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The Use of Tranquility Rating for Urban Spaces

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Abstract The Tranquility Rating coefficient (TR) is a tool proposed for assessing the quality of urban green areas, which considers both visual and acoustic aspects. This paper aims to verify how the proposed TR coefficient works for the assessment of the audiovisual quality of a typical urban space in a vicinity of an arterial road. Three different versions of the same urban space are considered: loud and visually unappealing (current state), quiet and visually unappealing (after considerable traffic reduction), and visually appealing and quiet (after redesigning). The values of noise levels required for the calculation of TR are taken from the noise maps based on the in-situ measurements, and the values of the percentage ratio of the features which are natural or man-made but contained within the visual scene (NCF) are taken from a survey conducted in the research. The results show that for the urban areas, even with very low noise levels, the TR is described as "unacceptable". This may indicate the need for introducing an amendment for TR to be used in typical urban areas.

Keywords: noise, noise map, happy city, L_{Aeq}

1. Introduction

Excessive environmental noise may adversely affect humans' health in numerous ways [1–4]. It directly causes sleep disturbances and annoyance, being one of the reasons for increasing anxiety amongst societies [5,6]. What is more, noise contributes to the development of cardiovascular diseases, cognitive dysfunctions, and simply disturbs everyday activities, being a nuisance in the soundscape [7]. For this reason, noise exposure should be controlled, and in fact, different approaches for the assessment of noise arise [8]. The applicable legal resolutions for protecting people against excessive noise are based on the evaluation of the long-term noise indicators or equivalent noise levels in particular time intervals. However, in the analysis of the urban soundscape, the acoustic and visual aspects are equally important and cannot be considered separately [9,10].

A popular approach for analyzing urban sondscapes and their influence on the inhabitants is the use of a so-called *soundwalk*. This method consists in walking in a certain area, observing the visual scene, and recording the acoustic signal simultaneously [11]. It was acknowledged for the cognition of the sociological influence of the soundscape on the perception of a particular space in a combination with the visual aspects. However, it only allows the analysis of the already existing places, since it is based on the acoustic signals recorded in the defined locations. For the process of designing, the analysis of soundscape becomes difficult and would require the use of auralization methods [5].

Another measure, proposed to assess the quality of the audiovisual scene, is the Tranquility Rating coefficient (TR), which combines the auditory impression with the visual aspect of the city [12]. It was introduced for the assessment of urban green spaces, such as, for example, parks. This paper aims to verify how the proposed TR coefficient works for the assessment of the audiovisual quality of typical urban area. In order to do so, the TR coefficients were calculated for a chosen urban area, in the vicinity of an arterial road, in three different versions: the urban space in its current state (loud and visually unappealing), the same urban space after considerable reduction of traffic (still visually unappealing, but quiet), and the same urban space but after redesigning according to the idea of a "happy city" (visually appealing and quite) [13]. The noise level in the discussed urban space was determined using noise maps prepared in Soundplan software and verified based on the in-situ noise measurements. The noise maps were prepared for L_{Aeq}

instead of normally used L_{den} and L_n since they were used for the calculation of TR coefficient and not for the assessment of noise. For assessing the last version of the discussed space (the "happy city"), the designs developed during the interdisciplinary workshops *Nowa Przestrzeń* were used. The workshops were aimed at the modernization of the urban spaces of the city of Kraków, in a way that considers all the basic human needs.

2. Tranquility Rating

The perception of the urban space is an issue of psychoacoustics. This is why most studies on urban landscapes are based on surveys and psychoacoustical tests [14,15]. In the last decade, attempts were taken to analyze urban landscapes based on mathematical formulations, which would take into account both visual and acoustic aspects [9,12]. Such an approach is shown in [12]. The authors proposed a Tranquility Rating coefficient as a method for assessing urban landscapes, which combines both visual and acoustic aspects. The Tranquility Rating coefficient (TR) was defined as follows:

$$TR = 13.93 - 0.165L_{Amax} + 0.024NF, \qquad (1)$$
$$TR = 8.67 - 0.11L_{Aeq} + 0.036NF, \qquad (2)$$

