Descriptors and indicators for soundscape design: vibrancy as an example

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ABSTRACT

In order to implement the soundscape approach into the urban environment management and design practice, there is a current need to develop operative tools; namely, soundscape descriptors and indicators. So far, a number of descriptors have been proposed in literature and many of them focused on describing calmness and tranquillity constructs. However, there might be other dimensions of soundscape appreciation, like vibrancy, that could be more relevant for different urban contexts. The first part of this paper reviews systematically descriptors and indicators for soundscape design, and the second part of the paper focuses on vibrancy, where starting from a group interview with researchers and practitioners, it explored what elements are likely to contribute to vibrancy perception in the urban realm. It emerged that both aural and visual cues are important to make an environment vibrant. From the aural point of view, vibrancy implies human sound sources, time variability and loudness; whilst the presence of people, colourfulness and the activities of the place are visually important factors for soundscape vibrancy perception. The paper finally discusses how to develop a predictive model for soundscape vibrancy, according to a set of aural and visual indicators related to the above mentioned factors.

Keywords: Soundscape, Descriptor, Indicator, Vibrancy I-INCE Classification of Subjects Number(s): 56.3; 63.7

1. INTRODUCTION

Soundscape research is going through a standardization process of its definitions and methods for both data collection and analysis (1-3). There is an urgent need to go beyond mere noise control engineering approaches in environmental management policies, and due to its perceptual and user-centred focus, soundscape seems to be a viable methodology. Subsequently, researchers are increasingly investigating the potential of operative tools to implement the soundscape approach into a broader concept of 'urban sound planning' (4-6). These include soundscape descriptors and indicators, the lack of which has already been acknowledged as an important gap to fill (7, 8). In order to be relevant for design purposes, such tools need to be able to 'anticipate' what soundscapes one could achieve by modifying the built and natural environment, so research should make bigger efforts to work on predictive models for soundscape (9).

Within the framework of this research, we refer to descriptors and indicators as defined in (10): descriptors are "measures of how people perceive the acoustic environment", whereas indicators are "measures used to predict the value of a soundscape descriptor".

This paper has two aims. Firstly, it offers a summary of the main soundscape descriptors retrieved from the literature, and their corresponding indicators. Secondly, it proposes and discusses a set of potential indicators for a soundscape descriptor, namely 'vibrancy', which has received limited attention so far, despite of its likely potential for design purposes in urban contexts.

2. REVIEW OF SOUNDSCAPE DESCRIPTORS AND INDICATORS

Over the years, a number of descriptors have been proposed for soundscape studies. Assuming that descriptors are needed for design purposes, we will chiefly consider those for which associations with physical metrics (i.e. indicators) have been sought in the form of predictive models or statistical

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correlations. A literature review (10) revealed that there are eight main descriptors to choose from, meeting the above mentioned criterion. These are: (*1*) Noise annoyance, (*2*) Pleasantness, (*3*) Quietness or tranquillity, (*4*) Music-likeness, (*5*) Perceived affective quality, (*6*) Restorativeness, (*7*) Soundscape quality, and (*8*) Appropriateness. Table 1 summarises the main descriptors and their corresponding indicators (where applicable).

It can be observed that descriptors either referred to single perceptual dimensions (e.g. 'calmness'), or to soundscape holistically (e.g. 'soundscape quality'). Many descriptors tended to focus on quietness constructs, possibly due to the attention that this concept received in the Environmental Noise Directive (11).

Interestingly, other attributes that one could reasonably expect to be relevant in urban contexts, like vibrancy, eventfulness or excitement, have received scarce research attention, from the modelling and/or prediction perspective. Therefore, in the following sections, a proposal to establish a predictive model for soundscape vibrancy will be presented.

