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Road traffic noise abatement scenarios in Gothenburg 2015 – 2035

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ABSTRACT

Exposure to high levels of road traffic noise at the most exposed building facade is increasing, both due to urbanization and due to overall traffic increase. This study investigated how different noise reduction measures would influence the noise exposure on a city-wide scale in Gothenburg, a city in Sweden with approximately 550,000 inhabitants. Noise exposure was estimated under several different scenarios for the period 2015–2035, using the standardized Nordic noise prediction method together with traffic flow measurements and population statistics. The scenarios were based on reducing speed limits, reducing traffic flows, introducing more electrically powered vehicles and introducing low-noise tires and pavements. The most effective measures were introducing low-noise tires or pavements, which in comparison to business as usual produced between 13% and 29% reduction in the number of inhabitants exposed above 55 dB equivalent level.

1. Introduction

It is well-established that traffic noise can cause adverse health effects (Fritschi et al., 2011; Stansfeld, 2015; Münzel et al., 2014). In many cities a large part of the population is exposed to high noise levels at their homes, and for the majority of these road traffic is the principal noise source. With continuing urbanization and population growth, traffic noise is a growing problem.

Increased road traffic in urban areas has long been an environmental concern. If measures such as modal shift (moving transport from roads to railway, pedestrian and bicycle traffic) can indeed reduce the amount of road traffic, the problem will decrease in the future. However, so far road traffic is still increasing and is expected to continue to increase for a long time (Capros et al., 2016).

If road traffic increases, then the reduction of noise exposure requires measures to be taken at the source. However, noise emission per vehicle has not changed significantly since the early seventies (Sandberg et al., 2006; Sandberg, 2001). On the other hand, there has been success in reducing air pollution emissions from road traffic; in Gothenburg, nitrogen oxide levels from road traffic have decreased by more than 60% between 1983 and 2007 (Molnár et al., 2015). This is an example of a reduction of environmental impact that has been achieved by measures directed at reducing the emission at the source, and it has been effective in spite of increasing traffic over the period.

In this study our aim was to investigate the effectiveness of different noise reduction strategies, focusing on traffic flow, possible reductions of noise emission from road vehicles and restrictions on new residential buildings. The study was conducted in Gothenburg, a medium sized port city on the west coast of Sweden with approximately 550,000 inhabitants. Using population data, a database of traffic flow measurements and a noise prediction method we estimate the noise exposure in the period 1975 – 2015, examine several different scenarios for the period 2015 – 2035 and consider their feasibility. Our main outcome was the number of inhabitants exposed above 55 dB equivalent level on the most exposed façade of the dwelling. We choose this level since it is often used as a target level for new dwellings in Sweden, but the results are presented for other equivalent levels and the European noise indicator L_{den} (ISO, 2016) as interactive plots. The exposure across the whole city was taken into account, making it possible to compare local measures such as low-noise pavements to global approaches such as using a higher percentage of electric vehicles.

Previous research has shown that the strategies which address the noise at the source are often the most effective (Herman, 1998; Nijland et al., 2003; Kropp et al., 2007; Den Boer and Schroten, 2007), but there are many ways to do this. Driving behavior, tire and pavement properties, vehicle design and speed are the most important parameters (Sandberg and Ejsmont, 2002). This paper extends the scope of previous research by analyzing the effect of such measures in a complex city environment complete with diverse traffic situations, varying population density and different building structures.

The different noise reduction scenarios are divided into those that reduce rolling noise from traffic, i.e. low noise tires and pavements, and others that affect the propulsion noise, the traffic flow or the population distribution. Rolling noise is the most important noise source for higher

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speeds, but propulsion noise is also important at lower speeds, especially for heavy vehicles (Sandberg and Ejsmont, 2002).

Reducing the rolling noise can be achieved by using low noise tires or pavements. Low noise pavements can be either elastic, such as rubberized asphalt, or porous as porous or drain asphalt, or both (poroelastic pavements). Rubberized asphalt is already in use in many areas (Vázquez and Paje, 2016; Licitra et al., 2015; Sandberg, 2010), and reductions compared to standard pavements are in the order of 3 – 10 dB. Porous asphalt is also in use and reductions are in the same range, and poroelastic surfaces can give even higher reductions but are at the research stage (Sirin, 2016; Ohiduzzaman et al., 2016; Goubert and Sandberg, 2010).

Low noise tires are already available in different forms and the reduction that can be achieved is between 3 and 5 dB (Sandberg et al., 2006; Heutschi et al., 2016). Research prototypes have achieved more than 10 dB reduction compared to standard tires (Sandberg, 2009; Larsson, 2003).

2. Methods

2.1. Noise emission

The calculations of noise levels were based on the Nordic prediction method for road traffic noise (Jonasson and Nielsen, 1996). This method calculates the equivalent sound pressure level at a receiving point based on traffic flow, distribution between light and heavy vehicles and posted speed limits for road traffic in the vicinity of the receiver. The method also calculates the effect of propagation distance, ground effect, reflections and screening; both by terrain, by buildings and noise barriers.

