

COVER PAGE

Document downloaded by @DAEL

Fri Nov 27 23:54:22 2026
For personal use

When automatic English translation is provided, only the original document is authentic.
The EAA cannot be held responsible of any translation error

Bibliographical reference

Urban Acoustic Environments – An Acoustic Model for Total Distraction Coefficient, Mia Suhanek, Ivan Djurek, Sanja Grubeša and Antonio Petošić, Acta Acustica **vol. 105** (Number 2), 2019, pp. 334-342

DOI
https://doi.org/10.3813/AAA.919316

Acta Acustica united with Acustica
Vol. 105 (2019) 334 – 342

DOI 10.3813/AAA.919316

Urban Acoustic Environments – An Acoustic Model for Total Distraction Coefficient

Mia Suhanek, Ivan Djurek, Sanja Grubeša, Antonio Petošić
University of Zagreb, Faculty of EE and Computing, Unska 3, Zagreb, Croatia. mia.suhanek@fer.hr

Summary
In this paper we propose an acoustical model which quantifies how much a certain acoustic environment affects human concentration and daily activities. For developing the model an analysis has been made of four different urban acoustic environments both in objective (loudness, loudness growth rate and sharpness) and subjective (measuring the time-variations of human volunteers' distraction) parameters which are then combined into a numerical parameter (*Total Distraction Coefficient*) using linear regression. Finally, a model has been tested on the fifth recorded and unanalyzed acoustic environment and proven its application. This model can be applied to other recorded acoustic environments in terms of evaluating them, preserving them and also in designing new and more pleasant soundscapes for residents. Soundscape design is envisaged to be important aspect of future city planning. The proposed model may thus be a valuable guideline in soundscape design.

PACS no. 43.50.Qp, 43.50.Rq, 43.66.Ba, 43.66.Cb, 43.66.Ed

1. Introduction

One of the burning problems of contemporary urban life is the noise pollution, i.e. exposure of people to undesired sources arising from e.g. traffic, industry, children etc. In general, artificial noises are perceived as more annoying than natural sounds [1, 2]; however, if natural sounds are loud enough or are uncommon for a particular environment, they also may be considered annoying [3]. Another important aspect of soundscape studies also include sound detection, recognition and classification due to the fact that certain sound sources contribute to the overall soundscape pleasantness [4, 5].

An extensive overview of recent progresses in the area of urban soundscape studies and relevant indicators for the acoustic field is given in [6, 7, 8]. Field investigation has identified a number of primary factors in the subjective description of urban soundscapes [9, 10, 11]. In general, loudness-related indicators are an important component, however a feature related to the spectral structure and the temporal structure also often emerge [12]. For soundscape analyses sound quality measurements have been suggested [13, 14] due to the reason that they can capture loudness, spectral content and short time fluctuations in a way that is more closely related to the listeners' subjective preferences. For instance, in [15] several tests have been conducted during which listeners did not describe the overall noise as annoying, but rather did so with certain types of sound, which had different characteristics from the so called average sound print. This means that sounds which do not belong to a certain soundscape or context exhibit a large influence on its perception [15, 16], i.e. that people can adapt to some noise environment. In tests performed in [17] the subjects were required to listen to synthetic noises with sudden increases in loudness, with various rise times and loudness differences. It was found that for sounds with level difference higher than 10 dB and loudness difference higher than 3 sone compared to a reference level are perceived as more annoying regardless of the sound type. Of course, the annoyance level increases with higher level and loudness differences. It was also found [17] that the annoyance level depends on the sounds' rise time. In general, if the level increase is higher and shorter, the sound will be perceived as more annoying.

Although various aspects of human perception of urban soundscapes have thus been researched, it can still be noted that most of the researchers rely on subjective descriptors (attribute pairs, semantic differential etc.) while evaluating the pleasantness of a certain soundscape [18, 19]. Thus, there is a need for developing relevant objective figures of merit by which various soundscapes and their perception can be compared and understood in numerical terms. In this paper we propose a simple acoustical model by which the perceived distraction level (i.e. the soundscape "pleasantness") can be calculated taking into account the loudness, sharpness and loudness changes in some particular level. The model is based on our previous research [20, 21] where we have established a set of five statistically significant set of bipolar adjectives in terms of which the human perception of different soundscapes can be described. Within this model we calculate the objective value which we term *Total Distraction Coefficient* (TDC).

Received 16 July 2018,
accepted 26 December 2018.

© S. Hirzel Verlag · EAA



Figure 1. The considered locations: Upper left: Children's park; Upper right: Expressway; Lower left: Industrial hall; Lower right: Stream.

This parameter can contribute to standardization of soundscape research and serve as a guideline in design of pleasant and calming urban soundscapes for everyone, which is one of the goals in the modern concept of so-called smart cities [22, 23].

