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A review and comparative analysis of European priority indices for noise action plans

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HIGHLIGHTS

- We did a review of the noise priority indices used in action plans.
- Noise indices related to health effects and annoyance were considered.
- We applied several noise scores to a real area selected as case study.
- We compared the results and the effects of the selection of noise scores.
- We highlighted the influence of the selection of noise indices on action plans.

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ABSTRACT

The European Union has provided in recent years (and is going to update) several tools to harmonise noise mapping methodologies through directives and guidelines. Unfortunately the same efforts have not been put in the harmonisation of approaches for Noise Action Plans, the effective instruments to manage noise impacts. As a consequence, each European Member State at national or even at local level defined its own methodology, usually considerably different one from the others. Nevertheless, the most common approach to deal with noise impact at a policy, economic and strategy level is the use of priority indices focused to highlight areas or buildings where mitigation actions are more advisable or urgent. The aim of the present research is to provide a review of the most used European priority indices and also to test some of them in a study area. The comparative analysis demonstrates that the method chosen for the prioritisation deeply affects the ranking of the areas where noise measures need to be realized. Some methods tend to give high priority to noise sensitive locations, others to high populated buildings, and others to the areas where noise levels are high. The study proves how much common approaches are needed also for Noise Action Plans to reach a coherent noise policy within European boundaries.

1. Introduction

Environmental noise is a global problem and, even if it is not possible to define precisely how it is evolving with time (European Environmental Agency, 2014; Arana, 2010), it is nowadays one of the most impacting pollutants in Europe and worldwide. It can be estimated that the effects of noise will increase due to the growing spread of urbanization, especially in developing countries: the United Nations estimates that more than two thirds of the inhabitants of the world will live in urban areas by 2050 (United Nations, 2014).

Increasing urbanization can be associated with a greater variety of noise and some negative health issues. In fact, the World Health Organization claims that environmental noise annoys one in three Europeans during the course of a given day. One in five will have their sleep disturbed for the same reason (World Health Organization, Regional Office for Europe, 2011). Furthermore, the European Environment Agency estimates that 65% of Europeans citizens of major cities are exposed to high noise levels (55 dB L_{den}, 50 dB L_{night}), and more than 20% to night time noise levels at which adverse health effects occur frequently (European Union, 2013).

Continued noise exposure has been linked to cardiovascular diseases (Babisch, 2014), cognitive impairment in children, sleep disturbance and tinnitus (World Health Organization, Regional Office for Europe, 2011). Several studies (Navrud, 2002; CE Delft et al., 2011) have also assessed the social costs of environmental noise for the European Union, including health care costs, house depreciation, limitation to land use, loss of working hours due to stress or insomnia, and learning impairment: it is estimated that road traffic

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noise alone costs 38 billion euros per year (0.4% of the EU gross national product), a terrific amount that is about one third of the social costs related to road accidents. So noise cannot be considered only an environmental problem, but it has serious consequences on health and economics.

Moreover, several studies have clearly highlighted that the awareness of citizens on noise issues is increasing. For instance, a survey-based research performed in 2014 in 5 different European States proved that the willingness-to-pay (WTP, i.e. the largest amount of money an individual is agreeable to pay for a product or service) to avoid health risks related to air and noise pollution is similar. The study observed that the WTP to avoid road traffic noise effects varies from 90 to 320 € per person per year depending on the awareness on noise related health risks of the interviewees; the lowest value was given by a poorly informed population while the highest one by those having detailed information (Istamto et al., 2014).

In 2002 the European Union issued the fundamental tool to tackle noise issues with a common approach between all the Member States: the European Directive 2002/49/CE, also called the END (Environmental Noise Directive) (European Union, 2002). The goal of this legislative instrument is "to define a common approach intended to avoid, prevent or reduce on a prioritized basis the harmful effects, including annoyance, due to exposure to environmental noise".

To this extent several actions are needed by each Member State:

- evaluation of the population exposed to high levels of noise (not considering military activities, neighbourhood or occupational noise) by means of noise mapping activities;
- a proper information and communication campaign to increase the awareness of citizens and all the involved stakeholders about noise related effects;
- definition of common strategies to solve or mitigate noise problems and protect quiet areas.

The END specifically requests to agglomerations, i.e. urban areas with more than 100,000 inhabitants, roads with more than three million vehicle passages per year, railways with more than 30,000 train passages per year and airports with more than 50,000 movements per year to realize a noise map of their emissions, evaluating the exposure of the population, and to plan actions to tackle these issues (Action plans). Other impacting sources, such as large industrial plants (Alayrac et al., 2010), wind farms (Nissenbaum et al., 2012) or ports (Murphy and King, 2014; Schenone et al., 2014), are not specifically considered in the END (they are analysed only if they are included inside an agglomeration), even if their noise emissions can be detrimental for citizens' health.

