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VISUAL AND ACOUSTIC ASSESSMENT OF ACOUSTICALLY ALTERNATIVE URBAN SPACES DETERMINED BY THE TRANQUILLITY FACTOR

ABSTRACT

A balance between what we see and what we hear is necessary in all the spaces where people live. In a city, there are a number of sounds that are perceived by most inhabitants as disturbing. It is therefore necessary to mask these sounds, and this type of intervention in the soundscape creates acoustically alternative urban spaces. The evaluation of the applied solutions changing the soundscape should be reviewed. The previously used tranquillity indices for assessing the visual and acoustic soundscapes have their limitations. They do not take into account the perception of space at night or the sound structure regardless of the time of day. This paper starts a discussion on how the tranquillity factor should evolve so that it can be used to evaluate the progressively changing urban spaces.

KEY WORDS

soundscape ; tranquillity factor; urban spaces; space; city; acoustically alternative urban spaces

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Visual and acoustic assessment of acoustically alternative urban spaces determined by the tranquillity factor

Introduction

Modern city hosts several types of areas: residential, recreational, dedicated to education or sports, as well as places where the permanent and temporary residents work. In some cases, these spaces function separately or intermingle with each other.

In the residential areas, everyone expects comfort and tranquillity, and this is clearly equated not so much with silence as with a welcoming soundscape. In the recreational areas[1], the sound of the city is masked by labyrinths, park instruments, tubes or spheres with a friendly soundscape, amphitheatres, underground museums, earphones, playing sculptures, stairs and benches.

[1] *Audiosfera miasta*, eds. R. Losiak, R. Tańczuk, Wrocław 2012.

In spaces where there are large groups of employees, buildings provide the adequate acoustic comfort. In addition, pocket parks are established, providing places to sit, eat and relax. Sometimes they include a four-level waterfall, with tables and armchairs on each level. Sometimes only fountains are put up, in which the flowing water also masks the perceived sounds, and creates zones of tranquillity.

The ways of masking of city sounds presented above represent a certain attempt at interfering with the soundscape by creating acoustically alternative urban spaces.

The contemporary functioning spaces should and will change. The interference will concern the methods of storage of energy and water as well as innovative solutions to fight smog. They will change the visual landscape and the soundscape of individual areas. Care should be taken to ensure that the changes do not interfere with the landscape in a way which makes urban spaces too difficult to perceive.

In order to evaluate the upcoming solutions, it is required to create coefficients that allow a reliable verification of the psycho-acoustic perception of a given space. The idea is to strike a balance between what we see and what we hear, and what we need and what is emerging as part of thee innovative solutions dedicated to cities.

Nowadays, one of the coefficients defining the evaluation/suitability of a site is the tranquillity rating. The rating is constructed as:

$$TS = X \pm \alpha \cdot A_1 \pm \beta \cdot A_2 \pm \ldots \pm \omega \cdot A_n \qquad (1)$$

where:

X – is a certain constant which, like the other indicators, is determined on the basis of psycho-acoustic research. Regression analysis is used to determine the straight line equation.

$A_1, A_2, \ldots, A_n$ – are the sociologically determined elements shaping the perception of tranquillity in a well-defined place.

$\alpha, \beta, \ldots, \omega$ – are the quantifiers of the impact of each of the above elements.

inAW Journal
Multidisciplinary Academic Magazine

VOLUME 1, ISSUE 1 (2020)

The tranquility factor can include a number of indicators, whereby the positive visual and auditory elements increase the tranquility index and negative ones decrease it (Photo 1, Fig. 1). Research[2] shows that all elements in a developed space that are connected to nature, such as the trees in photo 1, increase the tranquility index. Flora, fauna, geological features including stone walls and water were considered the natural features. Architectural features integrated into nature will also increase the index. Anything related to industrial infrastructure or roads in the landscape will lower the tranquillity index.

[2] R.J. Pheasant, K.V. Horoshenkov, G.R. Watts, *Tranquillity rating prediction tool (TRAPT)*, „Acoustics Bulletin", 2010, No. 35 (6), pp. 18–24.