where L_{Amax} is the maximum A-weighted level, L_{Aeq} is the A-weighted equivalent sound pressure level during the daytime, and NF is the percentage ratio of natural features in the landscape, such as trees, plants, and water. Equations (1) and (2) were derived based on tests on a representative group of people, who were presented photographs of chosen spaces from parks in England. In the course of the research, the authors noticed that taking into account only the natural features is inadequate and the elements which are man-made but contained within the visual scene must be considered as well. This led to a different formulation of TR, which uses the NCF coefficient – the percentage ratio of the features which are natural or man-made but contained within the visual scene:

$$TR = 9.68 - 0.146L_{Aeq} + 0.041NCF. \qquad (3)$$

In the end, the acoustic parameter was chosen to be L_{Aeq}, A-weighted equivalent sound level during daytime. The authors performed a multiple linear regression analysis for the TR values obtained for L_{Aeq} and L_{Amax} and the subjective parameters of the studied space and showed that using L_{Aeq} instead of L_{Amax} provides higher coefficient of determination. The TR values are within the range of 0-10, where 0 means that the described space is unfavorable, and 10 – the space in question is comfortable and calm. The values of TR above 10 and below 0 are set to 10 and 0, respectively, as described in [16].

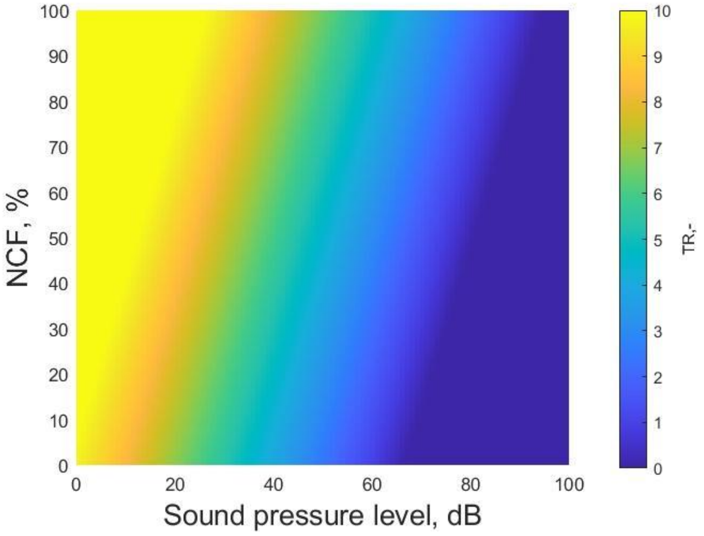

Fig. 1. Tranquility rating (TR) as a function of NCF and sound pressure level.

Based on the derived equations and the methods for analyzing the audiovisual scenes developed in [12,16], the ranges describing the quality of the TR coefficient were defined (Tab. 1). As shown in Fig. 1, the TR coefficient takes the values described at least as "acceptable" for the L_{Aeq} less than 50 dB, with NCF of around 40-50%. Such low noise levels in the urban areas close to the main communication arteries are scarce. Even for the NCF equal to 100% and $L_{Aeq} = 50$ dB, TR takes the value of 6.48 and can be described as "fairly good". Despite that, an urban space with the sound level L_{Aeq} slightly exceeding 50 dB can be generally perceived as comfortable.

Tab. 1. The assessment of TR values.

TR	quality of TR
< 5	unacceptable
$5 - 5.9$	just acceptable
$6 - 6.9$	fairly good
$7 - 7.9$	good
≥ 8	excellent

3. The studied space

The analysis included a part of the urban area of the city of Kraków between the *Rondo Antoniego Matecznego* and *Borek Fałęcki* (in Fig. 3 marked with an eye). Fig. 2 shows the current state of the studied space and also two different versions of the same area, but after redesigning it according to the idea of a "happy city".

Fig. 2. The site under study; top left – current state, top right the Tree of Life design, bottom – the Alsos Alley.