2. Subjective perception of different acoustic environments

Using the soundwalk method [24] we have recorded four characteristic (but entirely different) urban acoustic environments. The four acoustic environment samples were chosen due to their relatively different characteristics. An average person living in an urban setting is familiar with three of them: the children's park, the expressway and the stream. Due to the fact that most of the study participants are younger people (e.g. students) residing in urban areas, and the industrial hall is situated on the outskirts of the city (with practically no residential areas near it), it is safe to make an assumption that participants are not familiar with this specific acoustic environment. Comparing the generally familiar acoustic environment samples with an unfamiliar one (industrial hall) enabled us to analyze whether a familiar acoustic environment would be perceived as less annoying. The considered locations are shown in Figure 1.

Table I. The causes of variable portion in acoustic environments.

Acoustic environment	Cause of variable portion
The children's park	People talking; children crying and screaming
The expressway	Truck passing by; traffic audio signal
The stream	Dog barking; vehicles passing by
The industrial hall	Power tools (grinders, hammers…)

The recorded time diagrams of the considered acoustic environments (Figure 2) are characterized by *steady* and *variable* portion, which are both easily discernible. The causes of variable parts in the acoustic environments (which are clearly heard in recordings) are summarized in Table I and marked in Figure 2. The chosen time frame of 400 seconds can be regarded as representative enough for analytical purposes. For all the acoustic environments the average reproduced sound pressure level in the steady part of the recordings is relatively low and amounts 50 dB(A), which, calculated using Zwicker's method [25, 26] corresponds to loudness of about 4 sones. The Zwicker's

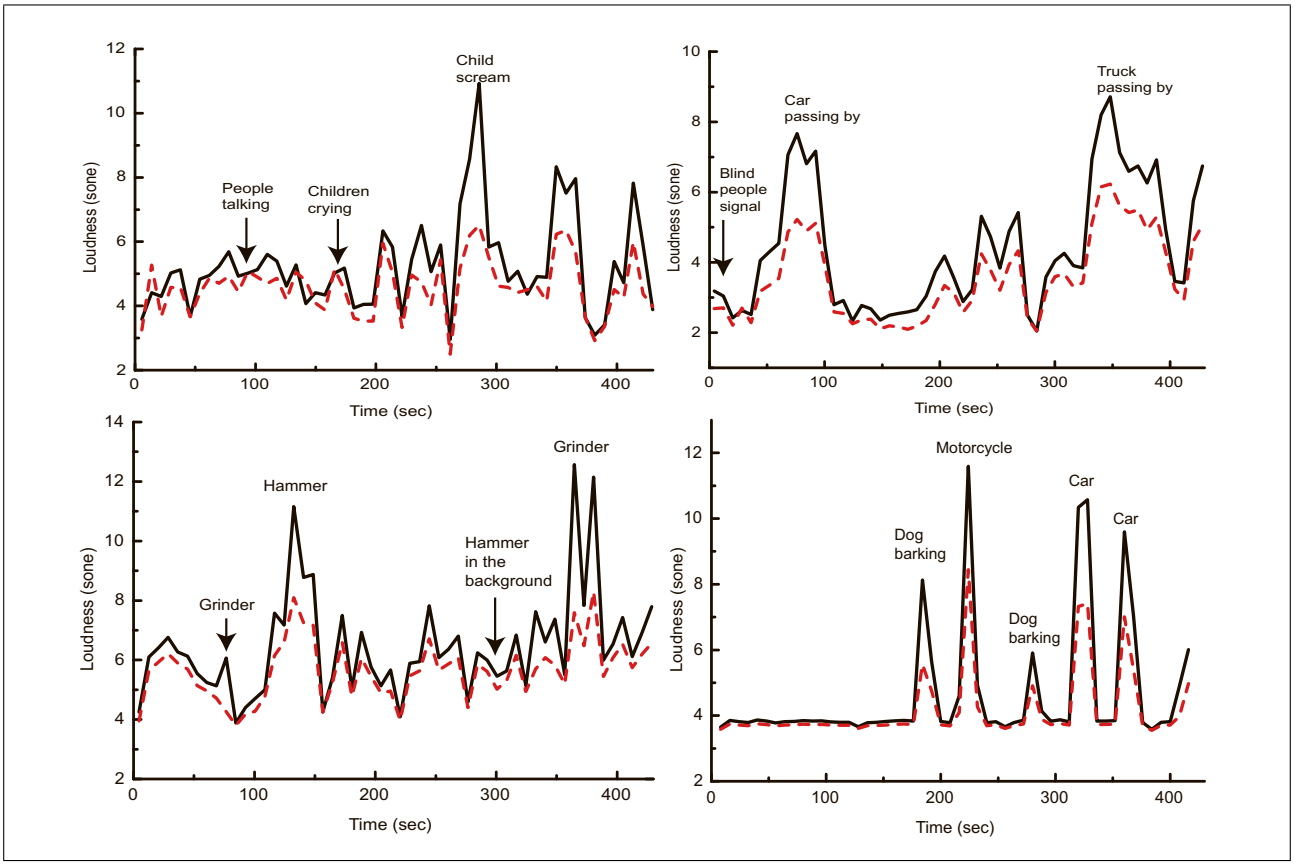


Figure 2. The recorded time diagrams of loudness for the considered acoustic environments for experimental (solid) and control (dotted) group. Upper left: Children's park; Upper right: Expressway; Lower left: Industrial hall; Lower right: Stream.

