

The Application of the Soundscape Approach in the Evaluation of the Urban Public Spaces

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An important issue in the development of European cities is the design and renovation of the urban public areas. Typically, a broad variety of approaches (sociological, ecological, environmental, physical, etc.) is needed and earlier studies have shown the necessity of the transversal multi-disciplinary approach in this issue. In order to study the acoustical dimension, the concept of soundscape needs to be proposed and elaborated. The soundscape approach differs from the classical statistical noise analysis in the evaluation of a context-related noise and in the extrapolation of environmental sounds in its complexity. Nowadays, even by using recently developed sophisticated acoustical and psycho-acoustical measurable and quantifiable parameters, it still remains difficult to grasp the complete meaning of a soundscape in words only or by numbers only. Our hypothesis is that the description of the city soundscape might be successfully done by combination of acoustical numbers and words.

1 Introduction

In view of designing sustainable urban environments, an important question is how to design a soundscape, suitable for a given cityscape. The latter one is determined by urban engineers, architects, and by economical (business development) and sociological (e.g. population settlement) evolutions, which is not always possible to control or even predict. Along with these evolutions, the soundscape evolves in a spontaneous way. In many cases we therefore speak more about the soundscape description and evaluation, than about the soundscape design as such.

Most of the existing studies done in large urban or rural areas were in the past based on noise measurements (e.g. quantitative description) and noise propagation [2, 3]. Measurement of noise is rather straightforward due to its clear definition and its impact on human health has been investigated in terms of auditory and non-auditory effects. [4-6] Therefore, if we plan to evaluate an urban area, the measurements of noise should never be omitted. Series of noise regulations have been already established and the noise maps in many EU countries have been prepared. [7]

In the seventies, a new approach to the sonic environment including the qualitative assessment of urban areas was introduced and developed through the soundscape description. [8] Several authors have shown the masking effect of sound as an important factor in creating the satisfactory acoustical conditions. Some studies have even concluded that because of this reason (i.e. masking effect), the reduction of noise levels not always contribute to global acoustical comfort. [9, 10, 11].

The recent research shows the importance of multidisciplinary approach to this topic. Several authors compare statistical values of sound pressure level (such L_{90} , L_{50} L_{10} or L_{Aeq}) with results based on number of interviews in situ. In the work of Yang and Kang [9] it has been concluded that the background sound levels act as an important quantity in evaluation of urban public spaces. Further, it has been also confirmed that the acoustical comfort perception is more affected by the character of the sound source than by its general sound level.

Numerous studies have been performed with a special attention to rural quiet areas by looking for a multi-criterion assessment based on a set of carefully chosen indicators, suitable for the development of the categorization and quality labels. [12, 13] Acoustical comfort in residential areas has been also separately investigated and evaluated by many authors and can be found in the literature. [14, 15]

However, the description of the soundscape needs not only the acoustical numbers, but also semantic data. It is often necessary to look at the context of the noise instead of just

simply evaluating it by different acoustical quantities. In the research of Dubois [16], the cognitive categories related to description of soundscapes were considered while comparing the individual experiences of people and collective representations shared in the language of society.

Some other works deal with the acoustic similarity of soundscapes and its identification by the multidimensional tool called “dualistic psychoacoustic strategy” [17] This tool is based on the collection of all available and detailed acoustic information that may be picked up by human perceptual system when listening to a complex sonic situation. However, the research on neural network models still needs further development.

One of the most important questions related to the sonic environment evaluation is “how to collect the reliable data”. The fast evaluation of streets, squares and parks can be sometimes based on recordings of the binaural sound, while walking through the city. [18] So called “Soundwalk method” allows us to collect the information along the streets instead of just placing one or few measuring points on fixed positions.

Dealing with the development of sustainable cities, a comparison of the acoustical situation in the past and present with a prediction of the future sonic conditions might be appealing. Since the technology of high quality sound recording is rather new, the information about the acoustical situation in the past can be found only in the literature, contemporary paintings, photographic material or other accessible historical sources. Some research has been already done in this way [19].