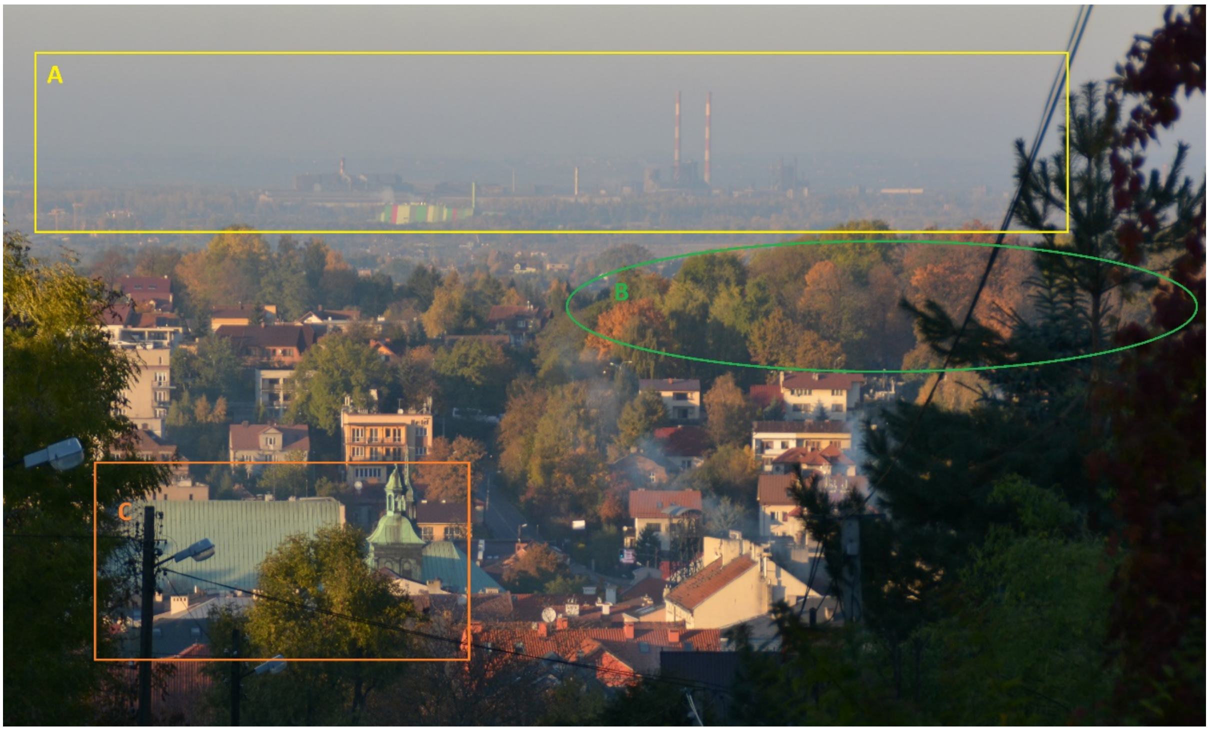

Photo 1. View of Nowa Huta and Wieliczka from Stok pod Baranem. Fragments of the photo marked as areas B and C are the natural elements and architecture integrated with the nature that increase the positive perception of the space. The fragment of the Tadeusz Sendzimir Steelworks infrastructure, marked as area A, negatively influences the perception of space.

