Conference Paper

Noise As a Factor of Green Areas Soundscape Creation

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Abstract

The research subject presented in the paper is acoustic perception, the perception of a sound landscape by a human. The paper aim was formulated - knowing the sources of noise based on the subjective assessment of recipients allows for sustainable management of green areas (city parks). The need to shape a harmonious landscape may contribute to finding a new function and attractive form for the studied areas. Research carried out for selected city parks in Bydgoszcz (Poland) concerns the registration of responses of people assessing the sound landscape (subjective approach). Completed studies allow ”translating” subjective assessments into meaningful values using fuzzy cognitive maps. The scenarios completed show the possibility of using tools supporting the decision-making process in urban planning of city parks in relation to existing acoustic conditions.

Keywords: Noise, Soundscape, Green areas, Urban planning, Environment

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1. Introduction

Problems related to excessive noise in urban areas are becoming more common. Particularly acoustically sensitive areas are city parks. Sustainable space management in terms of sound distribution definitely affects the comfort of users. To properly create the soundscape, various approaches and tools are used.

They can be divided into three groups:

- objective methods - allow obtaining information about the soundscape from the analysis of physical parameters or spectrograms,
- subjective methods - information about the soundscape is obtained on the basis of questionnaires or interviews, as well as through on-site observation and assessment,

- mixed-method - a combination of objective and subjective soundscape analysis techniques [1–3].

Studies show that street-level noise is one of the main sources of noise in urban space. This source includes various means of transport, human activities and ambient sounds, as well as sounds of nature. Continuous exposure to high-level noise can lead to health and psychological problems that directly threaten public health and well-being [4].

Protection against noise and vibration is included in regulations and action programs in the field of environmental protection and development. The current acoustic requirements are formulated as mandatory limit values. For industrial sources, the requirements are stricter than for road or rail noise. This differentiation results from subjective assessment - industrial noise is perceived as more onerous than rail noise with the same level. Formal and legal tools used in noise management can be replaced or supplemented with economic tools. The use of this type of mechanism is part of the concept of sustainable development. Acoustic maps are a graphic presentation of measurements of equivalent sound levels. They show places where the limit values were exceeded. Based on them, areas threatened with excessive noise can be determined. This is an objective approach, where the results are compared to the applicable regulations. On this basis, space is analyzed and protective measures are taken. However, the human factor is not taken into account in these studies. Surveys about the acoustic situation are a good tool. Often, the results of surveys differ from the conclusions made on the basis of sound level measurements [5, 6]. Acoustic space shaping is based on forming acoustic conditions so that sound stimuli do not exceed the permissible values and are optimal from the point of view of human health needs. They should guarantee the creation of favorable operating conditions and the preservation of the so-called acoustic comfort.

The soundscape is defined as the full range of sounds felt in a given landscape, at a given time and the way how people respond to these acoustic signals. Unlike environmental noise studies, soundscape studies are designed to gather information about the environment and the subjective perception of sounds that are components of this environment. Studies on a subjective perception of sounds are important from the point of spatial planning view. Getting to know the opinions of visitors can help in the proper management of space, especially in cities. Hence the aim of the paper - knowing the sources of noise in city parks, based on the subjective assessment of recipients and objective factors (measurements) - their confrontations - allows for proper creation of these areas and sustainable management of these areas [7–9].

2. Methodology

Three parks located in the center of Bydgoszcz were selected to assess the soundscape:

- the Kazimierz Wielki Park (area: 2.24 ha),
- the Jan Kochanowski Park (area 3.15 ha)
- the Wincenty Witos Folks Park (area 6.42 ha) (Figure 1).

Figure 1: Localization of studied parks Source: [10]

The first park was created in XVII century This is the oldest park in Bydgoszcz. The second, Jan Kochanowski park, created in 1901, is an example of the English style by Konrad Neuman. This park is located in a ”music district” of Bydgoszcz. The Wincenty Witos Folks Park was founded on the site of the cemetery of the Evangelical United Commune around 1952. Selected parks have similar features - location, function and

much social as well as landscape. The differences are - size and surroundings: historic buildings, a neighborhood of main streets.