The designs were developed during the workshops *Nowa Przestrzeń 2018,* organized in cooperation with the Faculty of Interior Design – Jan Matejko Academy of Fine Arts, the Faculty of Architecture – Cracow University of Technology, the Institute of Sociology of the Jagiellonian University, and the Department of Mechanics and Vibroacoustics – AGH University of Science and Technology. During the workshops, seven different designs were developed. In this work, two of them are used: The Tree of Life (*Drzewo Życia)* and the Alsos Alley (*Aleja Alsos*) [17]. All the projects were visionary, developed according to the idea of a "happy city" [13]. According to the authors of this concept, a "happy city" is a city, in which the people are the most important in public space planning. As a result, the traffic is considerably reduced (or even totally forbidden – like in the case of Vauban in Freiburg) and the pedestrians and cyclists are the primary users of the roads. The road becomes not only a way from A to B but also a creative space for living and just spending time. One of the first experiments of such kind was performed in Bogotá by the mayor Enrique Peñalosa. Apart from building public libraries, he introduced a car-free day and proposed a net of city parks and bicycle paths to fight social inequality. His idea was spread across different Columbia cities, as the *Ciclovia,* but also worldwide: to Melbourne, Miami, and New York and its *Summer Streets.* Despite some controversies at the beginning, like in the case of New York, the idea of "returning" the streets to the inhabitants for at least one day of the year was received enthusiastically and is still practiced. In this paper, the cities designed according to the idea of a "happy city" are a reference point for a perfect urban space.

3.1. The Tree of life

The main idea for The Tree of Life project was to prioritize the people over the vehicles and transportation [17]. The main focuses were: noise reduction, improving air quality, and creating space for outdoor activities. All those aspects were ensured by a significant reduction of traffic and designing a park in the middle of the existing road. The park was supposed to be a recreational space for integration meant for all the space users. The design symbolized the rebirth of nature, which was additionally emphasized by trees, inspired by Gardens by the Bay in Singapore [18]. The tree-like constructions, built of graphene, are used for nests for birds, beehives, and photovoltaic cells, creating a sustainable and people-friendly space.

3.2. Alsos Alley

The Alsos Alley project was based on the history of the designed area. It used a water creek along the way as a reference to a historical health resort. The water has visual functions, becomes a masker for undesired sounds, and together with its surroundings, gives space for people to relax. A metal ribbon parallel to the creek works as a shed, bus stops, and art-promotion space. Those two elements integrate the whole area and eliminate the existing divisions between the living, working, and shopping areas. Most of the traffic was moved underground, and the entire road area was divided between pedestrians, cyclists and occasionally passing cars, with a speed limit. It increased the safety within the region and allowed the integration of the whole space, additionally enriched with natural elements.

3.3. The assessment of NCF

For assessing the TR coefficient, we need to know the value of NCF – the percentage ratio of the features that are natural or man-made but contained within the visual scene. It is relatively easy to decide whether the object is natural, but whether a man-made object is contained within the visual scene is more subjective. This is why, in order to assess the NCF of the particular versions of the city, a survey was conducted, in which the respondents were to evaluate the landscaped shown in Fig. 2. Each visual was divided into 80 even rectangles and the respondents answered the following question: "Is this part of the landscape natural or man-made but contained within the visual scene". The possible answers were: yes/no. The respondents were shown the whole pictures for a general impression and those already divided. Using the answers given by the respondents, the percentage ratios of the features which are natural or man-made but contained within the visual scene were determined for each version of the city, excluding the area of the sky. 18 people were interviewed, and the answers were tested for outliers; the values of NCF, which were not within the range of three scaled median absolute deviations were excluded from the analysis and the mean values from the rest of the results were taken. Two answers were excluded for the city in its current state; in the case of the Tree of Life and the Alsos Alley the analysis did not indicate any outliers. The results of the survey are shown in Tab. 2. For the redesigned version of the city, the value of NCF more than tripled. In addition, the respondents assessed the three versions of the city as a whole, answering the question: "Is this landscape pleasant?". As expected, generally the city in its current state was assessed as unpleasant, and after redesigning, in both versions – pleasant.

Tab. 2. Mean values of NCF for different versions of the area under study

NCF	value
current state	13.6%
the Tree of Life	44.4%
the Alsos Alley	44.0%

3.4. The assessment of L_{Aeq}

The A-weighted equivalent sound pressure level during daytime L_{Aeq}, required for the calculation of the TR coefficient, was determined based on the prepared noise maps. The noise levels and traffic intensity and structure measurements were made in the area under consideration. The obtained results were used to develop and verify the calculation model in the SoundPLAN software. The measurement positions are shown in Fig. 3 (points P1-P7) and the results of the measurements are shown in Tab. 3. The calculations were made for two versions:

1. Current state,
2. After the following changes:
   - decreasing traffic intensity to 20 cars per hour (light vehicles),
   - decreasing the speed limit to 30 km/h,
   - eliminating tracking and haulage (trucks and other heavy vehicles).