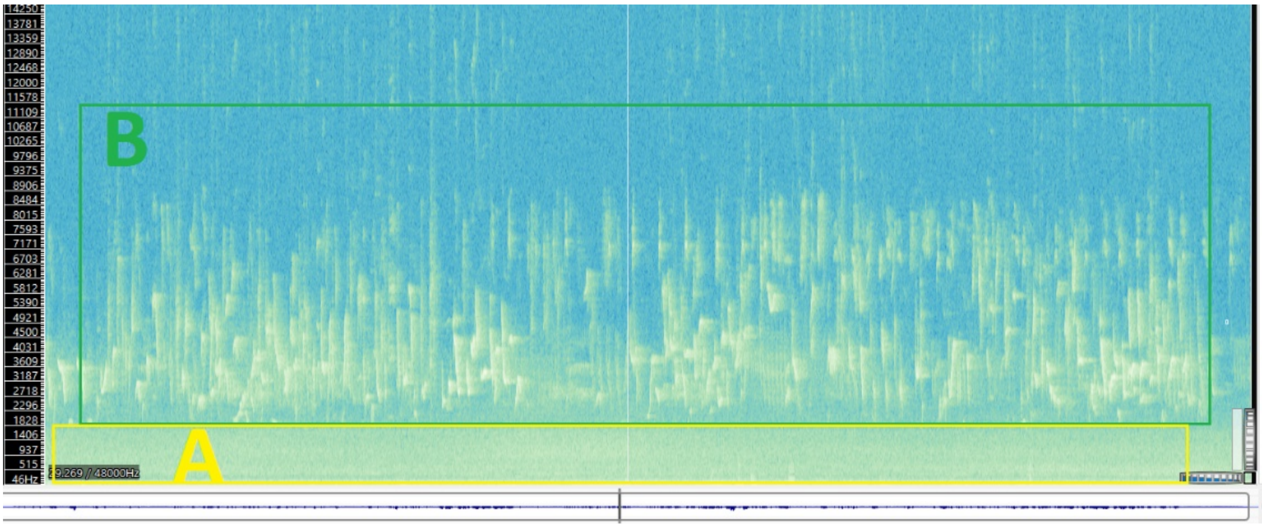

Fig. 1. Spectrogram from sounds recorded in the Niepołomice Forest in spring 2018. Noises from the motorway - negatively affecting the perception of the soundscape - were marked on the spectrogram with a rectangle labelled A. The green rectangle labelled B indicates birdsong increasing the positive perception of the soundscape. The sounds of nature do not mask sounds of transport

The model used contemporarily[3] to assess the visual and acoustic landscape takes into account the daytime equivalent sound level A (7.00 to 19.00) and the NCF percentage (0-100), which was designed to determine to what extent the space is filled by nature and by the architecture that is in harmony with nature.

$$TR = 9.68 + 0.041\ NCF - 0.146\ L_{Aeq} + MF \quad (2)$$

MF is a moderating factor allowing the addition of elements that positively or negatively influence the perception of a given space. Its influence is rated at ±1 point.

[3] R.J. Pheasant, K.V. Horoshenkov, G.R. Watts, *Tranquillity rating prediction tool (TRAPT)*, „Acoustics Bulletin", 2010, No. 35 (6), pp. 18–24.

inAW Journal
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The tranquillity factor is determined on a scale from 0 to 10 (Figure 2). The assessment of the terrain was classified as follows: below 5 - unacceptable; from 5 to 6 - acceptable; from 6 to 7 - relatively good; from 7 to 8 - good; for 8 and above – excellent.

