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A study of relationships between traffic noise and annoyance for different urban site typologies

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ABSTRACT

The paper intends to analyse the different attitudes of residents in urban areas in regard to annoyance induced by traffic noise, account taken of the effects of the street configuration and of the presence of specific public transport modes in the definition of the dose-response curves.

People's annoyance was investigated through a campaign of noise and traffic measurements and an epidemiological survey, administered to a sample of 830 residents in the buildings close to the measurement points.

An ordinal regression model taking into account environmental and urban characteristics was used to identify a dose-response relationship. The cumulative probabilities allowed to define two cut points on the dose-response curves (60 and 75 dB(A)), grouping people in three classes and making the representation of the dose-response relationships different from those traditionally defined that use only the percentage of highly annoyed people.

The results show different people's attitudes towards the annoyance in the urban sites while the dose-response relationship shows that the correlation between annoyance and noise is low. For the same value of day equivalent level, 10% more people are annoyed in L sections (broad streets) than in U sections (narrow streets). Furthermore, all the dose-response curves show a higher sensitivity of people living in L sections; this difference can be measured as a shift of about 4 dB(A). Noise levels are, arguably, a useful indicator, but they are not reliable enough to define the discomfort of the residents, while the site characteristics could shed light on annoyance variability.

Introduction

Studying noise emissions and related annoyance is important from different points of view because noise affects the quality of the environment, the resident's satisfaction (Kroesen et al., 2009), as well as their well-being and health (Camusso et al., 2010; Ohrstrom, 2004).

Noise brings on social and behavioural effects, notably annoyance and sleep disturbance. From a medical point of view, effects of noise on human health are well documented: hearing impairment, speech intelligibility, physiological dysfunctions, mental illness, performance reduction, cardiovascular diseases (WHO, 1999, 2011; Pearsons, 1998; Pearsons

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et al., 1995; Passchier-Vermeer, 1993; Ohrstrom, 1993). Many of these effects are assumed to result from the interaction of a number of auditory and non-auditory variables.

For this reason, several research projects (SILENCE, Qcity, Harmonoise) have been undertaken to define mitigation techniques as well as a common European approach to reduce the noise emitted in the residential areas (Kephalopoulos et al., 2014; Salomons et al., 2011). However, the need to safeguard the quality of life and the health of the population calls for further efforts for transport noise abatement in regard to the increasing mobility demands. To reconcile these conflicting needs, the EU 6th Action Programme "Environment 2010: Our Future, Our Choice" stipulated that the number of people regularly effected by long-term high levels of noise, estimated as 100 million people in the year 2000, should decrease by around 10% by 2010 and by 20% by 2020. The difficulty to attain those targets is that 54% of people live in urban areas (WHO, 2014), where transport infrastructures represent the most important source of noise. In fact, today 115 million people are exposed to noise levels L_{den} (day-evening-night noise indicator) higher than 55 dB(A) and 80 million people are exposed to L_{night} (night-time noise indicator) higher than 50 dB(A) (EEA, 2011). All over the world, a total of 2 billion citizens are subjected to road traffic L_{den} of over 55 dB (De Vos and Van Beek, 2011). Thence, policy makers are increasingly demanding the use of reliable and homogeneous instruments for monitoring and evaluating transport noise emissions. In some cases, national norms establish rules to preserve the acoustic quality in specific areas (e.g. parks, hospitals, schools) and to reduce people's noise exposure, recommending the adoption of noise indicators and setting thresholds to comply with.

To this extent, in the literature different noise indicators are proposed (Pronello and Camusso, 2012; Folkeson et al., 2010) according to the type of transport system and to the purpose of the evaluation.

In Europe, the need to define guidelines to set common noise legislation led to the Environmental Noise Directive 2002/49/EC, also known as the "END" (EC, 2002). This Directive requires to monitor noise levels in European cities over one million inhabitants and along the main transport infrastructures. To this end noise maps, showing the L_{den} and L_{night} to which people are exposed, are mandatory and dose–response relationships should be defined.

This task is quite challenging because the relationship between annoyance and noise exposure does not depend only on the noise sources, but also on the environmental context in which people live. Furthermore, the diversity of the effect on annoyance caused by the different transport modes suggests that different dose–response relationships can be defined (Miedema and Oudshoorn, 2001; Kryter, 1982; Schultz, 1978). However, while the evaluation of the noise impact of individual transport modes is well established, the assessment of the annoyance due to the noise emissions coming from different sources is more difficult (WHO, 2002; Miedema, 1986, 1996; Vos, 1992; Rice, 1986; Taylor, 1982).

In urban areas, noise is influenced by pavement and traffic typologies (Freitas et al., 2012), by street dimension (Tang and Wang, 2007; Nicol and Wilson, 2004), by urban shape (Montalvão Guedes et al., 2011) and by the presence of public transport (Paunović et al., 2014). Some researchers suggest to take into account the unpleasant noise events (Foertsch and Davies, 2013; WHO, 2009) or the awaking percentage and rattle (Eagan, 2007) to better explain annoyance. Also the typology of the area can influence people's disturbance; the access to a quiet area or a green area could decrease the annoyance of the residents (Li et al., 2010; Gidlöf-Gunnarsson and Ohrstrom, 2007; Ohrstrom et al., 2006; WHO, 2003). Moreover, the same noise source could produce a different annoyance, depending on the area – urban or rural (Knall and Schuemer, 1983) – but both areas, if people show high noise sensitivity, are mainly associated with high annoyance (Schreckenberg et al., 2010; Fyhri and Klaeboe, 2009; Miedema and Vos, 1999).

While the physical variables influencing noise and annoyance are easy to measure, the psycho-physical variables are more subjective, depending on the context and the characteristics of the residents, and they are not easy to interpret (Miedema and Vos, 1999; Fields, 1993).

The dose–response curves have been used to measure annoyance, but the most frequently used ones are based on average values and do not take into account the effect of the different urban contexts.

The paper aims at analysing the annoyance, induced by traffic flows passing along transport infrastructures, on the residents in urban areas and proposing alternative dose–response curves, taking into account the effect of the street configuration and of the presence of specific public transport modes, both on the noise propagation and on the definition of the dose–response curve.

The next section explains the methodology adopted to design the survey and the data analysis. Section 'Results' reports the results of the traffic and the noise measurements, showing the correlation with the annoyance for each of the three periods surveyed: day, evening and night. Finally, the dose–response relationships built on the epidemiological survey are presented. Section 'Discussion and conclusion' discusses those results and matches them with the relevant literature.

Methodology: the survey and data analysis design

The noise produced by transport in urban areas as well as the disturbance perceived by people subjected to traffic noise is influenced by several variables. Restricting the analysis to the traffic characteristics allows the identification of source typology and its acoustic power, but it does not take into account the context where the infrastructure is located. This could seriously hamper the understanding of people's annoyance, as attitudes of exposed subjects towards noise and their perception are quite significant.

To define the relationships between noise levels and disturbance under a wider perspective, the methodology is based on a four steps approach: (a) the definition of the variables to be measured; (b) the selection of the urban sites where the survey