Tab. 3. The A-weighted equivalent sound pressure level during daytime L_{Aeq} and traffic intensity in the measurement positions for the city's current state and after modifications.

No.	L_{Aeq}, dB	traffic intensity		
		vehicles	current state	after modification
1	71.3	light	3442/h	20
		heavy	348/h	0
2	N/A	light	1000/h	20
		heavy	50/h	0
3	73.4	light	2768/h	20
		heavy	276/h	0
4	68	light	900/h	20
		heavy	30/h	0
5	72.9	light	1800/h	20
		heavy	80/h	0
6	73	light	1000/h	20
		heavy	60/h	0
7	68.2	light	800/h	20
		heavy	30/h	0

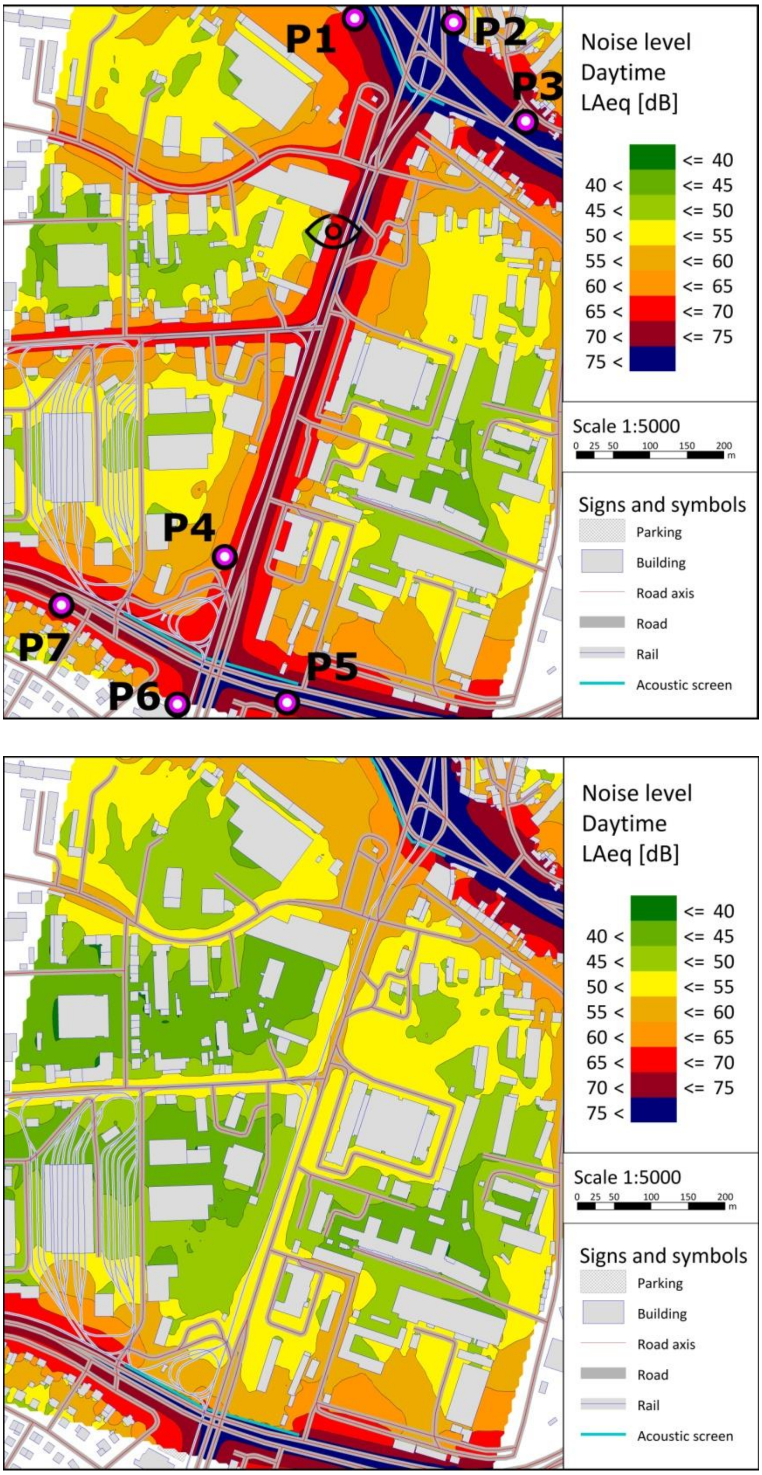

Fig. 3. Distribution of the A-weighted equivalent sound pressure level during daytime L_{Aeq}. Top – current state, bottom – after modifications. P1-P7 are the measurement positions and the considered area is marked with an eye symbol.