2 Description of our research context

Acoustical research is done in the framework of the multidisciplinary project, which deals with the development and renovation of urban public places in Belgium. This research carries many transversal activities between several research fields such as sociology, microclimate and windcomfort, density, mobility, vegetation and biodiversity. Due to the complexity of the project, optimal (simple and fast) method for the evaluation of different urban places is needed. We are aware of the importance of the acoustical details in soundscape description and about the danger of too much simplification. Nowadays, even by using the recently developed sophisticated acoustical and psychoacoustical measurable and quantifiable parameters, it still remains difficult to grasp the complete meaning of a soundscape in words only or by numbers only. Our hypothesis is that the description of the soundscape might be successfully done by combination of acoustical numbers and words.

3 Development of methodology

To have a complex view on each particular soundscape, we try to work on two basic levels: (1) **Noise evaluation (NE)** based on known noise maps and our own recordings in situ and (2) **Qualitative assessment (QA)** partially on “hard” data of binaural acoustical recordings and “soft” data with respect to the context of the sound and to people’s perception.

On the first level (i.e. NE), the impact of noise on human health is the priority, whereas the second level (i.e. QA) is about the human appreciation of the soundscape based on perception, evaluation and expectation. This leads us to start with description of the sonic environment not only by acoustical numbers or by semantic description, but by including of both types of data.

Strictly speaking, the collection of our acoustical data is based on binaural recordings in the chosen streets, squares and parks in the city centers, urban and suburban areas where we try to collect as much data as possible by performing the so called “soundwalks”. For each recording we make a picture and we keep the information about the day, time, weather conditions, etc. By having the original material stored in the binaural wave format, listening tests or new post-processing algorithm (such as changing of the integration time or development of new variable) can be done later on if necessary.

Acoustical recordings are accompanied by the interviews as well. Following the principles of grounded theory we try to avoid pre-conceptualization. We use our knowledge and literature sources only to formulate some “hints” or “sensitizing concepts” which are intended to facilitate the research process. However, at the same time we want to be open for potential discoveries. Grounded theory methodology serves here as a tool for investigating a phenomenon “in itself”, which means that neither “right theoretical framework”, nor “right answers” will be imposed. The concepts and hypotheses are rather developed during the research process than tested or borrowed from other theories.

3.1 Noise evaluation

The noise evaluation is considered at first and it consists of the known statistical analysis based on monitoring of the acoustical situation in the reference urban area. The analysis of noise by using statistical methods, such as calculation of the equivalent levels of noise L_{Aeq} [dB], L_{den} or other parameters such as L_5 [dB], L_{10} , L_{50} , L_{95} [dB] gives a good overview about the noise situation in an urban area. In this part, our measurements will be calibrated with general noise maps accessible for a given region and the precision of measurements will be estimated.

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3.2 Qualitative assessment of “hard” acoustical data

We presume that the perceived acoustical comfort of a given soundscape is mainly influenced by human

expectation. This presumption encourages us to look for common features of similar environments, such as shopping streets with or without traffic; residential streets with family houses or high blocks of flats; parks in the city center or in the suburbs, etc.

Commonly used or standardized quantities for qualitative assessment of urban public places have not been established so far. Several authors use known psychoacoustical parameters originally developed for the evaluation of stationary sound sources. [18, 21] However, urban soundscape usually consist of a mixture of several sounds with different intensities, directivities and durations. This makes the evaluation more difficult mainly in choosing the integration time during the calculation of the psychoacoustical parameters.

3.2.1 Psychoacoustical analysis

A part of our analysis is based on the estimation of Loudness N [son], Sharpness S [acum], Roughness R [cAsper] and Fluctuation strength F [cVacil] in time domain followed by the calculation of statistical values, expressed as value of the parameter (L , N , R , S or F) exceeded in x % of time.

