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► To cite this version:

Mia Suhanek, Ivan Djurek, Sanja Grubesa, Antonio Petosic. An Advanced Approach to Calculation of Overall Soundscape Annoyance Rating. Forum Acusticum, Dec 2020, Lyon, France. pp.1477-1481, <10.48465/fa.2020.0031>. <hal-03233631>

HAL Id: hal-03233631

<https://hal.science/hal-03233631v1>

Submitted on 26 May 2021

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AN ADVANCED APPROACH TO CALCULATION OF OVERALL SOUNDSCAPE ANNOYANCE RATING

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ABSTRACT

In this paper we propose a new soundscape characterization parameter which we termed the Overall Soundscape Annoyance Rating (*OSAR*) which relies on distribution of several objective acoustic parameters, namely loudness, loudness growth rate and sharpness. The aforementioned objective acoustic parameters were chosen taking into account our previous research in which we have proven their significance regarding the human perception of different acoustic environments. In addition, based on the survey among urban residents we have incorporated into our calculations a new subjective parameter which we term Sound Character Index (*SCI*). This index is subsequently included into the Overall Soundscape Annoyance Rating calculation, by which a more realistic sound perception rating is obtained. Such advanced rating system is intended to be used as an engineering guideline for design of acoustically pleasant urban environment within the concept of smart cities.

1. INTRODUCTION

The initial concept of soundscape was proposed as an attempt to create an analytical perspective that would show the total acoustic environment over time and across cultures [1]. Most soundscape studies concern the qualitative analysis of soundscapes, however, the methods for evaluating a soundscape are different according to the purposes of the researchers [2, 3]. The researchers usually while listening to soundscapes have used surveys with subjective descriptors. Taking into account loudness, sharpness and roughness [4, 5] it is possible to calculate an annoyance level of a certain sound or a soundscape [6]. Another part of soundscapes and sounds analysis deals with their distraction properties and how characteristic sounds influence people performing logical, mathematical and other concentration demanding tasks [7, 8].

Every day, people are exposed to different sound environments during their sleep, rest, work and other activities. We are all aware that, if someone resides in a sound environment for a long time, eventually will adapt to it, and small and expected loudness changes in soundscape would not significantly influence someone's perception of that soundscape [9]. Our everyday sound environments could only slightly change and if were exposed to them frequently we could adapt to them, and if they were not significantly loud, we would not perceive them as annoying [10]. An example for this statement are people who work every day in an open offices, whose

loudness distribution and spectral content would not significantly change through a long period of time. The other example are apartments next to a busy street or a playground. After some time, people living in these apartments will adapt to these sounds and they would not be annoyed if these sounds were not too loud.

Currently, soundscape research is a very active research field and everyday more and more scientists with different areas of expertise are being included while trying to make their contribution in terms of improving the overall quality of life especially in urban areas (e.g. acoustic engineers, urban planners, psychologists, architects, doctors etc.). Thus, we can conclude that nowadays more and more soundscape studies are oriented towards human health, well-being and overall quality of life [11].

In our previous research we have proposed an acoustical model, which allows one to quantify how much typical urban acoustic environments are subjectively perceived in terms of affecting the listeners' concentration. For that purpose, we have recorded several different soundscapes which were then reproduced to listeners in laboratory conditions. It was found that the linear model is adequate for calculating the parameter which we named respectively Total Distraction Coefficient (*TDC*) (e.g. the lowest *TDC* was obtained for the soundscape of stream) [12].

The motivation for this paper is proposing a slightly different approach to quantification of soundscape perception. We are suggesting a new soundscape parameter which we termed the overall soundscape annoyance rating (*OSAR*) parameter. The *OSAR* parameter relies on objective acoustic parameters, namely loudness, loudness growth rate and sharpness which have been proven to be significant in our previous work regarding the Total Distraction Coefficient (*TDC*) calculations in terms of human perception of different acoustic environments. In addition, we are incorporating in our calculations a new subjective parameter which we term Sound Character Index (*SCI*). We believe that this index now included into the Overall Soundscape Annoyance Rating calculations gives a more realistic sound source perception rating.