The results of the calculations are shown in Fig. 3, as the distributions of the A-weighted equivalent sound pressure level during daytime L_{Aeq} (daytime is understood as the time from 6:00 a.m. to 10:00 p.m.). The traffic was reduced for the road marked with an eye (Wadowicka street) and not for the perpendicular roads; this is why the noise levels observed at the measurement points did not change significantly.

However, a significant noise reduction can be observed along the Wadowicka street. Since the modeling results are expressed as intervals, the following levels were adopted for the calculation of TR: 65-70 dB for the current state (in Fig. 3 – red), and 50-55 dB after the traffic reduction (yellow).

4. Results and discussion

Using the acquired data on noise levels and NCF values described above, the values of Tranquility Rating were determined for three versions of the studied urban area: in its current state (loud and visually unappealing), the same urban area after significant traffic reduction (still visually unappealing but quiet), and the same urban area but after traffic reduction and redesigning according to the idea of a "happy city" (visually appealing and quite, in two versions: the Tree of Life, and the Alsos Alley). The values of A-weighted equivalent sound pressure level L_{Aeq}were given as intervals, and therefore the values of TR are also expressed as intervals.

Tab. 4. The interval values of TR for different versions of the city.

	current state	current visual state + noise reduction	The Tree of Life + noise reduction	Alsos Alley + noise reduction
TR,-	0.02-0.75	2.21-2.94	3.47-4.20	3.45-4.19

Tab. 4 shows the values of TR calculated for the three different versions of the city. We can see that even despite total redesigning of the space according to the idea of a "happy city", the obtained values of Tranquility Rating are still described as unacceptable. Even if the values of NCF were 100%, which means that all the elements of the landscape were natural or man-made but contained within the visual scene, with the modeled noise level, the maximum possible values of TR would be 5.75-6.48 and could be described as fairly good at best. Such a result can be interpreted two ways – maybe, the Tranquility Rating coefficient could be adjusted to be used in an urban space in the vicinity of an arterial road, by, for example, adding a "correction factor" of 2, because of the character of the area. Then, the urban area that is visually perfect (NCF 100%) and has a noise level of 50-55 dB could be described as good or excellent in terms of the Tranquility Rating coefficient. On the other hand, we can agree that by the definition of a city, the Tranquility Rating cannot be described as excellent in urban space of any form if the minimal functionality of the transportation is to be maintained. This is a sort of a city characteristic, which by definition cannot be quiet and peaceful, but on the contrary – must be dynamic and provide multisensory sensations.

5. Summary

To summarize, this paper verifies the possibility of using the Tranquility Rating coefficient for the assessment of the audiovisual landscape of an urban area, in the vicinity of an arterial road. The urban space under study was assessed in three different versions: in its current state (loud and visually unappealing), the same urban space after considerable reduction of traffic (still visually unappealing, but quiet), and the same urban space but after redesigning according to the idea of a "happy city" (visually appealing and quite). The new designs of the considered urban space were developed during the interdisciplinary workshops *Nowa Przestrzeń.* The visual assessment of the percentage ratio of the features which are natural or man-made but contained within the visual scene (NCF) was performed based on a survey conducted on 18 respondents. The values of A-weighted equivalent sound pressure level L_{Aeq} were taken from the noise calculations made in SoundPLAN software based on the in-situ measurements. The analyses were performed for two versions: for the current traffic intensity and after considerable traffic reduction. The results show that the values of TR calculated for the urban space in the vicinity of an arterial road, even after complete redesigning and maximum reduction of traffic do not reach 5, which means they cannot be described as "acceptable". This may indicate the need to introduce an amendment to the TR coefficient for typical urban spaces, for example, by introducing appropriate correction factors considering the character of the area. The methodology described in this paper is unique since it analyzes the same part of the city in different versions, as opposed to the so-far works which have only considered the existing urban spaces.

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