As previously demonstrated (Sandberg et al., 2006; Sandberg, 2001), the noise emission per vehicle did not change much between 1975 and 2005 in Denmark and Sweden. There was even a slight increasing trend for light vehicles; but this observation is uncertain and we assume no change for light or heavy vehicles in typical traffic conditions in Sweden from the start of our period in 1975 and until 2015. It is, however, worth asking what will happen in the future?

Our basic noise prediction method can only predict the total noise emission from the combination of all sources due to road traffic. In order to model the effect of changing only the tire/road noise (low-noise tires or pavements) or the propulsion noise (electric vehicles) we used results from the FOREVER project (Pallas et al., 2014). In this European research project, noise measurements and calculations were performed for electrical and hybrid vehicles and the results were compared to vehicles with traditional internal combustion engines (ICE). In order to separate propulsion noise from rolling noise, the source model of the official European noise calculation method Cnossos-EU (European Commission, 2015) was used. The uncertainty of the recommended values is higher for heavy vehicles than for light vehicles, since the number of measurements performed within the project was lower for heavy vehicles. The resulting overall relation between propulsion noise and rolling noise translated to sound exposure levels (SEL) used in the Nordic prediction method (Jonasson and Nielsen, 1996) is presented in Table 1.

Use of electric vehicles will dramatically reduce the propulsion noise, which will reduce the total noise emission significantly at low speeds. Based on measurements and calculations from the research project FOREVER (Pallas et al., 2014) we estimate how much noise reduction that can be achieved. According to FOREVER the total noise emitted by electrical light vehicles is 2.7 dB lower at 30 km/h but only 0.4 dB lower at 110 km/h. For heavy vehicles we estimate a reduction of 10 dB at 30 km/h and 1.5 dB at 90 km/h based on results from the FOREVER report (Pallas et al., 2014), but as explained above the uncertainty is higher for heavy vehicles.

It may seem odd that the propulsion noise component in Table 1 is slightly higher at 30 km/h than at 50 km/h. This follows from the Nordic method (Jonasson and Nielsen, 1996), and can be explained by the fact that the average vehicle uses a gear that gives higher engine speed, and also that vehicles more often accelerate and decelerate while driving at low speeds.

Table 1
A-weighted sound exposure level (SEL) in dB for a single vehicle pass-by at 10 m distance at different speeds. Calculated from measurements performed within the FOREVER project (Pallas et al., 2014) and adapted to the Nordic method for predicting noise from traffic (Jonasson and Nielsen, 1996). ICE = internal combustion engine. Heavy vehicles are restricted to speeds equal to or below 90 km/h in Sweden, and therefore no values are presented for 110 km/h.

Speed	30	50	70	90	110
Light vehicles					
Propulsion noise	67.7	66.6	68.3	70.2	71.5
Rolling noise	68.4	72.5	76.6	79.4	81.7
Difference electric vs. ICE	2.7	1.0	0.6	0.5	0.4
Heavy vehicles					
Propulsion noise	80.0	78.9	79.8	80.4	
Rolling noise	70.5	75.4	83.3	87.4	
Difference electric vs. ICE	10.0	5.1	1.6	0.8	

2.2. Noise exposure

When the noise emissions had been determined, noise propagation calculations were used to sum up all contributions at the receiver locations. The attenuation during propagation from source to receiver is determined by distance, terrain shape, noise barriers, ground effect, reflections at building façades and the intrinsic air attenuation (Jonasson and Nielsen, 1996). Reflection at façades is particularly important in urban canyon situations, where the sound energy can be reflected multiple times between parallel façades. Since we do not have complete information on the position and height of every building façade over the whole time period we have simplified the calculations, using a correction for the increase in noise level in urban canyon situations (Ögren and Barregard, 2016).

In order to estimate the noise exposure of the population it is necessary to have population data. We used the total number of inhabitants in 100 m squares every five years from 1975 to 2015 as our base statistics, and then used an algorithm to calculate how many inhabitants were exposed in each square. This algorithm distributes inhabitants evenly over the area of the corresponding square not occupied by roads and uses a numerical integration scheme to estimate noise levels (Ögren and Barregard, 2016). For each square the population density was integrated over the part of the square where the noise levels exceed 55 dB. The total number of exposed over the whole city was calculated as the sum of the exposed populations in all squares. Compared to official estimates for Gothenburg this method underestimates the number of people exposed above 55 dB by 11% (Ögren and Barregard, 2016).

For the time period 2015 – 2035 a new noise exposure calculation was performed with updated traffic, noise emission and population data as described in the scenarios below for every five years. The same noise propagation method and noise exposure estimation were used for the future scenarios as for the period 1975 – 2015.

The relative noise exposure was also assessed using the G_{den} indicator (Licitra and Ascari, 2014), which is an index based on the number of exposed people in relation to the total population, with a higher weighting for the more highly exposed groups. It can be considered as an equivalent level over the population instead of over time. It is based on the European noise indicator L_{den}, which is an A-weighted equivalent noise level with a penalty for nighttime and evening traffic. For a typical Swedish traffic distribution over 24 h L_{den} is approximately the equivalent level plus 3 dB (Jonasson and Gustafsson, 2010) ($L_{den} \approx L_{Aeq,24\,h} + 3$).