Concerning noise mapping, the European Commission has decided to harmonise the methodologies that the Member States need to adopt by introducing CNOSSOS-EU (Common Noise aSSessment MethOdS) (Kephalopoulos et al., 2012, 2014). This common method should be fully operational for the next round of EU strategic noise mapping in 2017. Of course having a common method does not necessarily guarantee good noise mapping, because of the need of providing the models with high quality input data to obtain significant outputs, according to the concept of "garbage in garbage out" (WG-AEN, 2007). However this is the first important step to obtain comparable data from all the Member States: this is of particular importance since one of the greatest failures of the first rounds of strategic noise mapping was the impossibility of comparing noise data and maps coming from the different EU countries (Arana et al., 2014).

On the contrary there are no common methodologies for the realization of action plans and for the time being no attempt to define or to build them has been made; in particular no procedure has been established for the identification of the most critical areas, i.e. areas that most urgently need noise mitigation actions. Commonly noise action plans rank the different parts of the examined area, i.e. agglomeration or area affected by road, railway or aircraft sources, in terms of how they are impacted by noise using scoring systems.

In the years a lot of scores have been proposed by researchers or public administrations, each characterized by a different algorithm. Some of them consider only the noise level in their formula, others also the number of people affected by noise, still others the presence of schools and hospitals and so on.

The scope of the paper is to provide a review of these scoring systems and to apply some of them to an area selected as a case study, in order to show the peculiarities of each of them and the differences deriving by their applications in a possible action plan.

Recently some authors have proposed other procedures, mainly based on the so called soundscape approach, that integrate physical parameters (acoustic measurements or calculations) with peoples' perception and expectations in noise action plan definition (Schomer et al., 2013; Vogiatzis and Remy, 2014). These procedures, though really interesting, requires a lot of qualitative data that cannot be found in noise maps and so they have not been considered suitable for a comparison with the other indices analysed in the present paper.

2. Review of noise priority indices

This section reports a review of the indices proposed by researchers, private bodies, public administrations or states to define a ranking of the areas where noise can be considered most impacting. These rankings are commonly used to give priorities to the mitigation measures proposed in noise action plans of transportation infrastructures or agglomerations, as the ones required by the END.

As the following text will show, some indices mainly focus on the sound pressure level, others on the land use, for instance highest values are reached if schools or hospitals are included in the area, others on the number of annoyed people and so on. A brief description of each index is reported in each subsection; further information can be found in the suggested references.

2.1. Indices based on effects of noise on people's health

The European Environment Agency released in 2010 a technical report aimed at summarizing some proved relationships between noise exposure and health effects such as annoyance, sleep disturbance and ischemic heart disease (European Environmental Agency, 2010), in particular the dose response relationships defined by Miedema and Oudshoorn (2001). Annoyance is defined as an "emotional state connected to feeling of discomfort, anger, depression and helplessness" that should be evaluated by means of ISO 15666 questionnaires (ISO 15666, 2013). Concerning this topic, the evaluations recommended by the report consider the kind of noise source and its acoustic impact in terms of L_{den}; the outcomes are the percentages of people annoyed (%A) and highly annoyed (%HA):

$$\%A_{road} = 1.795 * 10^{-4}(L_{den}-37)^3 + 2.110 * 10^{-2}(L_{den}-37)^2 + 0.5353(L_{den}-37) \quad (1)$$

$$\%HA_{road} = 9.868 * 10^{-4}(L_{den}-42)^3 - 1.436 * 10^{-2}(L_{den}-42)^2 + 0.5118(L_{den}-42) \quad (2)$$

$$\%A_{rail} = 4.538 * 10^{-4}(L_{den}-37)^3 + 9.482 * 10^{-2}(L_{den}-37)^2 + 0.2129(L_{den}-37) \quad (3)$$

$$\%HA_{rail} = 7.239 * 10^{-4}(L_{den}-42)^3 - 7.851 * 10^{-3}(L_{den}-42)^2 + 0.1695(L_{den}-42) \quad (4)$$

$$\%A_{air} = 8.588 * 10^{-6}(L_{den}-37)^3 + 1.777 * 10^{-2}(L_{den}-37)^2 + 1.221(L_{den}-37) \quad (5)$$