Global analysis of all measured places helps us to understand the behavior of the psychoacoustical parameters in the urban public places particularly. It can be seen, that the distribution of statistical values is different in case of each variable. Fig.1 left shows the statistical values of loudness ($N_1, N_2, \dots, N_{99}, N_{100}$) based on 50 recordings of a duration 10–15 minutes/per recording in several streets in Leuven. Fig.1 right shows the same data for Sharpness, etc.

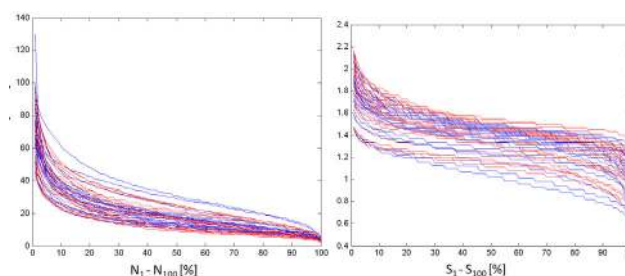


Fig.1. Statistical values of Loudness (left), and Sharpness (right)

To be able to decide about good descriptors, the maximal differences in soundscape within one place and the maximal differences between all the evaluated places concerning all chosen parameters have to be estimated and the character of the distribution has to be considered.

Figures 1 shows the distribution of the statistical values. The background noise in the streets defined by N_{95} fluctuates less from place to place than the peak values defined by N_5 . We can conclude that it would not be very convenient to work only with average values N_{50} . On the other hand, statistical values of sharpness based on measurements in urban public spaces have rather normal distribution and so it will probably allow us to work only with average sharpness values S_{50} in the future. The histograms of fluctuation strength and roughness are not included in this text due to the page limitation, but they also confirm that the average values F_{50} and R_{50} would not contribute as a sufficient quantity in the final set of descriptors

3.2.2 Parameters related to the binaural aspects of hearing

In previous studies about the acoustical comfort description, it has been shown that the perception of a person’s envelopment by sound sources and the ability to distinguish and localize the disturbing or pleasant sound sources influences the global perception of acoustical comfort. For this reason we try to involve the binaural aspect of hearing in the assessment of the urban soundscape, too. The perception of envelopment as well as the ability to localize sound sources is thanks to binaural cues and monaural cues encompassed in the Head-related transfer function (HRTF). However, the involvement of full HRTF in the urban soundscape context would be too complicated and probably not completely useful, since the monaural cues are too individual, due to the differences in the shape of the human ear and upper body. On the other hand, the binaural cues are more general and can be described by the interaural time difference (ITD) and interaural level difference (ILD). It is known that due to the shape of the human head, ILD is more pronounced in frequencies above 1.5kHz, and ITD in low frequencies. [20]

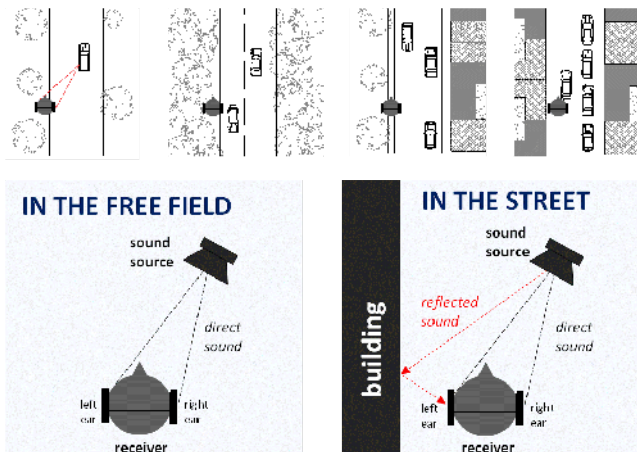


Fig.2. Principe of the “uILD number”.