Table 1 – Main soundscape descriptors and indicators as reviewed in (10)

Descriptor Category	Descriptor(s)'s name	Indicator(s)	Reference
Noise annoyance	Unbiased Annoyance	Loudness, sharpness and fluctuation strength	(12)
	Noise annoyance	Loudness intrusiveness, sharpness and distortion of informational content	(13)
	Evaluation index	Loudness, sharpness, roughness, impulsiveness and relative approach	(14)
Pleasantness	Pleasantness of noise	Loudness, sharpness, roughness and tonality	(15)
	Unpleasantness of sound	Sound levels and the relative duration of categories of sound sources	(16)
Quietness or tranquillity	Perceived Quietness	Slope	(17)
	Tranquillity	Sound levels and the percentage of natural features in a scene	(18)
Perceived music-likeness	Perceived music-likeness	Music-likeness (fuzzy)	(19)
Perceived affective quality	Pleasant, Unpleasant, Evenful, Uneventful, Calm, Monotonous, Exciting, Chaotic	Ongoing or not investigated	(20)
	Calm, Vibrant	Ongoing or not investigated	(21)
	Cacophony, Hubbub and Constant, Temporal	Ongoing or not investigated	(22)
	Restorativeness	Ongoing or not investigated	(23)
Soundscape quality	Environmental Sound Experience Indicator	Unrevealed	(24)
	Sound Quality	L50 and L10–L90	(25)
	Appropriateness	Ongoing or not investigated	(26)

3. TOWARDS A SOUNDSCAPE VIBRANCY PREDICTIVE MODEL

A number of studies considered vibrancy, sometimes referred as ‘excitement’, in soundscape research (21, 22). This concept is overall understood as a perceptual construct resulting from pleasant and eventful acoustic environments (20). However, to the knowledge of the authors, no attempt has been made to define models for vibrancy prediction so far.

For this purpose, a focus group was organised in order to gain deeper insights on what elements of the built environment could be relevant for soundscape vibrancy perception. Afterwards, a laboratory experiment was performed to gather individual responses on vibrancy and the structure of such data was explored through cluster analysis to investigate what physical metrics (i.e. indicators) might be useful for predicting vibrancy.

3.1 Focus group on ‘vibrancy’

For the preliminary stage of this research, seven postgraduate students, doctoral students and researchers in architecture, acoustics and planning were invited to participate in the focus group. It involved asking open questions about the overall understanding of the vibrancy construct (e.g. “*What does vibrancy mean for you?*”), as well as specific questions about the elements contributing to vibrant soundscapes (e.g. “*How would a vibrant place sound like?*”).

The transcription of the focus group was subsequently manually coded by an experimenter to identify core elements that people perceive as structural components of a vibrant soundscape. It emerged that such components are both aural and visual. The main aural components were: (a) loudness, (b) time variability, and (c) presence of people and music. The main visual components were: (a) presence of people, (b) activity, and (c) colourfulness. For the purpose of establishing a vibrancy predictive model, an educated guess was made about potential ‘proxy’ indicators that could be representative for the aural and visual components derived from the focus group. This resulted in the following parameters: Loudness (N), Loudness time variability (N_{10}-N_{90}), Number of people (*n*), Colourfulness Variety Index (CVI).

3.2 Laboratory experiment on vibrancy perception

Audio-visual data were collected from 26 locations in England using a Canon EOS 500D camera and a binaural headset (in-ear 1/8” DPA microphones) connected to an Edirol R44 portable recorder. Locations were selected from the city centre of Sheffield and Doncaster, to account for different contexts and activities (e.g. commercial, residential, service areas). At each of the 26 locations, eight contiguous pictures were taken with 45-degree steps to cover a 360-degree view in the horizontal plane. Directly after, a 30-second audio-recording with the binaural headset was performed, with a steady head orientation. Twenty-six videos were prepared accordingly to be used as audio-visual stimuli for the experiment. The videos were reproduced via a 16” laptop (Asus, Realtek Audio soundcard), and a pair of open circum-aural headphones (Sennheiser HD 558).

Thirty-five participants took part in the experiment (16 men; M_{age} = 26.5 years, SD_{age} = 5.8). The stimuli were presented in a silent meeting room in the University of Sheffield via an online platform in a randomised sequence for each participant. After each stimulus, participants were prompted to answer the following question on a ten-point scale ranging from “not at all” (0) to “extremely” (10): *“Overall, how vibrant was the sound environment that you have just experienced?”*. This question was thus associated to a vibrancy (VB) variable for further statistical analysis.