method represents a basis for few other methods in terms of loudness calculation for time varying sounds. Moore and Glasberg [27, 28] published a revision of Zwicker's loudness model. The revised model has the advantage that excitation patterns are calculated from analytical equations rather than from tables. One disadvantage of this revision was the fact that this model was not applicable to time-varying sounds. Another developed model from the same authors, described in [29] gave better results for time-varying signals. Chalupper and Fast also presented a dynamic loudness model [30] which predicts loudness of stationary and time-varying sounds. Implementation of this model showed that the proposed dynamic loudness model accounts for various numerous aspects of loudness perception. In this paper we have used Zwicker's method because we have already successfully implemented it in our previous research [20, 21] and furthermore, our study covered with this paper, includes primarily relative comparison of calculations. Therefore, in our opinion a different choice of the loudness calculation method would not provide significantly different results.

Using dynamic post-processing, where the recorded samples were passed through a compressor to lower the maximum values of loudness to 7 sones (but with the same average loudness) we have created four more samples with smaller variations in loudness. That way obtained two sets of samples (i.e. without and with post-processing), enable us to further study the influence of sudden and unexpected changes in loudness onto human activities. Thus, we have reproduced the recorded unprocessed and post-processed acoustic environment sets samples to the experimental and control group, respectively. The idea was to require the listeners to play a simple interactive computer game we have designed in MATLAB, while at the same time listening to a certain set of acoustic environments.

2.1. The research setup

The experimental group has thus listened to the unprocessed acoustic environments with frequent sudden and short loudness changes (up to 12 sones), while the control group has listened to the same acoustic environment with the same time-average loudness, however with maximum loudness of 7 sones. Each of the two groups has comprised 50 people that were randomly chosen among students. The median group age is 24 and the female-to-male ratio is equal to both groups, respectively. The recordings have been reproduced using AKG K55 closed electrodynamic headphones with an average sound pressure level of 50 dB(A) in the steady part of the recorded acoustic environment. Each sample was further prepared to last around 7 minutes and to be without sudden loudness changes in the first 2 minutes. According to our previous experience [19, 20, 21], such sample duration and time shape is suitable both for adapting to a new sound environment and to

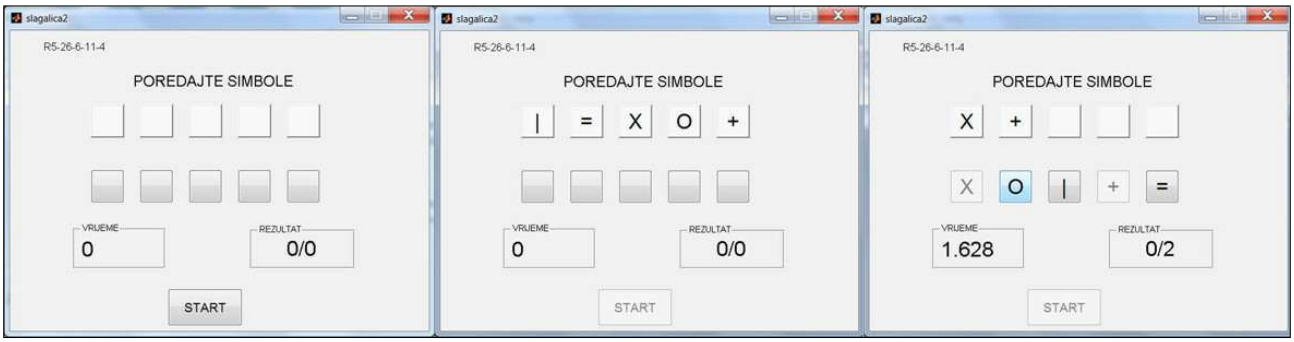


Figure 3. The snapshots of the designed game GUI in Croatian.

Table II. Game results for the experimental and control groups.

	Children's park		Expressway		Industrial hall		Stream	
Group	EG	CG	EG	CG	EG	CG	EG	CG
Average score	0.86	0.92	0.93	0.96	0.88	0.92	0.94	0.96
Stand. deviation	0.091	0.071	0.058	0.041	0.074	0.056	0.055	0.043
The lowest score	0.47	0.56	0.67	0.79	0.58	0.7	10.83	0.84
N5 (sone) (7 min)	8.1	6.1	8	6.5	10.5	8.1	9.5	6