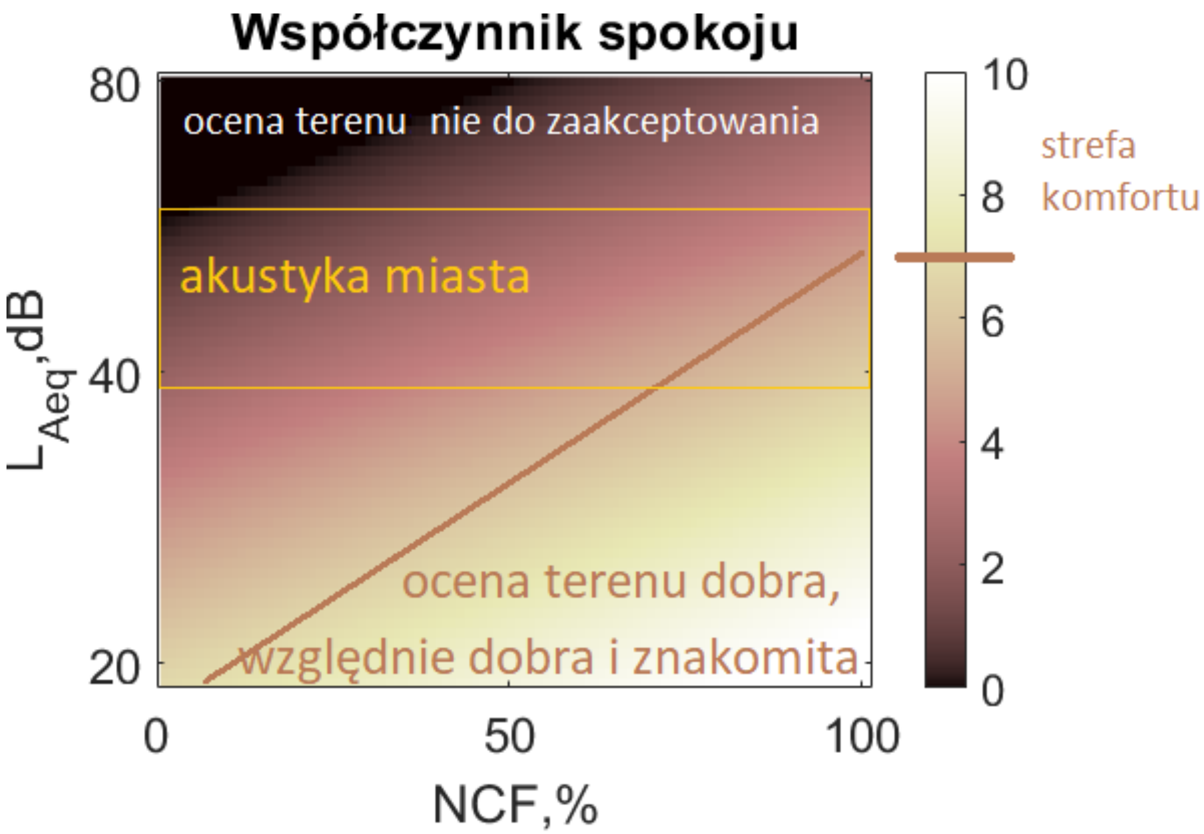

Fig. 2. Tranquillity factor as a function of the equivalent sound level LAeq and the NCF ratio, which was designed to determine to what extent the space is filled by nature and by the architecture in harmony with nature

Expression (2) characterises both urban and rural areas, and this is probably the main obstacle to using it to assess the urban space upgrading projects. With the designed model described by equation (2), there is no possibility of obtaining a better value than an acceptable one in the city (Fig. 2), which does not fully reflect the reality.

inAW Journal
Multidisciplinary Academic Magazine

VOLUME 1, ISSUE 1 (2020)

If the human comfort zone should have a TR above 7, then according to model (2), the sound level should be reduced to 32 dB at 50% NCF. At 100% NCF the sound level must not exceed 40 dB. Values of 30-40 dB are difficult to achieve in a city. A conversation in a café is at 60 dB, which even at 100% NCF gives TR=5.02 + 1p for MF. Therefore, a model change seems necessary.

Discussion on the need to modify the tranquillity factor

The MF factor was to serve the purpose of making the perception of urban space more realistic. However, the direction in which the researchers break down the MF into factors characteristic of a given place for the users of a given space does not allow generalisations to be made. It is difficult to compare the analyses conducted in Pisa with the urban space of Krakow, Wieliczka or Nowa Huta. These cities have a different character, differently organised transport, different urban parks, different infrastructure intended for tourists. Moreover, the research on the MF focuses on what is available here and now. It does not address the modernisation that will occur with technological progress and climate change in the coming decade.

First change – reception of a city at night-time vs. reception of a city during the day

A discussion should be initiated on the assessment of the night-time tranquillity factor[4]. According to a WHO report[5], one in five Europeans is regularly exposed at night to sound levels that are significantly detrimental to health[6]. Urban residential areas should be designed in a way that protects users. In this case, solutions to reduce sound levels should be worked on.

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[4] R.J. Pheasant, K.V. Horoshenkov, G.R. Watts, *Tranquillity rating prediction tool (TRAPT)*, „Acoustics Bulletin", 2010, No. 35(6), pp. 18–24.

