An activity-based and dynamic approach to calculate road traffic noise damages

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In this paper, an activity-based and dynamic approach is presented to analyze population exposures to road traffic noise. The contribution of this innovative approach is that (1) affected people at the workplace and places of education are incorporated and (2) the within day dynamics of varying population densities in different areas of the city is explicitly taken into account. The proposed methodology is applied to a real-world case study of the Greater Berlin area. The results demonstrate the need to account for the spatial and temporal variation in the population since the use of static resident numbers would result in an overestimation of residential noise damages. Going beyond residential exposures, the inclusion of further activity types is found to have a substantial effect on the results. Assuming individuals at work or education to be additionally affected by noise, population exposures in the central business districts are much larger than in residential areas. The proposed approach may be seen as a first step towards improved noise mapping standards to provide better recommendations for policy makers and ensure a more efficient use of noise control strategies.

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1. Introduction and problem statement

Environmental noise is described as a growing public health problem (WHO Europe, 2011) and to cause sleep disturbance, cognitive impairment, tinnitus and cardiovascular diseases (see, e.g., Ising et al., 1996; Stassen et al., 2008; WHO Europe, 2009, 2011; Babisch et al., 2013). A recent survey reveals that more than half of the population in Germany feels annoyed or disturbed by road traffic noise (Rückert-John et al., 2013). The Environmental Noise Directive of the European Union 2002/49/EC aims to reduce these effects. In order to identify priorities for action planning, an approach is defined to draw up strategic noise maps based on national computation methods and a standardized noise indicator (2002/49/EC, App. 1 and 2). Several noise computation models have been developed in different countries, e.g. the RLS-90 (Richtlinien für den Lärmschutz an Straßen) in Germany (FGSV, 1992), the CoRTN (Calculation of Road Traffic Noise) in the United Kingdom (Department of Transport, 1988), the Nordic Prediction Method in Norway, Denmark, Sweden and Finland (Nielsen et al., 1996). In a recent study by Garg and Maji (2014) a comparative review of the different calculation approaches is provided.

For the prioritization of noise control measures the computation of noise exposures to individuals is a crucial element. According to App. 4 of 2002/49/EC strategic noise mapping may include the presentation of a noise indicator or the exceed-
ing of limit values, but also of estimates for the number of people or certain buildings that are exposed to noise. Eriksson et al. (2013) compare predicted and survey-based exposures and find Swedish noise maps to be useful for the assessment of residential traffic noise exposures. To indicate the exposures to the population, most noise maps include the building boundaries, however, the number of people that is exposed to certain noise levels is usually not directly shown in the map (see, e.g., SenStadt (2012b) for Berlin and DEFRA (2014) for London). Tables or charts may additionally provide estimates for the population exposures, however, these numbers are usually spatially aggregated at city or post code level (see, e.g. SenStadt, 2012a; DEFRA, 2015).

Since certain buildings, i.e. schools and hospitals, are explicitly mentioned in 2002/49/EC, noise exposure analysis is not limited to residents at their home location. However, the data to be sent to the European Commission specified in App. 6 of 2002/49/EC only refers to residential noise exposures. Moreover, also the ‘Good Practice Guide for Strategic Noise mapping and the Production of Associated Data on Noise Exposures’ which provides recommendations regarding the computation of sound sources, noise propagation and noise immittance at the receiver point, only refers to people that are affected in dwellings (WG-AEN, 2006). As a consequence, noise exposure analysis usually follows a home-based approach by estimating the number of people living in each building (see, e.g. SenStadt, 2012a; DEFRA, 2015; Gulliver et al., 2015). This also seems to be the practice of many assessment approaches in which noise exposure costs are computed based on static resident numbers (see, e.g., FGSV, 1997; ITP and VWI, 2006). This makes sense for night times (see, e.g , BVU et al., 2003, pp. 187–189), whereas, during the day residents may have left their homes in order to perform other activities at different locations. Hence, the estimated noise costs or exposure analysis may lead to wrong recommendations for policy makers. Lam and Chung (2012) consider the socio-economic characteristics and find older and less educated residents in Hong Kong’s private buildings to be worst affected by traffic noise. Murphy and King (2010) address the absence of a standard method for the estimation of population exposures to noise in the European Union and mention the importance of considering residents who regularly leave their home town (e.g. weekend commuters). However, the authors do not refer to residents who leave their dwelling during the day (e.g. daily commuters). Ruiz-Padillo et al. (2014) present a methodology to compute a road stretch-specific priority index to be used for action planning. This index is composed of several variables including the noise level and residential exposures. Moreover, the proposed index takes into consideration the land use, i.e. noise sensitive buildings. Tenailleau et al. (2015) discuss the definition of the considered area for the quantification of noise exposures and point out that in epidemiological research this exposure area is primarily limited to the home, i.e. the dwelling, whereas, in case outdoor exposures are considered, this area is usually extended to the relevant neighborhood. The authors conclude that noise exposures should ideally be individually evaluated to account for the differences in the daily activity and travel behavior patterns. Whereas, in context of air pollution, Hatzopoulou and Miller (2010) explicitly consider the temporal and spatial variation in air quality and population by using an activity-based demand model.