avoid fatigue. Each listener listened to one by one acoustic environment sample with a time gap of at least one week by which we have provided time to recover and eliminate any potential mutual influence of the recordings [31, 32]. The order of the listening of the recordings was fixed for all listeners, which is in line with [31, 32] and is as follows: the children's park, the expressway, the industrial hall and the stream soundscape. The participants were informed that they would be listening to a recording while at the same time playing a simplified version of ĂňMemory CardsĂő game on the computer. They were also told that the whole study will take about a month and that they will undergo in total four iterations of listening (for the control group) and five iterations (for the experimental group) with a time gap of one week between each listening to avoid fatigue. However, the listeners were not informed to the content of the recording which is in line with the established psychological research methodology [31]. As mentioned above, during listening the test subjects have played a computer game. The game GUI snapshots are shown in Figure 3. The game is basically a variation of a popular memory game which consists of five common symbols (i.e. X, O, I, +, =) which appear randomly during the game [21]. The symbols on the cards are revealed to a listener for four seconds in a random order and are closed. The goal of a listener was to line up the symbols on the cards according to the order in which they appeared. The listener had seven seconds for that task and a two second pause before the next layout of the symbols. If the listener makes a mistake while arranging the symbols on cards, a new order of cards begins automatically. The game generates orders of symbols for 7 minutes, as long as the recording of the soundscape lasts. During the game, the program recorded their success in arranging the symbols. In that way we could analyze how the results of the game depended on time, and pinpoint certain parts of a soundscape that could have caused the listeners' distraction. The results of the game are given by a number, which represents the success ratio of each move. For example, if a listener successfully arranged all the symbols in the given seven seconds, his/her results for this move was 1. If the listener successfully arranged only 3 of 5 symbols, the result was 3/5=0.6, and so on. Also, we calculated the average score for each soundscape overall and compared them. It is important to emphasize that the game itself is not intended to be too complicated as its principal purpose is to serve as a concentration level measure, or in other words as a measure of listeners' distraction, by mimicking the real continuous time. That way we may assess the listener's distraction level in real time and observe the effect of specific sound events in each soundscape.

2.2. The time-domain concentration levels

The averaged results of the game (which may thus be considered as time-varying concentration levels) are shown in Figure 4 in time domain, while the averaged results are shown in Table II. By taking a closer look it can be seen that all the diagrams exhibit a similar pattern – in the beginning the recorded average score take some time to stabilize, which can be ascribed to adaptation to the game environment. In addition, the average scores generally tend to slightly increase toward the end of the sample duration, for each considered soundscape. This is principally caused by the adaptation to the soundscape. Note that for times with smaller loudness change (see Figure 2 for comparison) and for the control group soundscapes where loudness changes were intentionally lower these effects are less pronounced. This is indicative of the importance of the occurrence of sudden and unexpected sounds. Therefore, in further analysis and calculations we will be taking the re-