2. THE SURVEY

Based on our previous research [13] on five typical urban environments (i.e. children's park, expressway, industrial hall, stream and shopping mall) and its findings we have created a specific questionnaire with focus on the all sound sources which appear within the aforementioned acoustic environments (shown in Fig. 1).

GENDER _____
 AGE _____
 Please assign a grade (from 1 to 7) to the following sound sources bearing in mind that 1 is associated with sound sources which do not disturb or annoy you at all (they are practically unnoticeable) while 7 is associated with sound sources which you perceive extremely disturbing and annoying.
 Sound sources:

1□	2□	3□	4□	5□	6□	7□
Children screams						
1□	2□	3□	4□	5□	6□	7□
Children crying						
1□	2□	3□	4□	5□	6□	7□
Sound of a car						
1□	2□	3□	4□	5□	6□	7□
Sound of a truck						
1□	2□	3□	4□	5□	6□	7□
Sound of a grinder						
1□	2□	3□	4□	5□	6□	7□
Sound of a hammer						
1□	2□	3□	4□	5□	6□	7□
Dog barking						
1□	2□	3□	4□	5□	6□	7□
Sound of a stream						
1□	2□	3□	4□	5□	6□	7□
Music						
1□	2□	3□	4□	5□	6□	7□
Sound of a bus						
1□	2□	3□	4□	5□	6□	7□
Car horn						
1□	2□	3□	4□	5□	6□	7□
Speech						
1□	2□	3□	4□	5□	6□	7□

Figure 1. Questionnaire designed for this study

The participating in a survey was carried out anonymously in compliance with the established psychological research methodology [14], i.e. the participants only needed to state their age and gender (please see Fig. 1). In this particular study 80 participants were involved. The median age was 20 with the equal male to female ratio. The participants were not informed of the study hypothesis, they were kindly asked to fulfil the questionnaire in a way to evaluate certain sound sources according to their perceived distraction and annoyance. This evaluation was done using the semantic differential with a 7-grade scale (i.e. 1 was associated with practically unnoticeable sound sources while 7 was supposed to be assigned to sound sources perceived as disturbing and annoying.

Tab. 1 shows the results of the questionnaire survey.

	MEDIAN	MOST COMMON SCORE	DIFFERENCE	INDEX
Sound of stream	1.30	1 (66)	0	-2 (0)
Music	1.64	1 (51)	0.34	-1 (1)
Speech	2.16	2 (33)	0.53	0 (2)
Sound of a car	2.66	1 (24)	0.50	1 (2)
Sound of a bus	3.33	3 (3)	0.66	2 (4)
Sound of a truck	3.74	5 (28)	0.41	2.5 (4.5)
Dog barking	3.89	5 (27)	0.15	2.5 (4.5)
Sound of hammer	4.24	5 (23)	0.35	3 (5)
Children crying	4.89	5 (27)	0.65	4 (6)
Car horn	4.89	5 (25)	0.00	4 (6)
Sound of a grinder	5.23	7 (25)	0.34	5 (7)
Children screams	5.26	6 (29)	0.04	5 (7)

Table 1. Questionnaire survey results

By analyzing the results shown in Tab. 1 we can conclude that which sound sources are perceived as distracting and annoying and which are unnoticeable for the participants. The sound sources are already ranked in Tab. 1 from the least distracting to the utmost annoying and distracting. According to this type of ranking obtained from the participants scores, we proceeded to assign a certain index to each sound source (please see last column in Tab. 1). Intuitively a negative coefficient is assigned to the sound sources which were perceived unnoticeable and, therefore more pleasant such as sound of stream and music. In order to simplify later calculations this index was corrected in order not to have negative values by adding the number two to each value (please see the values in the last column in brackets Tab. 1).