[5] B. Berglund, Birgitta, Lindvall, Thomas, Schwela, Dietrich H & World Health Organization. *Occupational and Environmental Health Team*, 1999, Guidelines for community noise. World Health Organization. https://apps.who.int/iris/handle/10665/66217

[6] A. Lipowczan, *Akustyka ciszy*, „Bezpieczeństwo Pracy. Nauka i Praktyka", 2019, nr 5 (572), s. 6-10.

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Recreational areas, on the other hand, require a different definition of the NCF factor. The lighting of the space at night in the city is not negligible (Fig. 3.), and this has not yet been included in the model. The perception of the same space at night and during the day is so different that it should not be defined by the same factor.

Fig. 3. The Alsos project, which was created during the inter-university workshop New Space, carried out from 26 to 29 November 2018. Students worked on a proposal for changes that should take place in Krakow on the Mateczny-Borek Fałęcki route. The authors of the project are Karolina Motak and Paulina Habura (Academy of Fine Arts in Krakow, Faculty of Interior Design), Marta Bil and Sanara Słojewska (Krakow University of Technology, Faculty of Architecture), Julia Idczak (AGH University of Science and Technology, specialisation in acoustic engineering), Karol Piotrowski (Jagiellonian University, Institute of Sociology).

inAW Journal
Multidisciplinary Academic Magazine

VOLUME 1, ISSUE 1 (2020)

Second change - inclusion of sound structure in the model

In addition, the soundscape can be shaped by sound sources. The difficulty of this type of research is that the same sounds perceived as negative by one group of listeners may be neutral to another group.

Since the 0.146LDAY relationship estimated by the researchers in the regression analysis does not distinguish between sounds that are perceived negatively and those that are effectively and positively masking an unfavourable acoustic climate[7], for cities (and only for cities), the following modification of the model could be considered:

$$TR = 9{,}68 - 0{,}00146\, L_{Aeq}\, (100 - SC * f(L_{Aeq})) + 0{,}041\, NCF + MF \quad (3)$$

where SC (on a scale from 0 to 100) is a coefficient containing information on what percentage of the soundscape are sounds that residents perceive as friendly.

When creating the function $f(L_{DAY})$), the following thresholds shall be taken into account[8]:

- 20 dB is the sound level that is achievable at night in a park[9] where there are no sound sources other than those found in nature; such places are difficult to find in the urban areas;
- 70 dB is the lower limit for the level which is harmful to health and has a negative impact on the working efficiency; this is also the level which occurs in a busy street;
- Above 35 dB, the negative impact of sound levels on the human body begins;
- Values 55-60 dB reflect conversation between people, 50dB is the sound level found in offices or restaurants.

[7] P. Kleczkowski, *Percepcja dźwięku*, Kraków 2013.

[8] A. Ozga, *Scientific ideas included in the concepts of bioacoustics, acoustic ecology, ecoacoustics, soundscape ecology, and vibroacoustics*, „Archives of Acoustics", 2017, vol. 42, No. 3, pp. 415–421.

[9] J. Wiciak, D. Mleczko, A. Ozga, G. Wszołek, J. Wierzbicki, J. Piechowicz, P. Małecki, *Quietness in the soundscape of the Białowieża National Park*, „Acta Physica Polonica A", 2015, vol. 128, No. 1A, pp. A-79–A-84.

For example, a linear relationship with a negative directional coefficient characterizing the fact that the higher the LAeq the lesser the influence of friendly sounds would change the distribution structure into the friendly and the unacceptable areas as shown in Figure 4.