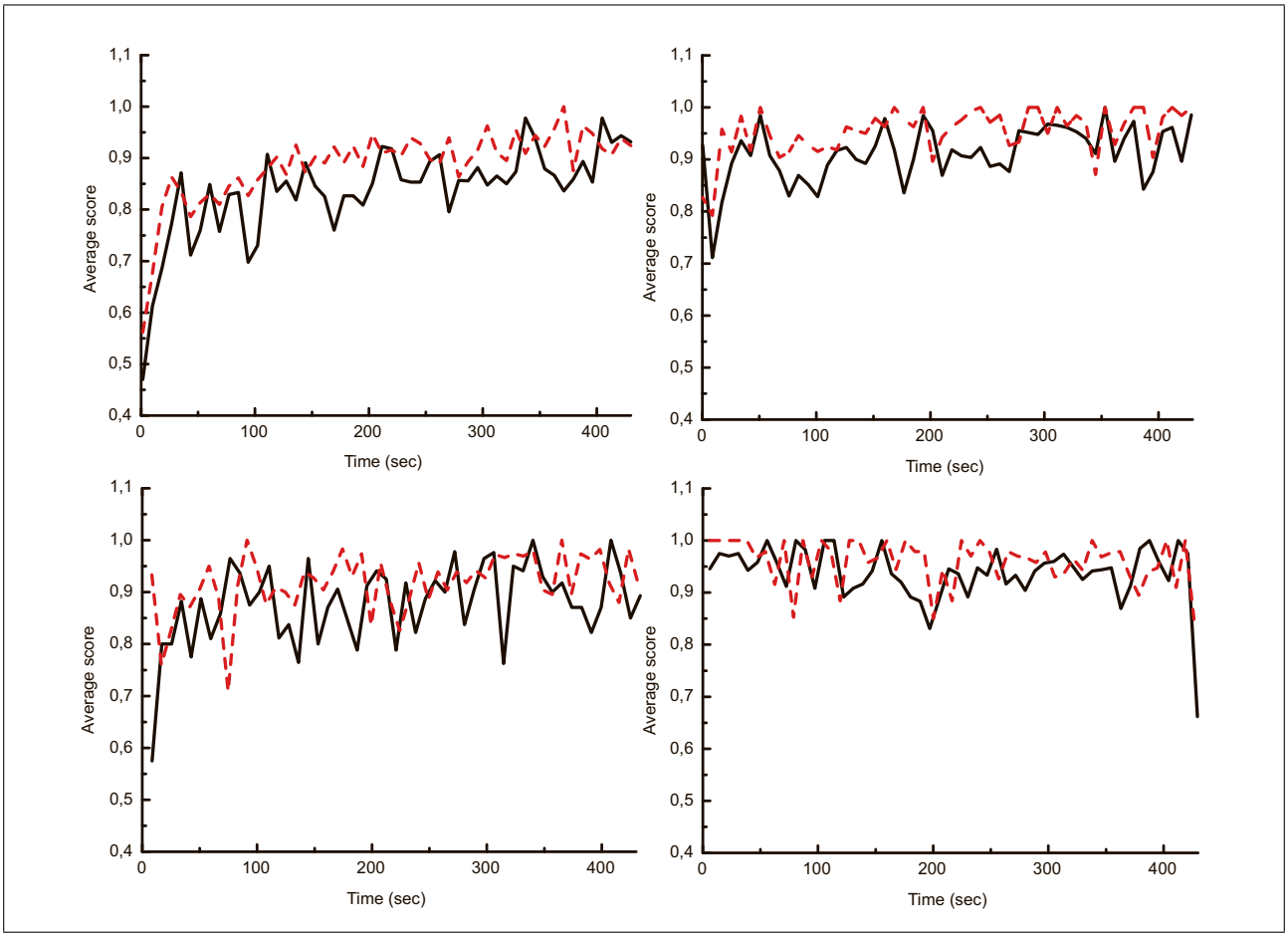


Figure 4. The time diagrams of the obtained score averages for experimental (solid) and control (dotted) group. Upper left: Children's park; Upper right: Expressway; Lower left: Industrial hall; Lower right: Stream.

Table III. Calculated mean values of pertinent objective parameters for the considered recordings for steady part of the signal.

	N_{mean} [sone]	LGR_{mean} [sone/sec]	S_{mean} [acum]
Children's park	3.88	1.5	1.69
Expressway	3.94	0.4	1.14
Industrial hall	5.82	1.1	1.7
Stream	3.34	0.25	1.55

Table IV. Objective difference parameters for developing the model for the considered acoustic environments.

	N_5 [sone]	LGR_5 [sone/sec]	S_5 [acum]
Children's park	5.73	5.85	0.45
Expressway	3.27	1.38	0.32
Industrial hall	7.02	6.6	0.37
Stream	1.88	1.03	0.16

sults of experimental group which had the tested stimulus e.g. sudden and unexpected changes in loudness.

3. The total distraction coefficient

In next stage we proceed with statistical analysis in order to find connection between subjective and objective acoustic parameters. We assume that the total distraction coefficient basically depends on difference values of the three objective parameters - loudness, loudness growth rate and sharpness (given in sones, sones per second and acums, respectively). We denote differential values respectively as ΔN_5, ΔLGR_5 and ΔS_5 and use the criterion for calculation of difference parameter by finding the difference value taking into account the value that is not exceeded for more than 95% of the time [24]. All the objective parameters are calculated by the analysis of the recorded soundscapes (Figure 2) using MATLAB, while the results are summarized in Tables III and IV. The choice of objective variables affecting the distraction level is justified by our research in [19, 20, 21] where we have shown that they are relevant for assessing the soundscape itself in terms of listener's distraction.

The mentioned differential values are calculated as follows. At first, we calculated mean values of loudness, loudness growth rate and sharpness for the stationary part of each recorded acoustic environment. The stationary part of each recorded signal is a part where loudness changes

Table V. Calculated deviation factors (objective measures) and concentration loss coefficient (subjective measure) for the considered soundscapes.

	L_{DIF}	LGR_{DIF}	S_{DIF}	CLC
Children's park	1.4768	3.9	0.26627	0.143
Expressway	0.82995	3.45	0.2807	0.062
Industrial hall	1.20619	6	0.21765	0.128
Stream	0.56287	4.12	0.10323	0.069

are relatively small. For example, the stream acoustic environment mainly consists of the water sound, which is constant throughout the entire signal. These steady part parameters are marked as N_{mean}, LGR_{mean} and S_{mean}, and calculated values are given in Table III. After that, we calculated the same mean parameters in one second intervals, for the duration of entire recorded signals. Our previous research [21] included a test in which study participants listened startling signals incorporated in a mainly steady signal. They had the option to change loudness, duration and growth rate of the startling sounds in order to adjust the sound using these parameters to the moment and level when the sound becomes a distraction to the listener. It was found that the average duration of these startling sounds, chosen by the subjects, was around 1 second. With this data we could calculate the difference between the one-second average values and the respective average values calculated from the steady part of the signals. We denoted these differential values respectively as ΔN, ΔLGR and ΔS. These one second differences served as a basis for calculating probability density functions (PDFs) for each parameter ΔN, ΔLGR and ΔS, for the entire recorded signals. From these PDFs we calculated differences that are not exceeded for more than 95% of time. These values are denoted as ΔN_5, ΔLGR_5 and ΔS_5. The calculated values for all acoustic environments are given in Table IV.