Shaping the sound space in the Kazimierz Wielki park is primarily influenced by communication (especially by tram), people (conversations, sounds from the playground), sounds from the nearby church and high school (bell), natural sounds (fountain, leaf noise). Based on the noise map of Bydgoszcz, noise penetration into the park can be noticed only from the north. It is related to the tram traffic on Gdańska Street. The noise level is 55-60dB - the permissible level for this type of area is 65dB - therefore there is no exceeding of the permissible standards. The park is surrounded on all sides by old buildings - tenements, which significantly inhibits the ingress of external noise.

Jan Kochanowski Park is characterized by the following sound sources: communication (car), people (conversations, sounds from the playground), sounds from a nearby music school, natural sounds (fountain ”Light-Sound”, leaf noise). The analysis of the acoustic map shows the penetration of road noise into the park from the north-east and east at a level of 55-65dB - the limit of the permissible level. The buildings surround the park from the southwest. Further on, the park is bordered by streets with medium traffic (about 3000/day) and bus (about 180/day).

Wincentego Witosa Folks Park is an area bordering busy streets from the north-east and south-west, with high traffic and public transport (about 13,000 vehicles per day). The noise penetration into the park from the street side is significant (sound level reaches 70dB) and covers the whole area. Sound sources in addition to traffic noise are people (conversations, sounds from the playground), tennis court, occasionally - concert shell and natural sound - leaf noise.

The parks space was assessed using results of questionnaires and tool that allows building fuzzy cognitive maps (FCM) - Mental Modeler - based on data from an acoustic map and surveys. The equivalent sound level measurements were made during the summer season both on workdays and holidays. The geometric mean of measurements was adopted for the analysis. It was compared with the values from the noise map. Subsequently, the noise values are only referenced values for comparative analyzes with the survey results. Surveys were carried out at the same time in a group of 50 people visiting the park also in the summer season.

2.1. Surveys - statistic

Surveys give information about the subjective perception of heard sounds. For the parks analyzed, a survey conducted in the summer season gave an answer about the sounds

that park visitors paid attention to. These sources were grouped into four classes and the results were collected and summarized in Table 1.

TABLE 1: Subjective respondents sound perception Source: [own elaboration]

Sound sources	Kazimierz Wielki Park [%]	Jan Kochanowski Park [%	Wincenty Witos Folks Park [%]	Mean value [%]
Traffic	47	53	56	52
Human factor	33	24	24	27
Nature	8	5	6	6
Other	12	18	14	15

2.2. Surveys - fuzzy analysis

Fuzzy cognitive maps (FCM) are a complex form of data collection. They can be a way to assess the qualitative perception of noise/sounds. Fuzzy cognitive maps are used to study the structure and behavior of complex systems and interactions between concepts. They are often the basis for starting the initial stages of integrated assessment, e.g. complex environmental problems, as described by Vasslides and Jensen [11]. For the analysis of data contained in FCM, methods based on graph analysis are used, and the structure of a single FCM can be presented as a square adjacency matrix. The assessment of the quality of the soundscape seems to be the assessment where the application of FCM-based modeling, i.e. techniques for imaging human interaction with the environment in socio-ecological systems, works great. The Mental Modeler used allowed the FCM construction of the analyzed parks [11–13].

3. Results

Based on the means values of the subjective reception of sounds (Table 1), a structural graph of sound perception was made in selected city parks (Figure 2).

Because the Kazimierz Wielki Park of and Jan Kochanowski Park are comparable in area, and similar features can be distinguished that shape the soundscape, an aggregated cognitive map based on the survey was created. Uncertain causal knowledge is stored in a fuzzy map mark, where the nodes represent variable phenomena, transforming weighted and summed input data into numerical data, analogous to the artificial neuron model (Figure 3).