In our previous work [12] we have introduced and calculated subjective parameters namely Concentration Loss Coefficient (*CLC*) and Total Distraction Coefficient (*TDC*). Each acoustic environment consists of several sound sources which make them recognizable and each one of that sound sources has a different impact on the listener and effects the overall perception of the acoustic environment. Following that premises and logic which was confirmed in our previous work [12, 13] in the next step of this research we have decided to calculate Sound Character Index shown in Tab. 2. The calculation is performed by summing the index from Tab. 1 for all the sound sources that were recognize by listeners within a certain acoustic environment and dividing the sum with the number of sources to obtain a median value. To be more precise, the Sound Character Index is calculated in the following way:

$$SCI = \frac{Index_{n1} + \dots + Index_{nx}}{x} \quad (1)$$

where $Index_n$ represents the distinctive sound sources for a certain acoustic environment and x is the number of those sources. For example, acoustic environment children's park consists of the three distinctive sound sources: children screams (Index = 7), children crying (Index = 6) and speech (Index = 2). SCI for children's park according to expression (1) is then 5 which is shown in Tab. 2. Distinctive sound sources for an expressway are: sounds of a car and a car horn; for an industrial hall: sound of hammers, grinder and music; and for stream: dog barking, sound of stream, a truck passing by and children screams.

	Concentration Loss Coefficient (CLC)	Total Distraction Coefficient (TDC)	Sound Character Index (SCI)
EXPRESSWAY	0.062	0.276	4
CHILDREN'S PARK	0.143	0.343	5
INDUSTRIAL HALL	0.128	0.336	4.3
STREAM	0.069	0.184	4

Table 2. Sound Character Index

3. DEVELOPING THE MODEL

In order to incorporate the Sound Character Index in the Overall Soundscape Annoyance Rating, we have calculated three objective parameters for each acoustic environment: loudness, loudness growth rate and sharpness. Our previous research [12, 13] has shown that these three parameters primary contribute to listeners' annoyance rating. In this case scenario we decided to use a slightly different approach. To be more precise, instead of calculating overall total values of previously mentioned parameters, we have calculated their probability density function. Our previous research [12] resulted with a model for the Total Distraction Coefficient (TDC), which is based on how objective parameters change with comparison to their average values for the entire sound environment. It was found out that the most annoying sound environment included frequent changes of these three parameters i.e. the listeners perceived a certain environment more annoying if the environment significantly changed when compared to its "steady" part.

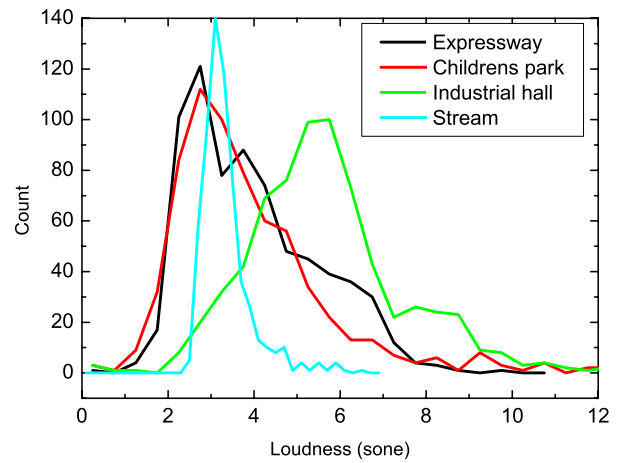


Figure 2. Probability density function of loudness; Gaussian distribution

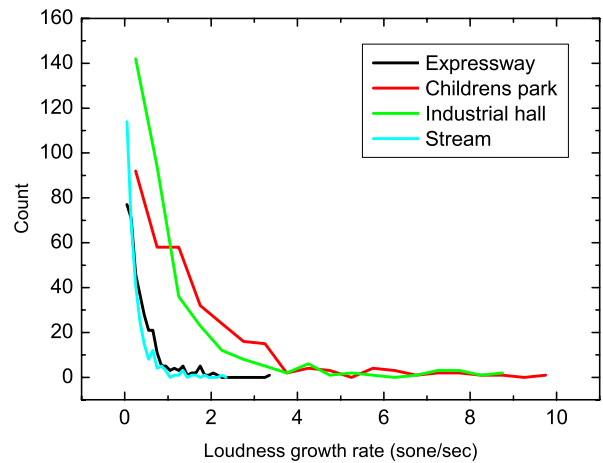


Figure 3. Probability density function of loudness growth; exponential distribution