In our research, the development of the parameter called “urban interaural level difference” (*uILD*) is in progress. This parameter is based on the comparison of the acoustical situation in the left ear and right ear with respect to the level difference. Proposed “*uILD* number” $uILD_1$ and $uILD_2$ are defined as:

$$uILD_1 = \frac{\sum_{i=1}^n (L_{Li} - L_{Ri})}{n} \quad [\text{dB}] \quad (1)$$

$$uILD_2 = \sum_{i=1}^n \sqrt{\frac{(L_{Li} - L_{Ri})^2}{n}} \quad [\text{dB}] \quad (2)$$

where X_{Li} is a value of the acoustical parameter (L , N , R , S or F) in the left channel in the time i . X_{Ri} is a value of the acoustical parameter (L , N , R , S or F) in the right channel in the time i and n is the number of the values. Binaurality is checked for the psychoacoustical parameters N , R , S and F and is defined as $uIND$, $uIRD$, $uISD$ and $uIFD$ in the same way as $uILD_1$ and $uILD_2$.

The proposed parameter $uILD_1$ should show, which ear (left or right) was most of the time exposed to higher sound levels, sharpness values, etc. The $uILD_2$ gives information about the surrounding of a person by sources in general and

it is less sensitive on turning of the head during the recordings.

3.2.3 An example of the case study: street assessment by the “hard” acoustical data analysis

Our case study street, Bondgenotenlaan in Leuven, is one of the main shopping streets in the city center. This street connects the railway station with the main square in the town and it is 1 km long. The traffic, such as cars and busses, makes this street well accessible, but it is also a source of noise. The acoustical situation in this street depends on the day of the week and the hour during the day. Since the peak hours of shopping are on Saturdays and on the week days between 17-18, when people return from work and still go shopping or they leave the city center by car or other transportation.

Seven binaural recordings have been performed by using the so called “Soundwalk” method.

Analysis of the statistical values was done with a respect to the calculation of L_A and 4 psychoacoustical parameters (N , R , S and F). For this article, results of the L_A , S and F were chosen and are given in the figures 3-5.

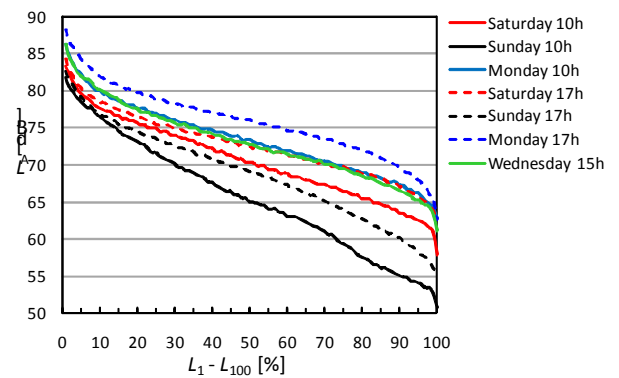


Fig.3. Comparison of the statistical values $L_1 - L_{100}$

Figure 3 shows that the peak levels don’t differ so much as the values of L_{95} . This is probably caused by the busses regularly passing this street during the whole week. Frequency of the busses passing in the week days (Monday and Wednesday) is higher in comparison with the weekend, what is confirmed by the values of L_5 . From the figure 5 we can also conclude, that the noise situation in this street is nearly identical on Wednesday at 15h, Monday at 10h. Average noise situation defined by L_{50} and background noise situation given by value L_{95} on Saturday at 17h is also very similar to Wednesday at 15h and Monday at 10h.