Because the Wincenty Witos Folks Park is larger and has slightly different components, a separate fuzzy cognitive map was made (Figure 4).

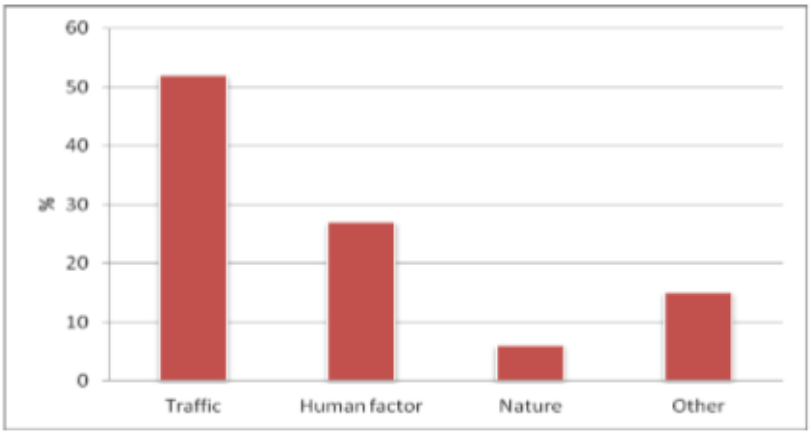

Figure 2: Average subjective sound perception Source: [own elaboration]

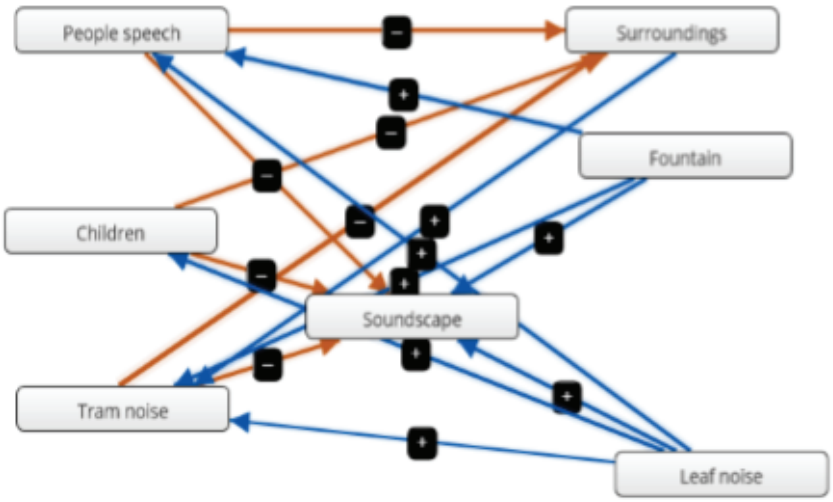

Figure 3: Fuzzy cognitive map of Kazimierz Wielki Park and Jan Kochanowski Park Source: [own elaboration using Mental Modeler]

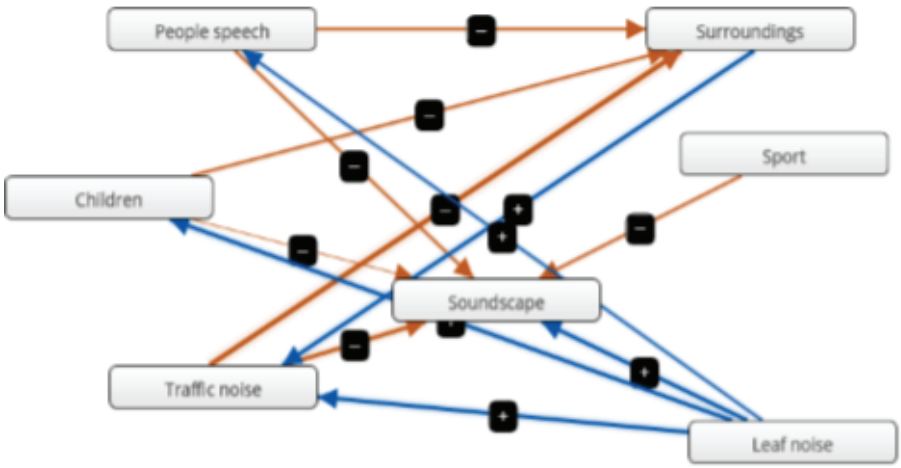

Figure 4: Fuzzy cognitive map of Wincenty Witos Folk Park Source: [own elaboration using Mental Modeler]