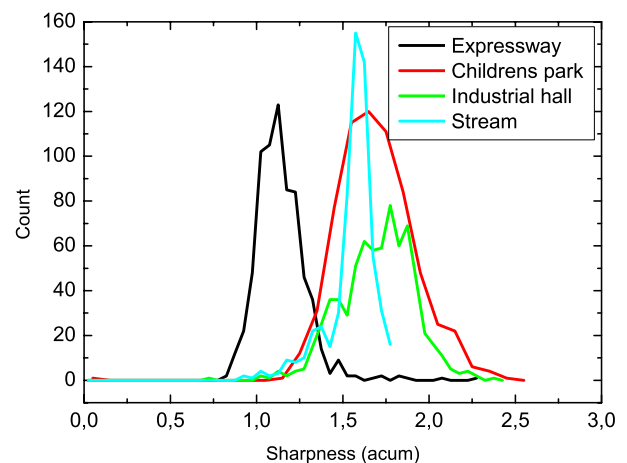


Figure 4. Probability density function of sharpness; Gaussian distribution

In order to better indicate how objective acoustic parameters in a certain sound environment change, we have decided to calculate their probability density functions (PDFs). As can be seen from Figs 2, 3 and 4, distribution of loudness (Fig. 2) and sharpness (Fig. 4) can be fitted with Gaussian distribution (Eq. (1)), while distribution for loudness growth rate (Fig. 3) can be fitted with an exponential distribution (Eq. (2)). There are two distinctive parameters for the Gaussian distribution, the mean and standard deviation. In case of the exponential distribution there are the mean or the expected value and standard deviation, which are basically the same parameter. Tab. 3 shows calculated distribution values of all three objective parameters for all analyzed acoustic environments.

$$f(x, \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}, \quad (1)$$

mean: μ , variance: σ^2

$$f(x, \lambda) = \lambda e^{-\lambda x}, \quad x \geq 0, \quad (2)$$

mean: $1/\lambda$, variance: $1/\lambda^2$

	Mean	Variance	Product-L
Expressway	3.4	6.8	23.1
Children's park	3.2	4.8	15.4
Industrial hall	5.3	6.8	36.0
Stream	3.2	0.36	1.2

Table 3a. Calculated distribution values for loudness (*L*)

	Mean	Variance	Product-LGR
Expressway	0.4	0.16	0.06
Children's park	1.5	2.25	3.4
Industrial hall	0.83	0.7	0.6
Stream	0.2	0.04	0.008

Table 3b. Calculated distribution values for loudness growth rate (*LGR*)

	Mean	Variance	Product-S
Expressway	1.1	0.06	0.07
Children's park	1.7	0.2	0.3
Industrial hall	1.7	0.16	0.3
Stream	1.6	0.01	0.2

Table 3c. Calculated distribution values for sharpness (*S*)

By logical reasoning, an acoustic environment which is less annoying will have low mean distribution values and low standard deviation. For example, in case of loudness, the stream sound environment has higher mean value than the children's park, however its standard deviation is much lower. This means that in case of the stream acoustic environment loudness does not change significantly. Therefore, it is safe to assume that an acoustic environment which is loud and its loudness is frequently changing is the most annoying. Following that

reasoning, the same could be concluded for the other two objective parameters. A product of these two distribution values could be a good indication how certain objective parameter contributes to acoustic environment's annoyance. Tab. 4 shows products for all three objective parameters and all previously mentioned acoustic environments.

Since Sound Character Index is a parameter derived from subjective evaluations, its incorporation in a final formula for the Overall Soundscape Annoyance Rating is not that trivial. First of all, the range of this index could not be compared to ranges of products from Tab. 4. On the other hand, to calculate a model for the overall rating, contribution of each parameter must be considered. In the first iteration of this rating we simply added the three products from Tables 3a to 3c to the subjective Sound Character Index for each acoustic environment. The final result is shown in Tab. 4.