The tendency that most assessment methods and strategic noise mapping approaches are limited to residential exposures seems surprising as several regulations and studies also address noise in context of other activity types. Limit values which usually refer to the A-weighted and time-averaged sound level (noise assessment level), may be used for an activity-specific evaluation of noise exposures.

In Germany, limit values for traffic noise levels during the day, defined in 16. BImSchV, are differentiated according to the land use type, e.g. 57 dB(A) for hospitals, schools, sanatoriums, retirement homes, 59 dB(A) for residential areas, 69 dB(A) for commercial areas. For the night, limit values are reduced by 10 dB(A) compared to the day, which correspond to halving/doubling the perceived loudness. In contrast, for noise during night times, in WHO Europe (2009) a much lower outside noise level of 40 dB(A) is recommended. Further activity-specific noise limits are found in context of noise protection at the workplace. In addition to noise from outside of the building (e.g. traffic noise), these regulations usually include noise sources at the workplace (e.g. machines, conversations of colleagues). Thus, provided limit values refer to the indoor sound level. An evaluation which includes the effects of annoyance and disturbance in computer workspaces describe an averaged sound level below 30 dB(A) as the optimal working environment, 30–40 dB(A) as very good, 40–45 dB(A) as good, 45–50 dB(A) as acceptable in a commercial environment, 50–55 dB(A) as inconvenient and noise levels above 55 dB(A) as too high (Rau et al., 2003). DIN EN ISO 11690-1, an international standard adopted at European and national level, points in a similar direction and recommends noise limit values of 35–45 dB(A) for mainly mental activities and 45–55 dB(A) for repetitive office work; in classrooms, background noise levels should not exceed 30–40 dB(A). Since these values are indoor noise limits, values for the outside facade may be derived by adding a value for the insulation of the building. The level of sound reduction depends on the specific characteristics of the building (e.g. wall thickness, number and size of windows), the window technology (e.g. single vs. multiple glazing) as well as personal habits (e.g. open vs. closed windows). Numbers for the sound reduction of closed windows range from 25 dB to more than 48 dB (see, e.g. DIN 4109, Beiblatt 1, p. 55–56). Open windows are described to reduce the noise level by 5 dB, partly opened windows by about 15 dB (see, e.g. RPS, 2011, Appendix 8). During night times, windows in bedrooms are found to be closed in 25% of the nights, and as average inside/outside differences 21.3 dB (single-glazed window) and 22.2 dB (double-glazed window) are given (WHO Europe, 2009). Hence, outside noise levels above 35 dB(A) for open windows, and above 55 dB(A) for closed windows and the worst case noise insulation, may already lead to a not optimal working environment.

To the best of the authors’ knowledge, there are no studies on noise exposures which explicitly take into account the within day dynamics of varying population densities in different areas of the city and incorporate people that are affected at work, university or school. The present study takes up this lack of research and investigates for the case study of the Greater Berlin area the importance of dynamically considering various activity types.
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