Then, scenarios were made for the resulting cognitive maps. Interactions between the factors are presented as negative or positive graphs with variable values. The concepts in FCM are equivalent to neurons and are nonlinear functions that transform activated pathways (”causes”) into values in the set [-1.1]. A good solution for conflicting and no-conflicting interests is to create scenarios presenting the possible effects for various options (even opposite) as support for spatial decisions. Scenarios are a useful tool for assessing the potential consequences of selections [13, 14]. The bar diagram indicates how components can react in a given scenario. And so, for the Jan Kochanowski Park and Kazimierz Wielki Park initiated changes consisting in strengthening the natural features affecting the acoustics inside the park (Table 2; Figure 5).

TABLE 2: The scenario date for Kazimierz Wielki and Jan Kochanowski parks Source: [own elaboration]

Sound sources	Values
Tram noise	0.19
Children	0.17
People speech	0.22
Surroundings	-0.13
Soundscape	0.23

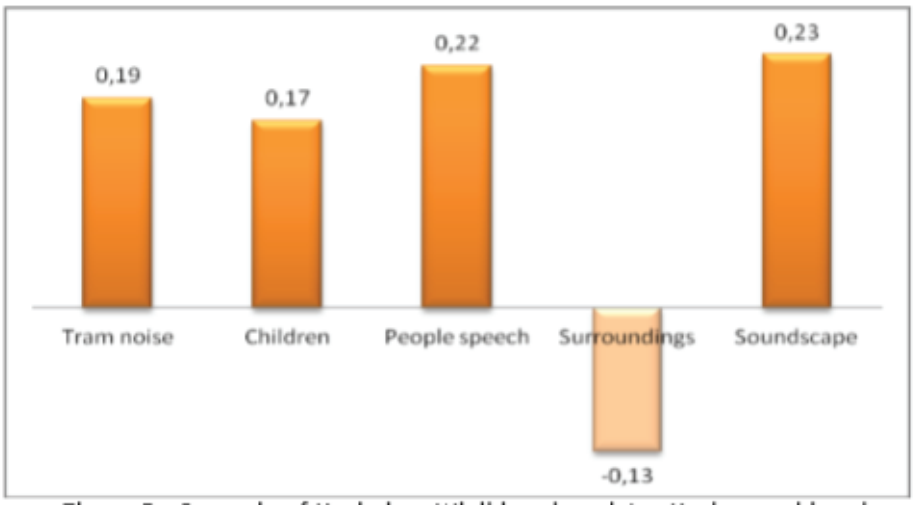

Figure 5: Scenario of Kazimierz Wielki park and Jan Kochanowski park Source: [own elaboration, Mental Modeler data]

And for the Wincenty Witos Folks Park to strengthen the natural noise of leaves, which resulted in an impact on traffic noise, children, people staying in its area and reduced the value of soundscape (Table 3; Figure 6).

Subsequently, other scenarios can be performed highlighting one or more components. On this basis, planning decisions can be made to improve the quality of the studied areas.