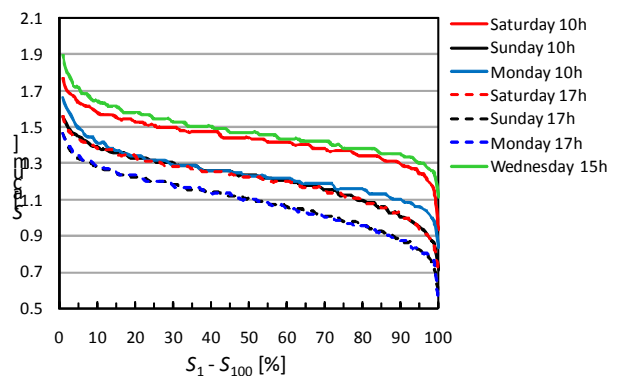


Fig.4. Comparison of the statistical values $S_1 - S_{100}$

The peak values on Saturday are statistically the same at 10h and 17h. Overall level of noise is significantly lower on Sunday morning, however the peak levels are similar to the situation on Saturday. This is probably due to the fact that the shops are closed and there are not many people in the street, but the busses are still passing in their regular times. Figure 4 shows the increase of the average sharpness on Saturday morning and Wednesday at 15h. Taking into account the levels in these days we can presume that on Sunday the increase of sharpness in sound is caused due to the overall lower levels of noise and thus the sounds with higher frequency spectra are not masked anymore by wideband noise. Higher values of Sharpness on Wednesday early afternoon is probably caused by some strong high frequency components in the overall sound spectrum what this might contribute to acoustical discomfort. Sharpness values on Monday afternoon are very low, since they are masked by other sounds with high intensities.

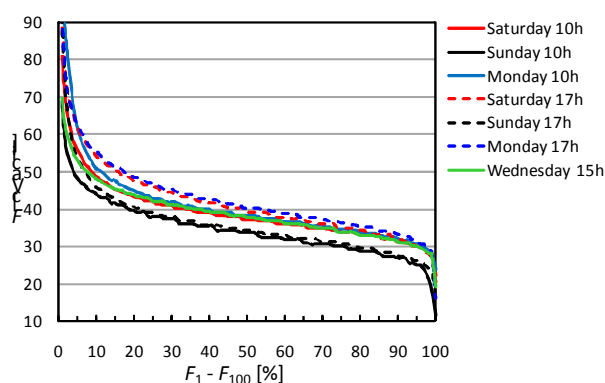


Fig.5. Comparison of the statistical values $F_1 - F_{100}$

Fluctuation strength usually reacts on sounds with short duration such as a hand clap, hammer sound or closing of the car door, but also to human voices. These kinds of sound often carry high amount of the acoustical energy accumulated in simple pulse and so they are often found in the sound level analysis as well. The average fluctuation strength $F_{50} = ca 40$ cVacil was in our case study highest on Monday and Saturday afternoon due to the sounds produced by people passing, talking, stepping etc. Lowest average values of about 35 cVacil were observed in the both recordings from Sunday. These differences are even more pronounced in the maximal values of fluctuation strength where the difference in F_2 is about 30 cVacil.

Analysis based on binaural parameters

In this paper, the results of three binaural parameters, $uILD$, $uISD$, and $uIFD$ are shown. Parameter $uILD_1$ is given in the Figure 8 (in the left set of seven bars) and shows overall higher levels of sound in the left ear than in the right one. This means that the person with the binaural microphone probably walked on the right side of the road, since the road should be logically the main source of the noise in this street. $uILD_2$ given in the Figure 6 (in the right set of seven bars) shows that there is still relatively large amount of sound coming to the right ear, since the differences given by $uILD_2$ are higher than $uILD_1$. This might be caused by the reflections from surrounding buildings but also by the sound sources on the right side of the person, such as music from the shops or windows, or speech produced by people in the street. However, this can't be decided based on $uILD_1$ and $uILD_2$ only.

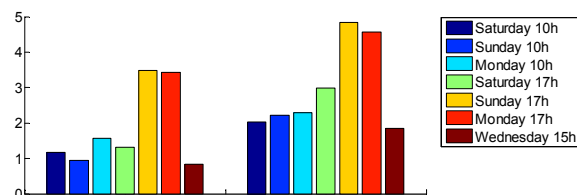


Fig.6. Values of the $uILD_1$ (1st set of 7 bars), and $uILD_2$ (2nd set of 7 bars) calculated based on 7 recordings in the reference street during 7 different days and times in the day

The $uISD_1$ values are relatively low, but they show the overall sharpness on Sunday higher in the right ear. The $uIFD_1$ values are highest on Sunday afternoon and the prevailing direction of the sound with high F values is coming from the road. We presume that this is caused not only by passing busses, but also by passing scooters and old bicycles producing high values of F in general, and by students talking to each other while driving bikes, while these sounds are not masked by other sounds.

