerství; 2000. 202 p.
6. Rasmussen SE. Experiencing architecture. Cambridge Mass.: M. I. T. Press, Massachusetts Institute of Technology; 1962. 245 p.
7. Rychtáriková M, Vermeir G. Soundscape categorization on the basis of objective acoustical parameters. Applied Acoustics. 2013 2//;74(2):240-7.
8. Kang J. From understanding to designing soundscapes. Front Archit Civ Eng China. 2010 2010/12/01;4(4):403-17. English.
9. Brown AL, Kang J, Gjestland T. Towards standardization in soundscape preference assessment. Applied Acoustics. 2011;72(6):387-92.
10. Augoyard JF. Sonic experience : a guide to everyday sounds. Torgue H, editor. Montréal ; London: McGill-Queen's University Press; 2006. 216- p.
11. Řiháček T. Zvukové prostředí města a jeho vliv na prožívání. Brno: Masarykova univerzita, Mezinárodní politologický ústav; 2009. 240 p.
12. Rihacek T. Place Boundaries from the Sonic Environment Perspective. Ferencuhova SHMGLVB, editor2009. + p.
13. Minoura K, Hiramatsu K, Matsui T, Takagi K, Oi K. AN INTENSIVE SURVEY ON COMMUNITY RESPONSE TO SONIC ENVIRONMENT IN A RESIDENTIAL–INDUSTRIAL MIXED USE AREA. Journal of Sound and Vibration. 1997 8/28/;205(4):481-92.
14. Kull RC. Natural and urban soundscapes: The need for a multi-disciplinary approach. Acta Acustica united with Acustica. 2006;92(6):898-902. English.
15. Schafer RM. The soundscape : our sonic environment and the tuning of the world. Rochester, Vt.: Destiny Books; 1994. 301- p.
16. Dubois D, Guastavino C, Raimbault M. A Cognitive Approach to Urban Soundscapes: Using Verbal Data to Access Everyday Life Auditory Categories. Acta Acustica united with Acustica. 2006 //;92(6):865-74.
17. Kang J, Zhang M. Semantic differential analysis of the soundscape in urban open public spaces. Building and Environment. 2010 1//;45(1):150-7.
18. Yang W, Kang J. Acoustic comfort evaluation in urban open public spaces. Applied Acoustics. 2005 2//;66(2):211-29.
19. Kang J. Urban sound environment. London ; New York: Taylor & Francis; 2007. 278 p.
20. Amphoux P. L'identité sonore des villes européennes: ide méthodologique à l'usage des gestionnaires de la ville, des techniciens du son et des chercheurs en sciences sociales. Lausanne: IREC; 1993. 40 p.
21. Leobon A. Urban sonic atmospheres qualification. Natures-Sciences-Societes. 1995;3(1):26-47.

22. Torgue H, Sémidor C, Beaumont J, Barlet A, Delas J, Régnault C, et al., editors. ASTUCE Research Project : one way to evaluate urban soundscapes2010 2010.
23. Woloszyn P, Leduc T. Urban Soundscape Informational Quantization: Validation Using a Comparative Approach. Service Science & Management. 2010;3:429-39.
24. Bruce NS, Davies WJ. The effects of expectation on the perception of soundscapes. Applied Acoustics. 2014 11//;85(0):1-11.
25. Sheridan T, Van Lengen K. Hearing Architecture: Exploring and Designing the Aural Environment. Journal of Architectural Education. 2003;57(2):37-44.
26. Androsch P, editor Linz Charter – Guideline for Urban Development. Vienna Real corp 2010 proceedings/tagungsband; 2010.