Furthermore, for modelling purposes we express the objective parameters in terms of the deviation factors, denoted respectively as L_{DIF}, LGR_{DIF} and S_{DIF}. These values are defined as a ratio of difference values (Table IV) and the mean value of the three considered objective parameters themselves (loudness, loudness growth difference, sharpness) given in Table III. For example, in case of the loudness difference, the ratio is calculated as $L_{DIF} = \Delta N_5 / N_{mean}$. Table V shows deviation factors for all objective parameters L_{DIF}, LGR_{DIF} and S_{DIF}.

As a subjective measure of the soundscape we express the average distraction levels for each soundscape (Table II) in terms *Concentration Loss Coefficient* (CLC) which is arguably more intuitive to comprehend than the game scores themselves. It is defined as

$$\mathrm{CLC} = 1 - AVG_{score}, \tag{1}$$

where AVG_{score} is the listener's average score obtained while solving the task. The calculated CLCs for the considered soundscapes are given in Table V.

Now we apply linear regression to find the dependence of Concentration Loss Coefficients on the objective acoustic parameters given above. We obtain the linear dependence of the Concentration Loss Coefficients of the task execution with each acoustic parameter (as given in Figures 5–7) and by analyzing the slopes of each respective line we finally obtain a mathematical expression for the numerical parameter which we term "Total Distraction Co-

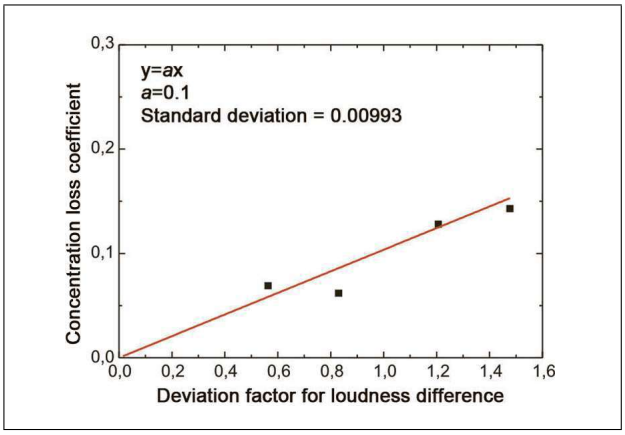


Figure 5. Dependence of the distraction index and the loudness difference with the calculated linear model.

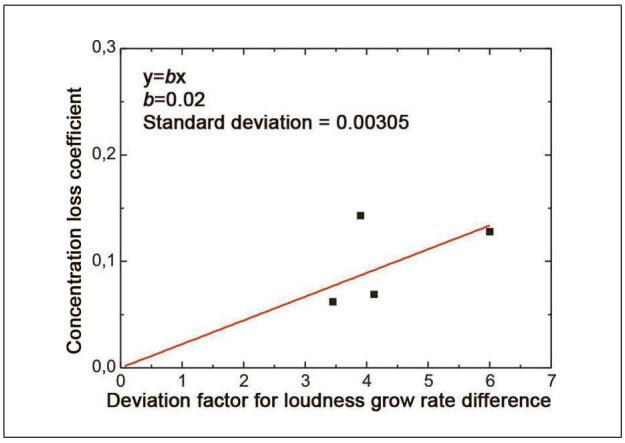


Figure 6. Dependence of the distraction index and the loudness growth rate difference with the calculated linear model.

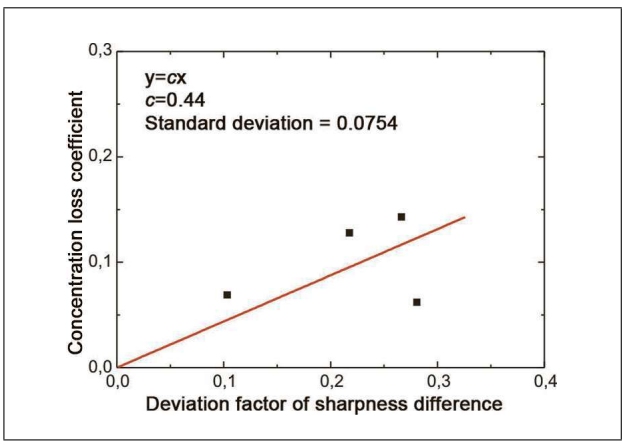


Figure 7. Dependence of the distraction index and the sharpness difference with the calculated linear model.

efficient" (TDC):

$$\mathrm{TDC} = 0.1 L_{\mathrm{DIF}} + 0.02 LGR_{\mathrm{DIF}} + 0.44 S_{\mathrm{DIF}}. \qquad (2)$$

This numerical value becomes then the characteristic value of the soundscape and can serve as an objective parameter or a measure for evaluation of soundscapes. Note that linear regression and linear model have been selected since after calculating linear and nonlinear models it was found that nonlinear models do not give significantly better dependence on the results of the three acoustic parameters mentioned above. This claim is corroborated by the fact that the standard error was significantly higher in nonlinear models. Thus, linear model can be considered as adequate enough for determination of the distraction coefficient.