3.3 Qualitative assessment of the “soft” data

To express the context of the sound by numbers is at the moment not completely possible. Within our project we therefore start with proposing a few categories, which will be described by words during the evaluation of the public place.

3.3.1 Proposed categories

1./ Keynote Sounds, defined by Schaffer as those, which “may not always be heard consciously, but they outline the character of the people living there”. Keynotes are created by nature or by permanently present sound sources. It is a kind of amorphous sound, in many cases sound perceived subconsciously as a background sound.

2./ The Sound Signals, understood as foreground sounds, listened consciously, such as warning devices, bells, whistles, horns, sirens, etc. We can identify and localize these kinds of sound events.

3./ The Soundmark, as a sound which is unique to an area. “Once a Soundmark has been identified, it deserves to be protected, for soundmarks make the acoustic life of a community unique” (Schaffer).

4./ The Rhythm. An urban area is determined by the rhythm of nature (changing day and night, or seasons in the year), but also by traffic jam events and quiet period or by trucks for garbage removal, etc. Some cities can be perceived slow and some fast.

5./ The Harmony can be understood as overall acoustical comfort which depends on our acoustical expectation, such in the street with traffic lights we expect cars breaking and in the square with café's we will expect people talking while having a drink.

3.3.2 Example of the city park assessment by using the “soft” data analysis.

For this case study was chosen Kasteelpark Arenberg in Leuven, Belgium. This area has a characteristic **keynote sound** produced by students driving old bikes during the

whole year and by singing birds 10 month per year. Nearby the Kasteelpark is a railway station Oud Heverlee which contributes to the observed area by its **sound signals** such a ring while the closing of the ramp. Bells of the castle produce a melody which becomes a **soundmark** of this area and it is unique for this place. **Rhythm** of this urban place is caused by Soundmark repeated every 30 minutes and by sound signals in the parts of the park close to the railway station several times per hour. **Harmony** of this place is by most of the people perceived as a place with acoustical comfort. However final answer will be given after the sociological research in this place will be finished.

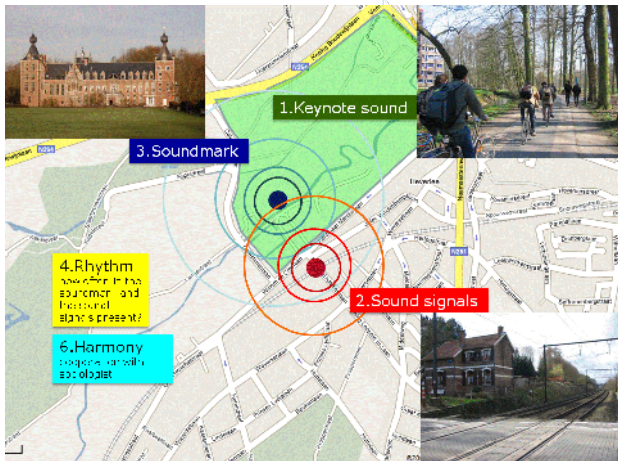


Fig.7. Example of the subject-related analysis

4 Conclusion

Soundscape of even a well defined cityscape location is a strongly varying phenomenon, and coincidental fluctuations can make the situation strongly deviating from the average during a long time, or actually make it impossible to define an average situation. However, in the pragmatical approach, it is safe to assume that optimizing the average soundscape within its acoustical situation, and taking measures to limit possible strong fluctuations will always be beneficial. Solutions will be found in the improvement of the urban places based on the results of our research.

First results, based on few examples from which two were presented in this paper, have shown the possibility to use our methodology for the description of some acoustical features of the given cityscapes. Future steps will be oriented to detailed statistical analysis of the acoustical data. It will be combined with the discovery what the human feeling of pleasantness or annoyance depends on and how to use this knowledge in the design and renovation will need comparison of the measured acoustical data with sociological investigations.

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