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A comparison of noise mapping data and people's assessment of annoyance: How can noise action plans be improved?

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ABSTRACT

In this paper the results of noise maps counted for cars and trams, in 10 areas in the city of Poznań, are analyzed in the context of possible action plans. These results are compared with the information from surveys, involving 794 participants, performed at the same 10 areas. The general results showed that basing solely on the values of noise indicators, i.e. information from the noise maps, is not sufficient for reliable planning of noise action plans, particularly those created in response to multiple noise sources. The exceedance of a noise limit for a given sound source does not necessarily mean that this source is the most annoying for inhabitants.

To find a solution to this problem, we propose conducting dedicated noise surveys in the specific areas in each city (in which the noise maps are calculated) where we know *a priori* that more than one noise source will occur at the same time and could be potentially annoying. In the proposed survey we suggest using two specified questions: whether a given sound source is annoying or not, and which sound source should be the first one to be eliminated, if this is possible.

This new survey proposal is the result of an analysis of the survey performed within this study. Some methodological changes are proposed with regard to the survey that was actually used. This new approach could improve decisions about action plans and provide more complex information about peoples' assessment of noise annoyance evoked by different sound sources.

1. Introduction

The European directive 2002/49/EC (European Union, 2002), Environmental Noise Directive (END) requires EU member countries to represent community noise in the form of strategic noise maps for major roads, railways, airports and agglomerations. The strategic noise maps are created independently for each traffic noise source (i.e. there are many maps and each one represents only one sound source, e.g. train). They represent the dose of the community noise source by means of the noise index L_{DEN} (day-evening-night sound level, averaged over one year).

The second important requirement from END is a tool called 'noise action plans' (NAP). Roughly speaking, in that term we understand all required actions aimed at improving the acoustical climate in the places where noise limits are exceeded. As (Vogiatzis and Remy, 2017) pointed out, "NAP. have two types of impacts: (a) reducing the noise levels (of both indicators L_{DEN} and L_N) regarding the infrastructure in operation and (b) reducing the number of people, buildings or surfaces exposed to high levels of environmental noise according to existing legislation". Based on the L_{DEN} value in a given place in a city, for a given noise source, it is possible to compare this value with the noise limit and decide on a possible action plan if this limit is exceeded. Both tools were

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introduced, as END says explicitly in Article 1, "to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise".

In END one can also find the term 'quiet urban area' (QUA). This means all valuable areas (from an acoustical point of view) within a city where people can rest, i.e. parks, squares, etc. Protecting such areas from noise is another aim of that directive. Nowadays this issue is receiving more and more interest, especially among architects and city planners who want to create modern cities with nice soundscapes (Craig et al., 2017; Velardi et al., 2017; Watts, 2017).

The END is based mainly on research carried out by Miedema and Oudshoorn (2001). Aggregating data from many previous papers regarding the problem of the relation between the values of noise indicators and people's annoyance assessments, they established three 'dose-response curves' for railway, aircraft and road traffic. The most important dose-response curve is the one which reflects the relation between the % of people who are highly annoyed by a given sound source (%HA) and the L_{DEN} values of that source. People are 'highly annoyed' when they assess noise generated by a source as 7.2 or more on a standardized numerical ICBEN scale (Fields et al., 2001).

END was a big step forward towards a standardized procedure for measuring noise in the environment and managing it. However, as some researchers point out (Arana et al., 2014; King and Murphy, 2016; Licitra et al., 2011), EU requirements are not strictly defined and it is difficult to compare acoustical maps and noise indicator values between different European cities and countries. Nevertheless, some trials were made to gather all existing data and compare them in a reliable way. E.g., Licitra and Ascari (2014) proposed computing an indicator called G_{DEN} which reflects not only noise levels but also the number of people exposed to them. This indicator seemed for authors to be a good way of transforming existing data and comparing it between different cities and countries. Another big comparison was made by Arana et al. (2014), showing that the lowest exposure to noise can be observed in Germany, while the highest is in Spain.

It was proved, that the same noise index, L_{DEN}, creates different noise annoyance assessment for different noise sources – not only Miedema's research but also (Gille et al., 2016b; Hall, 1984; Janssen et al., 2011; Pedersen and Persson Waye, 2004) pointed out this fact. On the basis of the L_{DEN} value alone it is not possible to predict which noise source generates the highest annoyance rating. Higher values of L_{DEN} do not necessarily mean a higher annoyance rating. But the information contained in noise maps is limited only to L_{DEN} values measured for different noise sources separately. It was proven that the relation between %HA and L_{DEN} values explains only, at the most, 30% of variance in annoyance assessment (Marquis-Favre et al., 2005) so some scientists question whether this relation should be the most important one (Sung et al., 2017). To get a deeper view of the factors which can influence noise annoyance assessment, several scientists have tried to develop more complex models using, e.g., multilinear regression (Gille et al., 2016c; Trollé et al., 2014) and factor equations (Kroesen and Schreckenberg, 2011; Lam et al., 2009).

Another problem is when considering situations – quite common in modern big cities – in which inhabitants are exposed to more than one noise source. There is no agreement on how to rate noise annoyance in such cases. Although in the literature there are some different approaches (such as the most popular by Vos (1992), a 'standard model' does not exist, and even in noisy cities every source is still considered separately, without interactions with other noises. However, that problem is not being neglected and there are some trials to relate NAPs to multiple sound exposure situations (e.g. Licitra et al., 2011). In this paper, to take into account such situations, we incorporated into our survey a question concerning the noisiest sound source, which should be the first one to be eliminated (see subsequent sections for more details).

In general we can observe three main directions in the literature regarding noise maps and NAPs, and we analyze them below.

1.1. Facilitating the gathering of noise data for noise maps

This trend can be clearly observed regarding problems of measuring noise at many points and their weak temporal resolution. The latter problem was noticed by (Wei et al., 2016). In their work, Wei et al. proposed a real-time procedure for noise monitoring, with updates every 15 min. As they have shown, more than 75% of L_{DEN} scores were better estimated using this new approach than when using data about traffic flow. This procedure also solves problems with accidental, but highly annoying events – like music or sports events – which are very annoying for inhabitants, but while averaged across whole year their significance is negligible.

Another problem with noise maps is the large number of data and the effort involved in the long-term monitoring of noise at many points in cities. Cai et al. (2017) proposed a new method of updating noise maps, which does not require totally new set of data; it make it possible to compute correction values and apply them to an already existing model. It simplifies the whole process and yet provides satisfactory precision.

1.2. Developing new ways of gathering data

The development of technology in recent years, especially regarding mobile devices (particularly smartphones) has enabled researchers to propose new ways of collecting data about environment – and also about soundscapes. Several articles (Aspuru et al., 2016; Guillaume et al., 2016; Herranz-Pascual et al., 2016; Murphy and King, 2016; Zuo et al., 2016) showed ways of measuring soundscapes using especially designed mobile apps and surveys – both user-friendly, also providing nice immediate feedback to their users. There are also many drawbacks to such methods, such as the problem of calibration when using a smartphone microphone, but it seems they can be overcome. On the other hand, the participation of citizens is also a useful way of gathering data.