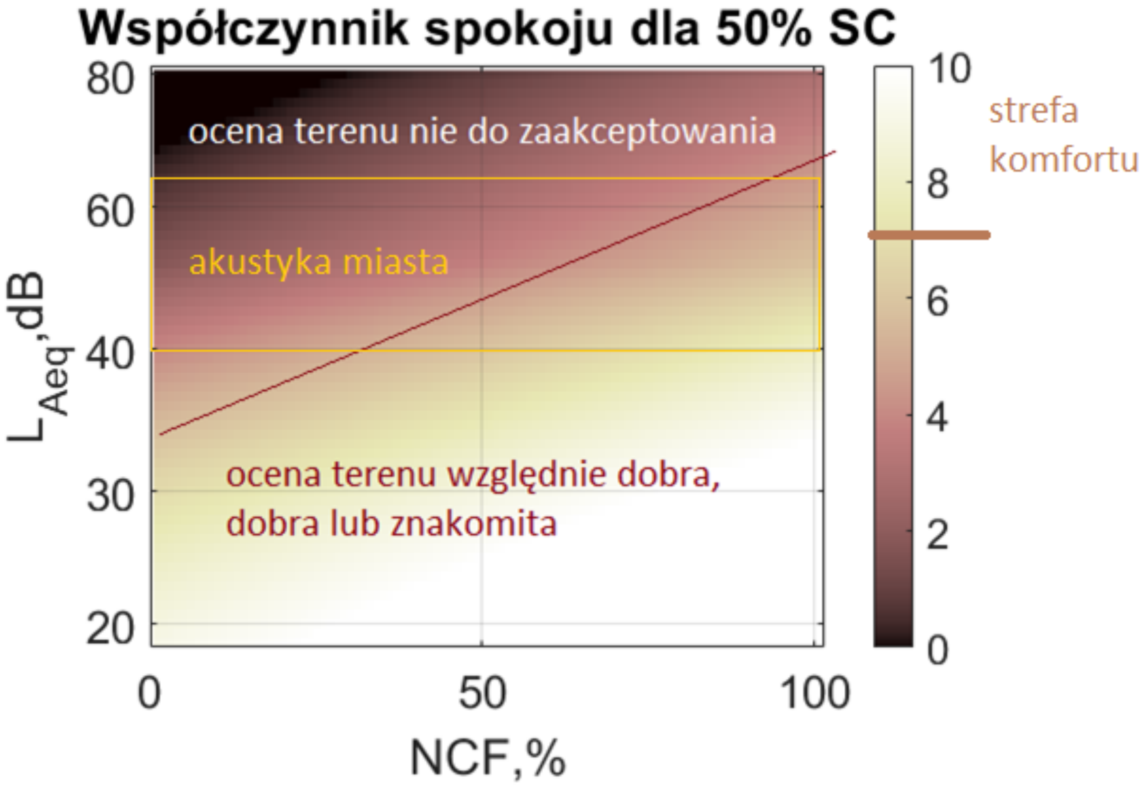

Figure 4: Modified tranquillity factor after taking into account the sound structure as a function of the equivalent sound level LAeq and the NCF factor, which was designed to determine to what extent the space is filled by nature and by the architecture harmonious with nature.

The introduction of a linear relationship to the SC sound structure has made the perception of urban space more realistic. With a soundscape containing friendly sounds in surroundings that we consider natural or in tune with nature, a TR factor of 7 and above includes areas that were previously wrongly classified as unacceptable. The more friendly masking sounds we introduce into the space of a modern city, the milder, although still extremely important, the influence of NCF on the perception of a given space will be.

Summary

The current models used with a view to visually and acoustically assess the urban space are inadequate for how the space is perceived by its users. Urban models need to evolve[10], in line with the trend called placemaking. The concept of placemaking is the idea of shaping public spaces in such a way that they continually evolve and adapt to the needs and changes resulting from responses to air pollution problems or the development of alternative energy. With such upcoming changes it will be necessary to interfere with the soundscape by masking unfriendly sounds with sounds perceived as positive. In this way it will be possible to create acoustically alternative urban spaces.

[10] J. Wiciak, D. Mleczko, A. Ozga, G. Wszołek, J. Wierzbicki, J. Piechowicz, P. Małecki, Quietness in the soundscape of the Białowieża National Park, "Acta Physica Polonica A", 2015, vol. 128, No. 1A, pp. A-79-A-84; Alternative public spaces: Mateczny-Borek Fałęcki: the future of sound in the city, edited by B. Gibała-Kapecka, T. Kapecki, A. Ozga, K. Czajczyk, D. Milczko, J. Wierzbicki, M. Nóżka, A. Lyn, J. Idczak, K. Juros, D. Wójcik, Kraków 2019

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