The calculated TDCs for the four considered acoustic environments are given in Table VI. It can be seen that the largest distraction occurs in children's park soundscape while the stream exhibits the least distraction. It may seem odd, that the children's park has the largest distraction coefficient, however this can be easily explained by larger content of higher frequencies, e.g. children screams, which contribute to higher sharpness level. On the other hand, the expressway soundscape has a lower distraction coefficient, due to rather steady loudness level and higher content of lower frequencies. When exposed to a rather constant sound source in other words, without sudden changes e.g. the traffic noise in an expressway soundscape after a while the human ear adapts to that sound and as a result the sound source becomes less noticeable. On the other hand, the human ear cannot be totally prepared for unexpected sudden loudness changes and therefore is not able to adapt instantly.

These findings may serve as a guideline in urban planning and reducing noise pollution e.g. in residential areas.

4. An application example - shopping mall

In order to apply the model obtained by analysis of four acoustic environments (children's park, expressway, industrial hall and stream), a final test was done on the fifth recorded acoustic environment; a large shopping mall (Figure 8). Since this soundscape serves only for testing the developed acoustic model, only 50 listeners as an experimental group participated in the study. The average game score (Figure 3) for this case is 0.89, which leads to the concentration loss coefficient (CLC) of 0.11. On the other hand, by using the expression (2) we have calculated the total distraction coefficient from the objective acoustic parameters obtained through analysis of soundscape recording (they are summarized in Table VII) which amounts TDC = 0.28.

If we compare the calculated TDC and concentration loss coefficient for shopping mall with the TDCs and concentration loss coefficients of the experimental group of each soundscape (Tables V and VI), it is apparent that the order of soundscapes is equal. In other words, the biggest total distraction coefficient corresponds to the smallest



Figure 8. Shopping mall.

Table VI. Calculated tdc for the four considered soundscapes.

Soundscape type	Total distraction coefficient (TDC)
Children's park	0.343
Expressway	0.276
Industrial hall	0.336
Stream	0.184

Table VII. Objective acoustic parameters for shopping mall acoustic environment.

	Loudness [sone]	L. growth rate [sone/sec]	Sharpness [acum]
Mean value	3.55	0.53	1.16
Differential value	2.5	2.75	0.28
Scaled value (deviation factor)	0.70	5.19	0.24
Total distraction coefficient (TDC): 0.28			

achieved average score, which is in accordance with our model. It can be concluded that the new objective acoustic parameters for the model are suitably selected and that the model for determining the total distraction coefficient can serve as a valuable tool in evaluating and assessing different acoustic environments (of course, the model can be refined in future if needed by using larger amount of data and following the same methodology).

5. Conclusion

In this paper we have proposed a simple acoustical model which allows one to quantify how much some kind of typical urban acoustic environment is subjectively perceived in terms of affecting the concentration. The model is based on analysis of four typical urban acoustic environments both in objective (loudness, loudness growth rate and sharpness) and subjective (time-variations of concen-

tration on human volunteers) parameters which are subsequently combined using linear regression into numerical parameter termed "total distraction level". The proposed model is intended to be used as a simple guideline in evaluating the listener's perception of different urban acoustic environments within the broader concept of smart cities (which includes an acoustic viewpoint as well).

We note that some bias in the particular model may be present since the whole research was performed in laboratory conditions, however we believe that the model has its relevance for perception in everyday life, which has to be confirmed by further research. In addition, the proposed model can be readily refined or adapted for specific purposes by considering more factors such as spectral content, appearance of artificial sound sources etc., that might have an effect on the soundscape pleasantness alongside the concentration level we primarily used for analysis in our research. Note that in model refinement one may also consider the psychological state of each participant (mood, fatigue level, familiarity with the acoustic environment etc.).

Nevertheless, it can be concluded that the approach used in the core of the proposed model can be a valuable tool in assessing the acoustic quality of the existing urban environments but also in preservation and synthesis of urban environments perceived as pleasant. By subjectively categorizing different urban acoustic environments and masking the undesired sound sources (and simultaneously emphasizing the pleasant ones) the quality of modern urban life can be generally improved, so the proposed model can be useful for that goal.

References

[1] W. Yang and J. Kang: Soundscape and Sound Preferences in Urban Squares: A Case Study in Sheffield. Journal of Urban Design (2005) 61–80.

[2] M. Yang, J. Kang: Psychoacoustical Evaluation of Natural and Urban Sounds in Soundscapes. Journal of the Acoustical Society of America (2013) 840–851.

[3] M. Suhanek, I. Đurek: Implementation of Bipolar Adjective Pairs in Analysis of Urban Acoustic Environments. Promet-Traffic & Transportation (2016) 461–470.

[4] S. Chu, S. Narayanan, C. C. Jay Kuo: Environmental Sound Recognition with Time-Frequency Audio Features. IEEE Transactions on Audio, Speech, and Language Processing (2009) 1142–1158.

[5] N. Wachowski, M. R. Azimi-Sadjadi: Detection and Classification of Nonstationary Transient Signals Using Sparse Approximations and Bayesian Networks. IEEE Transactions on Audio, Speech, and Language Processing (2014) 1750–1764.

