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Population exposure to road traffic noise: Experimental results from varying exposure estimation approaches

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ABSTRACT

This paper assesses four methods for estimating population exposure to road traffic noise within the terms of the strategic noise mapping process laid down in the Environmental Noise Directive (END). Employing a case study in central Dublin, Ireland, the methods – MAX, MIN, VBEB/CNOSSOS and AVE – are tested utilising the L_{den} and L_{night} indicators. The study first investigates the extent to which exposure estimates may vary depending on the method utilised while controlling for the noise calculation method. Second, it investigates how estimates of exposure vary depending on the calculation method used; in this case, CRTN and NMPB. The results show that controlling for noise calculation method and employing the same input data, estimations of population exposure differ substantially depending on the exposure method employed. Furthermore, the potential variability in estimated night-time exposure and the potential for under or over-estimation of the health effects of environmental noise on a given population when different methods are utilised is clearly demonstrated. The results also show that the method of noise calculation employed has an effect on estimated exposure, particularly for L_{den} measures. Values for L_{night} were found to be very similar regardless of the calculation method employed. The results therefore suggest that it is the exposure estimation method rather than the noise calculation method which has the greatest effect on population exposure estimation and should therefore be of greatest concern for understanding population health impacts and for achieving consistent results.

1. Introduction and context

Environmental noise pollution is an inherently spatial phenomenon – it varies across geographic space depending on the location of the noise source, the receiver and the intervening obstacles such as the terrain, buildings, and barriers (Murphy and King, 2014). Understanding how it varies across space, how many people it affects and how it can be mitigated is all part of the process of strategic noise mapping (see Kaddoura et al., 2017; Quiñones-Bolaños et al., 2016; Abbaspour et al., 2015; Asensio et al., 2009). The process of digitally mapping environmental noise across geographic space allows researchers and policymakers the possibility of not only identifying locations that are subject to excessive noise levels but also the number of individuals in particular areas that might be affected by excessive noise pollution. Through this process, it is possible to take steps that reduce noise levels so that public health is protected.

The EU is the world leader in terms of environmental noise policy and related legislation. Since the 1970s, legislative instruments have been developed to regulate noise at the source (mostly through legislation to reduce noise levels of automotive vehicles, outdoor equipment etc.). In recent years, legislation has transitioned from focussing on the source to mitigating environmental noise at the

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point of the receiver. This shift has occurred in the context of an emerging evidence base suggesting links between exposure to environmental noise and public health concerns (see Babisch, 2011; Perron et al., 2012; Halperin, 2014; Vienneau et al., 2015) and recognition that concentrating regulation only on the source is not sufficient in itself to alleviate the problem.

Exposure to night-time noise causes sleep disturbance (Douglas and Murphy, 2016) and this has a multitude of negative effects on health and well-being. Noise pollution causes adverse health effects by activating the autonomic nervous system and endocrine (hormonal) systems of the body, leading to changes in heart rate, blood pressure and the release of stress-associated hormones such as cortisol, which affects metabolism (Babisch, 2002, 2011). Noise pollution has been linked to impaired cognitive performance, lower levels of relaxation, hormonal disturbances, diabetes, stroke, cardiovascular disease and psychological ill health (Stansfeld and Matheson, 2003; Isling and Kruppa, 2004; Goines and Hagler, 2007; Sørensen et al., 2011; Sørensen et al., 2013; Fujiwara et al., 2017).

The aforementioned shift in policy emphasis began in 1993 with the *Fifth Environmental Action Programme of the European Community* which established a basic objective that individuals should not be exposed to noise levels which may endanger their health and quality of life (European Community, 1993); it also established a number of targets for mitigating exposure by the year 2000. Later, the EU *Green Paper on Future Noise Policy* was published (European Commission, 1996). As well as examining the various environmental impacts of noise and the noise situation in the EU, this document paid particular attention to the reduction of noise at source and limiting the transmission of noise between the source and the receiver. The document set out a framework for the assessment and reduction of noise exposure and future actions for noise mitigation. In this sense, it indicated the importance of shared responsibility across the EU for effective noise policy and reaffirmed that the management and reduction of noise from different sources should be prioritised.

A foundational document linking noise and exposure to public health concerns was produced by the World Health Organisation (WHO) – *Guidelines for Community Noise* (Berglund et al., 1999). This document was seminal in that it established noise pollution as a serious public health issue worldwide. At the time, the document estimated that 40% of the population of the EU was exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) during daytime; the corresponding figure for night-time was 30%. Taking all exposure to transportation together, it was estimated that approximately 50% of EU citizens lived in zones of acoustical discomfort. In response to the ever growing body of evidence, the *6th Environmental Action Programme of the European Community* specifically targeted the problem of environmental noise (European Commission, 2002). The programme stipulated that future environmental noise policy should be aimed at 'substantially reducing the number of people regularly affected by long-term average levels of noise, in particular from traffic…' as well as 'developing and implementing instruments to mitigate traffic noise' (p. 10, 12).

At the EU level, these policy documents together with academic research on noise and health relationships have been instrumental in the development of a legislative framework for the management of environmental noise in Europe, ultimately culminating in the passing of Directive 2002/49/EC, also known as the Environmental Noise Directive, or END (European Union, 2002). Recognising the potential public health concerns, the Directive has sought to develop a common approach towards the avoidance, prevention and reduction of the harmful effects of exposure to environmental noise using a strategic noise mapping process. Within the END, a strategic noise map is defined as 'a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area' (Murphy and King, 2010, 291). Under the terms of the Directive, determination of levels of exposure to environmental noise is to be achieved using strategic noise maps which employ the harmonised noise indicators L_{den} and L_{night}. These common indicators were developed specifically for the END.[1] The Directive requires competent authorities in each Member State to provide estimates of the number of people living in dwellings that are exposed to values of L_{den} and L_{night} in various categories at the most exposed building façade and separately for road, rail, air traffic and industrial noise (European Union, 2002, p. 24). Fig. 1 presents a standardised schematic of best practice steps involved in the strategic noise mapping process. The standardised approach has a series of components: data collection; noise calculation; validation and mapping; estimation of population exposed; noise action planning; and public dissemination.

While the development of the END represents an important legislative development for the regulation of noise in Europe, methodological issues and barriers to implementation have been identified. In the first phase of the END, the steps set out in Fig. 1 were interpreted and applied in a variable manner by each nation. Murphy and King (2010) have explored a range of methodological issues, placing particular emphasis on calculation and mapping methods. Indeed, more recent work has questioned the value of the process given the data which has emerged over two mapping phases (King and Murphy, 2016). One of the key issues is that no standardised noise calculation method has been fully developed thus far even though one is currently under development. Murphy and King (2010) identified seven different methods which were used for the calculation of road traffic noise across seventeen member states in the first phase of the END (June 2007). This means that results from different member states are simply not comparable. Indeed King and Rice (2009) have argued that in order to achieve standardisation across noise studies, competent authorities should be required not only to apply the same calculation procedures but also to employ the same calculation software.

In recognition of the lack of standardised methodologies, a number of policy documents have been developed with the potential to provide better guidance for the achievement of the aims of the END. Of particular note are the WHO *Night Noise Guidelines for Europe* (2009) which effectively updated *Guidelines for Community Noise* (1999). These guidelines recommended a non-binding limit value of 40 dB(A) $L_{night,\ outside}$ if authorities are to prevent their citizens from being exposed to harmful effects of environmental noise

[1] L_{den} is an annual noise indicator which describes the average day-evening-night-time A-weighted equivalent sound pressure levels over a complete year, while L_{night} describes the night-time A-weighted equivalent sound pressure level over a complete year.