	Product-L + Product-LGR + Product-S + <i>SCI</i>
Expressway	27.23
Children's park	24.1
Industrial hall	41.2
Stream	5.41

Table 4. Sum of distribution products with Sound Character Index (*SCI*)

4. CONCLUSIONS

In this research we suggest a new soundscape characterization parameter which we termed the Overall Soundscape Annoyance Rating (*OSAR*). The *OSAR* parameter depends on distribution of the following objective acoustic parameters: loudness, loudness growth rate and sharpness. These objective acoustic parameters were chosen according to our previous studies where we have proven their statistical significance in terms of listeners' distraction. The distraction was proven through extensive listening test of several typical acoustic environments. In order to obtain even better results we have introduced a new subjective parameter which we classified as Sound Character Index (*SCI*). This parameter was drawn from the results gained from a specially designed questionnaire in an independent survey. The focus of the survey was to rank sound sources which occur in several typical urban acoustic environments. Ranking was carried out in accordance to noticeability of sound sources with the study premises that more noticeable sound sources will cause a stronger feeling of annoyance and distraction.

Finally, loudness, loudness growth rate, sharpness and Sound Character Index are incorporated in the calculation of Overall Soundscape Annoyance Rating parameter.

We believe that this type of calculation can serve as an engineering guideline for design of acoustically pleasant urban environment within the concept of smart cities. Furthermore, by using this advanced rating system we should be able to improve the overall quality of life especially in urban acoustic environments which is the common goal of all researchers in the soundscape field.

ACKNOWLEDGEMENTS

This work has been supported by the European Union from European regional development fund (ERDF) under the project number under the project number KK.01.2.1.01.0103 4D Acoustical Camera (in Croatian: 4D Akustička kamera).

5. REFERENCES

- [1] R. M. Schafer; "Our Sonic Environment and the Soundscape: The Tuning of the World", (Destiny Books, Vermont, 1994).
- [2] B. Schulte-Fortkamp, A. Fiebig; "Soundscape Analysis in a Residential Area: An Evaluation of Noise and People's Mind", *Acta Acustica united with Acustica*, Vol. 92 (2006), p. 875-880
- [3] B. Berglund and M. E. Nilsson; "On a tool for measuring soundscape quality in urban residential areas", *Acta Acustica united with Acustica*, Vol. 92 (2006), p. 938-944
- [4] E. Zwicker; "Procedure for calculating loudness of temporally variable sounds", *J. Acoust. Soc. Am.* 62 (1977), p. 675-682.
- [5] E. Zwicker, H. Fastl; "Psychoacoustics: Facts and models", 2nd ed. Springer-Verlag, Berlin, Heidelberg, New York (1999), p. 220
- [6] U. Widmann; "A psychoacoustics annoyance concept for application in sound quality", *Proc. of NOISE-CON 97*, (1997), p 491-496
- [7] E. E. Ryherd, L. M. Wang; "The Effects of Noise from Building Mechanical Systems with Tonal Components on Human Performance and Perception", *ASHRAE Transactions*, 2010, AB-10-018 (RP-1322)
- [8] L. M. Wang; "Effects of Building Mechanical System Noise on Worker Performance and Perception", *Proc. of NOISE-CON 2010*, (2010)
- [9] H. Fastl, S. Kerber, N. Guzsvány; "Aspects of startling noises", *Proc. of Euronoise 2009*, Edinburgh (2009)
- [10] J. Vos; "The Loudness of Impulse and Road-Traffic Sounds in the Presence of Masking Background Noise", *Acustica – Acta Acustica*, Vol 84 (1998), p. 1119-1130
- [11] F. Aletta, T. Oberman, J. Kang; "Associations between Positive Health-Related Effects and Soundscapes Perceptual Constructs: A Systematic Review", *International Journal of Environmental Research and Public Health*; 2018; p. 1-15.
- [12] M. Suhanek, I. Djurek, S. Grubeša, A. Petošić; "Urban Acoustic Environments – An Acoustic Model for Total Distraction Coefficient", *Acta Acustica United with Acustica*; 2019; p. 334-342.
- [13] M. Suhanek, "Evaluation of Soundscapes regarding Sudden and Unexpected Sound Changes", PhD. Thesis, University of Zagreb, Faculty of Electrical Engineering and Computing, 2013.
- [14] G. Milas, "Research Methods in Psychology and other Social Sciences", [in Croatian], Zagreb: Naklada Slap, 2009, 91–118; 153–216. E. Author: "The Title of the Conference Paper," *Proceedings of the International Symposium on Music Information Retrieval*, pp. 000–111, 2000.