[6] F. Aletta, J. Kang, O. Axelsson: Soundscape descriptors and a conceptual framework for developing predictive soundscape models. Landscape and Urban Planning (2016) 65–74.

[7] L. Brown: A Review of Progress in Soundscapes and an Approach to Soundscape Planning. International Journal of Acoustics and Vibrations (2012) 73–81.

[8] A. Soloaga, K. Herranz-Pascual, GarcÃŇa-Borreguero Karmele, Igone Garcia: Validation of an indicator for the assessment of the environmental sound in urban places. Proceedings of Euronoise 2012, 2012.

[9] J. Kang, M. Zhang: Semantic Differential Analysis on the Soundscape of Urban Open Public Areas. Proceedings of the First Pan-American/Iberian Meeting on Acoustics, Cancun, Mexico, 2002.

[10] B. Berglund, M. Nilsson: An Attempt to Capture the Perceived Soundscape. Proceedings of the International Symposium on Noise Pollution and Health (NOPHER), Cambridge, UK, 2001.

[11] S. Viollon, C. Lavandier: Multidimensional Assessment of the Acoustic Quality of Urban Environments. Proceedings of Internoise (CDROM), Nice, France, 2000.

[12] B. Berglund, P. HassmÃĹn, A. Preis: Annoyance and Spectral Contrast are Cues for Similarity and Preference of Sounds. Journal of Sound and Vibration (2002) 53–64.

[13] K. Genuit: The Use of Psychoacoustic Parameters Combined with A-weighted SPL in Noise Description. Proceedings of Internoise, Fort Lauderdale, Florida, USA, 1999, 1887–1892.

[14] K. Genuit: Soundscape Design - Acoustical Challenge. Proceedings of Forum Acusticum, Sevilla, Spain, 2002.

[15] B. Schulte-Fortkamp, A. Fiebig: Soundscape Analysis in a Residential Area: An Evaluation of Noise and People's Mind. Acta Acustica united with Acustica (2006) 875–880.

[16] G. Brambilla, L. Maffei: Responses to Noise in Urban Parks and in Rural Quiet Areas. Acta Acustica united with Acustica (2006) 881–886.

[17] H. Fastl, S. Kerber, N. GuzsvÂůny: Aspects of startling noises. Proceedings of Euronoise 2009, Edinburgh, 2009.

[18] A. Torija, D. Ruiz, A. F. Ramos-Ridao: Application of a Methodology for Categorizing and Differentiating Urban Soundscapes Using Acoustical Descriptors and Semantic-Differential Attributes. Journal of the Acoustical Society of America (2012) 791–802.

[19] M. Suhanek, I. Đurek, K. Jambrošić: The Soundscape of Urban Public Places in Zagreb. Proceedings of 1st EAA - EuroRegio, 2010, 1–5.

[20] M. Suhanek, I. Đurek: Implementation of Bipolar Adjective Pairs in Analysis of Urban Acoustic Environments. Promet-Traffic & Transportation (2016) 461–470.

[21] M. Suhanek: Evaluation of Soundscapes Regarding Sudden and Unexpected Sound Changes. Ph.D. dissertation, Faculty of EE and Computing, Univ. of Zagreb, Zagreb, Croatia, 2013.

[22] A. Southern, F. Stevens, D. Murphy: Sounding out Smart cities: Auralization and Soundscape Monitoring for Environmental Sound Design. Journal of the Acoustical Society of America (2017) 3880.

[23] J. P. Bello, C. Mydlarz,, J. Salamon: Sound Analysis in Smart Cities. Computational Analysis of Sound Scenes and Events (2018) 373–397.

[24] C. Semidor: Listening to a City with the Soundwalk Method. Acta Acustica united with Acustica (2006) 959–964.

[25] E. Zwicker: Procedure for calculating loudness of temporally variable sounds. Journal of the Acoustical Society of America (1977) 675–682.

[26] E. Zwicker, H. Fastl: Psychoacoustics: Facts and models. 2nd edition. Springer-Verlag, Berlin, Heidelberg, New York, 1999, 220.

[27] B. C. J. Moore, B. R. Glasberg: A Revision of Zwicker's Loudness Model. Acta Acustica united with Acustica (1996) 335–345.

[28] B. C. J. Moore, B. R. Glasberg, T. Baer: A Model for the Prediction of Thresholds, Loudness and Partial Loudness. Journal of the Audio Engineering Society **45** (1997) 224–240.

[29] B. R. Glasberg, B. C. J. Moore: A Model of Loudness Applicable to Time-Varying Sounds. Journal of the Audio Engineering Society **50** (2002) 331–342.

[30] J. Chalupper, H. Fastl: Dynamic loudness model (DLM) for normal and hearing-impaired listeners. Acta Acustica united with Acustica **88** (2002) 378–386.

[31] G. Milas: Research Methods in Psychology and other Social Sciences [in Croatian]. Naklada Slap, Zagreb, 2009, 91–118; 153–216.

[32] M. MejovÃűek: Methods of Scientific Research in Social Sciences and Humanities [in Croatian]. Naklada Slap, Zagreb, 2007, 71–158.