Road noise charges based on the marginal cost principle

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INTRODUCTION

Noise emission from traffic is a growing environmental problem. The growth is both due to increasing traffic volumes, but also due to urbanization. In the end more people are being exposed to higher noise levels in their dwellings (Nijland et al. 2003).

To try to mitigate the effects of the noise the European Comission (EC) has decided that infrastructure use charges in the European Union (EU) should be based on the short-run marginal costs, which includes environmental costs such as noise, air pollution, global warming etc. If this is implemented in a manner where vehicles that cause less emissions and wear on the infrastructure pay less for the infrastructure use it will create an incentive to develop and use environmentally friendly technology. In the case of noise emissions this will lead to a demand for low noise technology such as low noise tires. It will also put a focus on the noise source itself, instead of solutions such as noise barriers and insulation windows. This is a positive development since it has been known for a long time that reducing the noise at the source is more cost effective than building barriers or improving façade insulation (Oertli 2000; de Vos 2003).

One key issue is of course to make relevant and accurate estimations of the social cost of noise, which is difficult since there are no easily observed market prices. Several approaches to evaluate the costs exist, either based on observed costs such as property prices or health care costs; or based on costs determined indirectly through questionnaires or interviews. In this paper the official valuations used in Sweden for cost/benefit analysis of infrastructure investments will be used (SIKA 2005). Two examples of other values that could have been used are the NEF system used in Denmark (Larsen 2005) and the European HEATCO values (Navrud 2005).

THE MARGINAL COST OF NOISE

As discussed above there are several possibilities to evaluate the cost of noise, or inversely the value of silence. Such models normally show the cost for one individual during one year whose dwelling is exposed to a certain noise level. This cost is dependant on the total traffic, which determines the total noise level. The marginal cost is the change in the social cost caused by adding the vehicle to be evaluated to the already present traffic. Thus it depends not only on the noise emission of the vehicle under study, but on the total traffic volume also. Expressed in mathematical terms the total social cost S of noise for a certain section of a road or railway line is

$$S = \sum C(L) , \qquad (1)$$

where $C(L)$ is the cost function describing the cost for one individual at sound level L and the sum is carried out over all inhabitants in the area. In other words it is simply the sum of the cost for all individuals exposed.

If we add one single vehicle to the traffic the noise level will increase, and we denote this increase ΔL . Then the marginal cost M can be calculated as

$$M = \sum C'(L)\Delta L \,, \qquad (2)$$

where $C'(L)$ is the marginal cost function, the derivative of the total cost function, and the sum is again carried out over all exposed inhabitants. The marginal cost function as Euro per person and year used here is plotted in Figure 1, note that the marginal cost is higher for high noise levels and that it is zero for noise levels below 50 dB (A-weighted equivalent level), and undefined above 75 dB. For a more detailed mathematical description see Andersson and Ögren (2007).

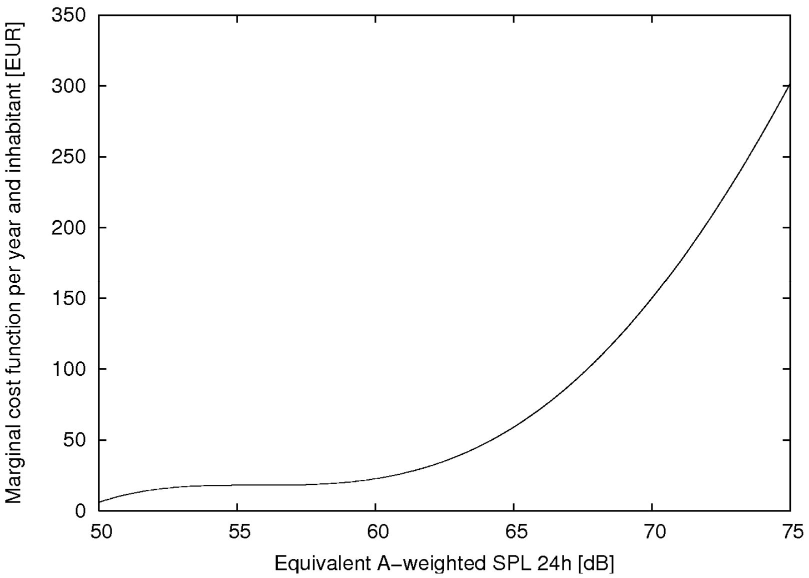

Figure 1: Marginal cost function $C'(L)$ in € per exposed person and year as a function of the equivalent A-weighted noise level

Adding a single vehicle to a large traffic flow such as a busy highway will only change the noise level by a tiny amount, but a lot of inhabitants can be exposed to this small change. On the other hand adding a freight train to a railway line with a low traffic volume, perhaps only a few freight train passages each day, may substantially increase the noise level. However, since the traffic is low fewer persons may be exposed. Thus the combined effect in economical terms is not straightforward to estimate.

THE MARGINAL ACOUSTICAL EFFECT

Calculating the marginal cost according to formula (2) requires that we know the sound level at the dwelling of each individual exposed to noise from the infrastructure section we are studying. Such data is normally obtained by using standardized noise calculation methods that calculate the noise level based on traffic volumes, the presence of screening terrain or buildings, meteorological conditions and so on. The change in sound level can also be calculated using the same methods, except if the vehicle is an experimental vehicle, for example a special low noise train. Then noise measurements or theoretically determined corrections are needed for the vehicle.