Regarding the physical metrics, Loudness (N) and Loudness time variability (N_{10}-N_{90}) (27) were computed for each binaural recording using the Artemis® Software. The Number of people (*n*) was counted manually as the sum of all persons across the eight pictures for each location. The Colourfulness Variety Index (CVI) was defined as follows. For each of the eight pictures, the histogram of pixel distribution across the tones’ spectrum (0-255) was extracted in Adobe Photoshop®. The histogram was divided into three equal bands (shadows 0-85, halftones 86-169, highlights 170-255). For each band, the pixels’ percentile value was determined and the standard deviation of these three percentiles was calculated. The CVI is represented by the average value of the standard deviations of the eight pictures, for each location.

3.3 Results

In order to obtain information on the structure of the data, a two-step cluster analysis procedure was performed to identify groups of locations with similar physical metrics. The algorithm of the procedure starts with the construction of a Cluster Features (CF) Tree. The nodes of the CF tree are subsequently grouped using an agglomerative clustering algorithm. The optimal number of clusters is determined using the Schwarz's Bayesian Criterion (BIC), as the clustering criterion. A four-cluster solution resulted in a good overall model quality.

The clusters' sizes and means, reported in Figure 1, suggest that the clusters are well separated and the most important predictor for the model is Loudness (N), followed by Number of people (n), Loudness time variability (N_{10}-N_{90}) and Colourfulness Variety Index (CVI), accordingly. The cluster comparison reported in Figure 2 shows a boxplot for the distribution of values within each cluster overlapping a boxplot for the overall values distributions. It can be observed that locations in cluster 1 had moderate loudness, loudness variability and number of people, and low colourfulness. Locations in cluster 2 were the quietest and least variable and crowded, but moderately colourful spots. Locations in cluster 3 were the most crowded, with moderate loudness and loudness variability and colourfulness. Locations in cluster 4 had the highest colourfulness, but moderate loudness, loudness variability and number of people.

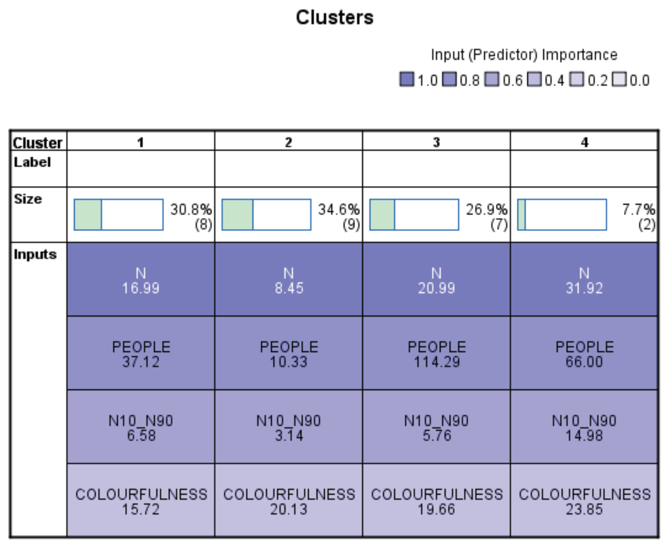

Figure 1 – Summary of clusters' composition, including size, mean values and importance of the input variables for the model