Table 3: The scenario date for Wincenty Witos Folks Park Source: [own elaboration]

Sound sources	Values
Traffic noise	0.19
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Soundscape	0.23

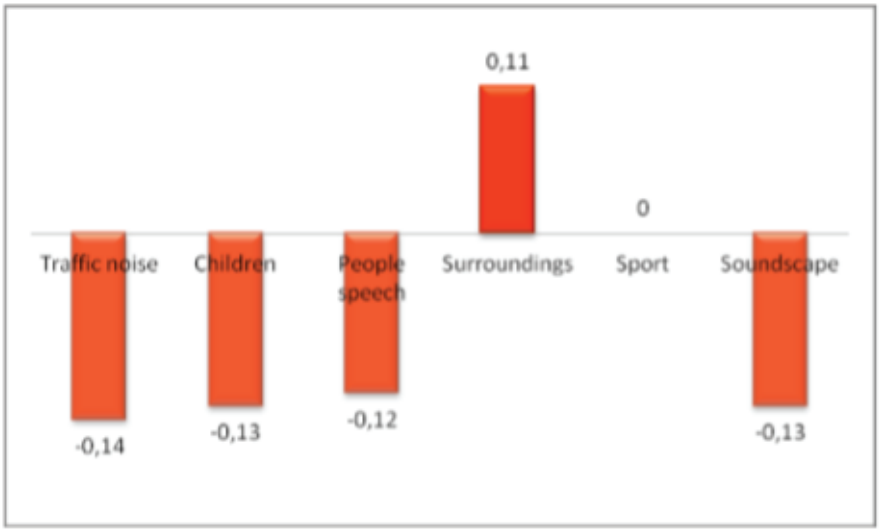

Figure 6: Scenario of Wincenty Witos Folk Park Source: [own elaboration, Mental Modeler data]

4. Discussion

Proper space modeling can be considered an indispensable component of good management. Environment perception is different from the perception of a single thing:

- elements of the environment are diverse and complex - perception takes time,
- size of the environment - a larger system means a more complex system,
- the environment as a surrounding - perception from the inside,
- the recipient should have navigational skills in the perception of the environment,
- human contact with the environment takes place for a specific aim - spatial information related to the recipient's aim is selected [15, 16].

Environmental audience and visual responses can generally be classified as:

- cognitive (related to knowledge and understanding),
- emotional (related to feelings, attitudes, and emotions),

- behavior (associated with changes in viewer behavior),
- physiological (biological or physical effects on the observer body) [11].

Studies [16, 17] have shown that landscape features that affect sound perception are:

- landform,
- vegetation,
- proximity to the sound source.

Authors show [7, 17–19] that the foreground and background sounds affect the perception of the environment differently. It is the background noise that correlates with the perception of space. It has also been shown that in the urban environment the perception of sounds their multitude influences - if there are a lot, it seems to the users that it is quieter [5], especially in the recreational and leisure areas, in the summer season.

Figure 7 below characterizes sound space well in relation to urban and rural areas, in correlation with sound frequency, surroundings, and the human factor.

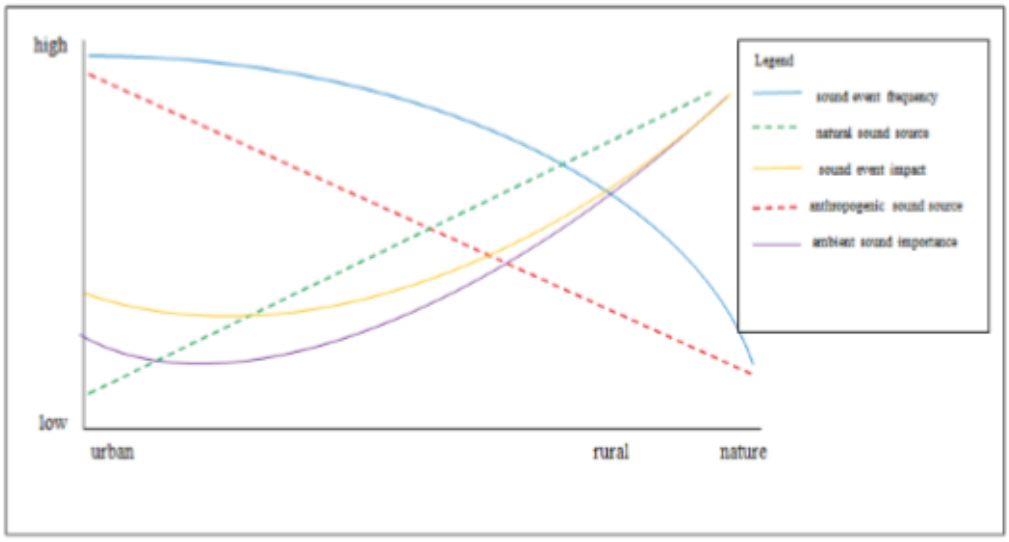

Figure 7: Sound-space dependence Source: [own elaboration on the basis of 20]