Fortunately the change in sound level expressed in dB is approximately constant and not dependent on distance, screening, meteorology and so on. Therefore the change can be taken out of the sum and we get

$$M = \Delta L \left(\sum C'(L) \right). \qquad (3)$$

As a result we have two factors, the first is the marginal acoustical change ΔL determined by the noise characteristics of the vehicle related to the total traffic, and the second Σ *C'(L)* is determined by the distribution of inhabitants along the infrastructure section and the total traffic. The details of the marginal cost function *C'(L)* is only relevant for the second factor.

CASE STUDY LERUM

Öhrström et al. (2005) conducted a study in the municipality Lerum close to Gothenburg on the Swedish west coast. Two major transport routes cross the municipality, one highway (E20) and one railway line (Västra Stambanan), both connecting Gothenburg and Stockholm. The area studied is sketched in Figure 2. In total 2,751 questionnaires were distributed in the area with a return rate of 71 %. The noise level from both road and rail traffic were calculated using the Nordic prediction methods. Many noise indicators were calculated, but here only the A-weighted equivalent level over 24 hours is used ($L_{AEq,24h}$). In Andersson & Ögren 2007 and Ögren & Andersson 2008) results are also given for the European indicator; level day evening night (L_{DEN}).

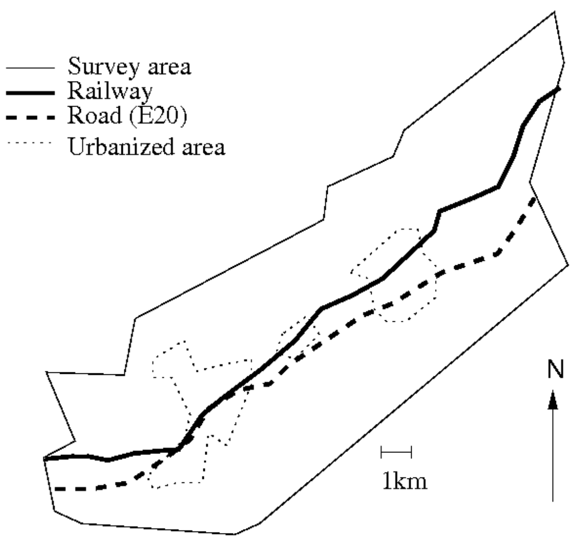

Figure 2: Sketch of the case study area in Lerum, Sweden

The number of exposed used in this paper is based on the questionnaire response on number of inhabitants in each household and on the percentage of households in the study compared to the total households within the research area, giving a total of

4,956 (4,671) persons exposed to $L_{AEq,24h}$ > 50 dB for road (rail) traffic noise. The sound level at each exposed dwelling is determined from the calculations mentioned above, and finally the second term in equation (3) can be calculated for road and railway traffic noise.

In order to calculate the marginal cost the first term in (3) we need the marginal change in sound level ΔL. In this study it is determined using the common European method HARMONOISE (de Vos et al. 2005) for road traffic and using the Nordic method for railway noise. The resulting marginal costs are given as noise charge per km in Table 1 together with the total traffic volumes.

Table 1: Estimated noise charges as Euro per km through the example area (Lerum, Sweden) in price level 2002

	Cars 2 axles 110 km/h	Trucks 5 axles 90 km/h	High speed train 200 m 135 km/h	Typical freight train 650 m 90 km/h
Total traffic 24 h	17 600	1740	34 (149[1])	41
SRMC Euro/km	0.00051	0.0059	0.033	0.30

[1] 34 high speed trains, and 149 counting all passenger trains together.

Note that it is difficult to use the calculated noise charges published here to compare the effects of railway noise and road traffic noise. One relevant comparison would be to compare the noise emission effect only, and then it is important to ensure that the number of exposed and length of the sections are identical, i.e. to remove the road and insert the railroad at the same position in the landscape. When comparing the two in the scope of a whole country or region, data for more than just one municipality would be necessary, and it would also be important to take factors such as transport volumes, mean velocity and so on into account.

DISCUSSION

The calculated values on the noise charges presented here are of limited value as such, since they only are relevant to the case study area, or other areas with similar population distribution, geography and so on. However, the approach as such shows that it is possible to estimate the marginal cost using standardized calculations methods for traffic noise combined with published valuation methods. The noise calculation method used in this paper is normally put to use for example during city planning, and the noise valuation method is in official use when performing cost benefit analysis of new road sections. As both methods are considered accurate and reliable enough to be usable in these contexts, the same should apply for estimation of relevant noise charges.

One interesting experiment is look at what economic incentives are available if road or rail noise charges are implemented in a way that permits lower charges for low noise vehicles. If we assume that the charges are based on the marginal cost principle, then using equation (3) we can easily estimate the effect of a vehicle with lower noise emission. Lowering the noise level with 5 dB gives a 70 % lower noise charge, a powerful incentive for the vehicle operator to introduce low noise technology. As examples 5 dB can be achieved by using low noise truck tires, and 8 dB is what the international railway union UIC estimates as the average reduction if a freight train is retrofitted from cast iron to composite brake blocks.

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