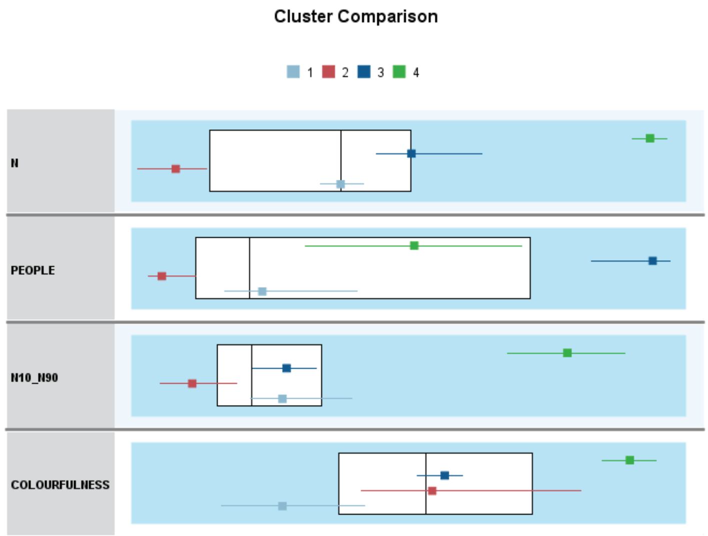

Figure 2 – Clusters' data for each variable compared to overall data

Moreover, a one-way between subjects analysis of variance (ANOVA) has been conducted to compare the effect of cluster membership on vibrancy (VB) scores. There is a significant effect of cluster membership on vibrancy at a $p < .05$ level for the four clusters: $F(3, 22) = 5.989$, $p = .004$. Cluster 3 reported the highest vibrancy score (M = 6.46), followed by cluster 4 (M = 5.93), cluster 1 (M

= 5.84), and cluster 2 (M = 4.54), as reported in Figure 3.

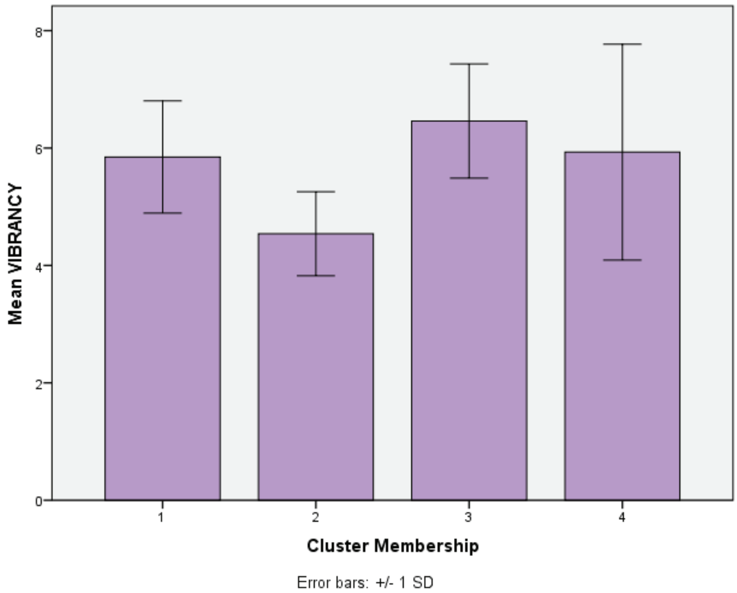

Figure 3 – Mean vibrancy values as a function of cluster membership

4. CONCLUSIONS

In this study, both a focus group and a listening experiment were developed to gather individual responses on perceived soundscape vibrancy. The two-step cluster analysis showed that it was possible to sort the investigated locations into different ‘profiles’ according to the selected physical variables, and the resulting profiles differ in a statistically significant way in terms of perceived vibrancy. The main conclusions of this study are:

- Both visual and aural cues contribute to vibrancy perception in urban soundscapes.
- Loudness (N), Number of people (*n*), Loudness time variability (N_{10}-N_{90}), and Colourfulness Variety Index (CVI), in the order of importance, resulted to be good predictors of a two-step cluster model for profiling different urban locations.
- Considering the investigated sample of locations, places that were highly crowded, moderately colourful, loud and variable in loudness resulted to be the most vibrant; conversely, places that were moderately colourful, but quiet and not variable in loudness resulted to be the least vibrant.

The review of the literature showed that descriptors tended to refer to single dimensions of soundscape appraisal or to soundscape quality overall. However, it might be worth investigating single dimensions’ descriptors that could be relevant for specific contexts, like city centres or alike. Thus, vibrancy was taken as an example. These findings claim for further attention on soundscape vibrancy, especially for its relevance in the urban realm. In the future, predictive models might be established (e.g. through multiple linear regression or fuzzy logic methods) for the vibrancy descriptor, using physical indicators.

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