Emissions of high-frequency noise and accumulation of anthropogenic sources are observed in the urban environment, which is decreasing outside the city and in the natural environment. Also, attention should be paid to sound events that disappear in cities, are imperceptible (the sound accumulation of different sound sources), while in the natural environment they are an important factor in the perception of the soundscape. The subjective feeling and sensitivity of a man to noise depends on his physiological predispositions and the characteristics of sound. Certain sounds can both create a

pleasant or nuisance experience. This is due to the individual characteristics of each person, age, health, mood and sensitivity, and mental resilience. In addition, the annoyance of noise increases if it appears unexpectedly and from an unknown source. Sound is perceived differently by its perpetrator and differently by its recipient.

In the analysis of Bydgoszcz parks, it is noteworthy that a human factor appears in the sound perception (visitors disturb other visitors). Each park has a separate playground area. In each of the parks, the respondents noticed the children making noise and while in smaller parks (Kazimierz Wielki and Jan Kochanowski) it was the leading factor as a source of noise, in the Wincenty Witos Folks Park this feature was also noted. In this case, further analysis of surveys based on information on the age of visitors seems to be important. The highlighted traffic factor is leading in each of the surveys. It should be remembered that the information obtained from surveys is descriptive, ”fuzzy” information. Therefore, the use of the fuzzy cognitive map tool is justified and gives information about the dependencies. Aggregated models allow you to build a scenario. As a result of the scenario for small parks, it can be seen that the amplification of natural sound factors most affects the sound space. It strengthens it. However, these are the sounds that cause the so-called ”white noise” - desirable for the health of visitors. In the second scenario, for a larger, popular folk park, the strengthening of nature's sound weakens other sound-forming factors. Therefore, in a larger area, sounds from natural sources have a greater impact on soundscape shaping. Analysis using the FCM tool is effective and can be helpful in discussions on improving the acoustic climate of city parks.

5. Conclusion

Functional zones of the city correspond to various zones of activity of residents. Each of them has different sources, levels and noise are perceived differently in each of them. Parks, as one of the important components of the natural and cultural environment, are areas of special importance for satisfying the needs of residents and improving their quality of life. They favor social contacts due to their location and functional and spatial features. The perception of the sound quality accompanying various phenomena and their characteristics (pitch, tone, intensity, consonance) leads to a sharper perception of the outer world. City parks, despite the concentration of a large number of sound stimuli in their areas, are treated by visitors as a kind of the ”rest oasis”. This study draws attention to the relationship between the types of sounds and their perception. The relationships between the individual components (communication sounds, human factor,

natural factor, and others) were analyzed and visualized using fuzzy cognitive maps. The resulting scenarios provide the basis for effective management of these areas. Space management processes based on people's preferences give a more complete view of the received environment. Understanding the sources of noise in an existing park can result in relevant entries in spatial plans. In small parks, it is more difficult to separate the quieter areas from the louder ones, but in larger parks, it is possible to separate the quieter areas. Information about sound level values in connection with feelings can effectively support spatial development plans so that they are accepted by the local community. Quoting D.W. Meining [7]: "... space consists not only of what our eyes see but also of what fits our head." In the case of a soundscape, an auditory impression should also be added to this statement. The claim that noise creates a sound space is true, but this creation is primarily associated with its subjective perception by users. If the architecture of parks is to create an acoustically friendly space, their perception should be investigated and interpreted.

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