Comparison between road and rail noise cost per transported ton of cargo

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Summary

The social cost of noise is normally used when performing cost-benefit analysis while planning infrastructure projects or noise mitigation measures. In this study it is used together with the official noise prediction methods to estimate the acoustic and monetary impact of transporting 1 ton of cargo through two separate transportation corridors from Gothenburg to Stockholm in Sweden, one via railway and the other via truck transport. The noise cost per transported ton is approximately twice as high for rail transport due to higher noise emissions per ton and more exposed dwellings close to the railway.

1   Introduction

The social cost of noise is normally used when performing benefit-cost analysis (BCA) while planning infrastructure projects or noise mitigation measures. There are many national models for determining the yearly cost of being exposed at home to a certain noise level, and they typically assign a valuation that gives the monetary effect as a function of the equivalent noise level in dB at the exposed façade of the dwelling. In this study we have used the official noise values in use in Sweden for road and railway traffic (ASEK 5) [1] together with the official noise prediction methods [2-3] to estimate the acoustic and monetary impact of transporting 1 ton of cargo through two example transportation corridors.

2   Method

The method employed in this paper is described in detail in [4], but the basic steps are to calculate the noise level at each residence using the standardized Nordic prediction methods for road and railway traffic noise [2-3], and then calculate the marginal increase in noise level one additional train/truck passage causes. The short run marginal cost (SRMC) can then be calculated using the official valuation functions by adding up the contribution for each residence along the road or railway segment under study.

The main difficulty with applying the method in practice is the demand for accurate input data, not only on the location of all residences close to the road or railway line and the total traffic flows including speeds, but also on all potentially screening objects such as terrain, buildings, noise barriers and so on. In this study we have chosen to simplify the input data as described in Table 1. The data on the infrastructure was supplied by the Swedish Traffic Administration (Trafikverket) and the Swedish National Road Database (NVDB). The population data was supplied by Statistics Sweden (SCB).

Table 1. Input data with data source and approximate resolution

Input data	Source and resolution
Railway network	Trafikverket, GIS lines including traffic per 24h, 25 m resolution
Road network	NVDB, GIS lines including traffic per 24h, 20 m resolution
Population	SCB, total population (all ages) in 250 m squares

For each population square (with 250 m side) the population was assumed to be uniformly distributed over the whole area of the square, except that no population was assumed closer to the source than 25 m. No detailed data on ground attenuation, noise barriers and screening by terrain was available so instead a simplified method was used where the inhabitants in each square were assumed to be distributed over both directly exposed positions and other screened positions. The distribution function was modeled after detailed calculations in more than 1,200 receiver positions in five different railway exposed areas and three road traffic noise exposed areas in Sweden [5]. The accuracy of the simplification is hard to estimate, but a crude estimation using two reference areas not used for the fitting of the model with approximately 100 receivers gives an uncertainty of ±35 % on the calculated SRMC.

The reference train was assumed to be a 500 m long electrically powered train set with 25 wagons and a total load of 1,500 metric tons. The reference truck was assumed to be a diesel powered vehicle with a total load of 42 metric tons. Both

were assumed to travel at 90 km/h where possible, and at the maximum allowable speed if it was lower than 90 km/h.

The valuation functions from ASEK 5 [1] give the yearly cost in SEK (1 SEK is approximately 0.15 USD or 0.12 EUR, June 2013) per person exposed as a function of the equivalent 24h noise level on the façade of the dwelling. The valuation functions for road and railway traffic noise are shown in Fig. 1. For lower equivalent levels the rail function gives lower values, but the relation is reversed above 69 dB. Note that normally many more inhabitants are exposed to lower levels since the higher levels only can be found very close to the road or railway.
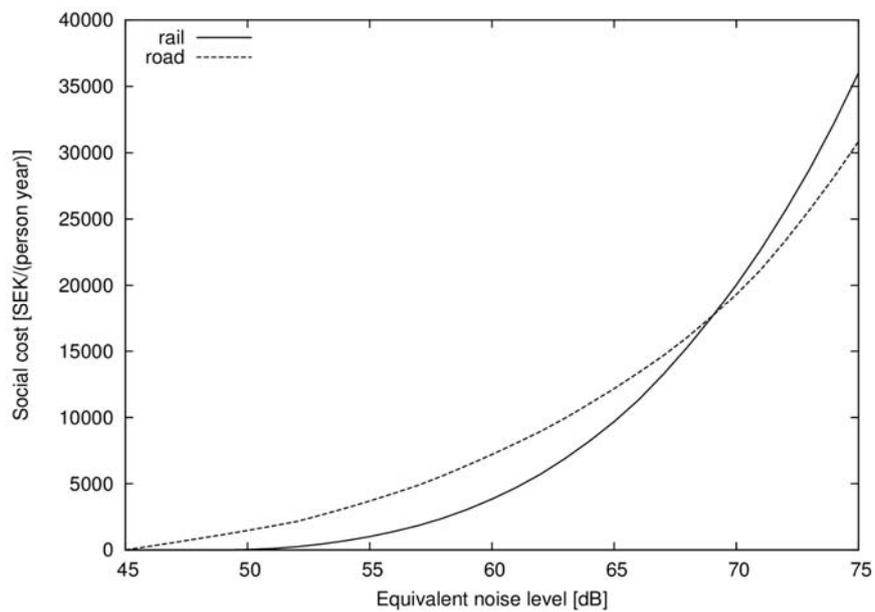

Fig. 1. Official Swedish valuation functions for traffic noise (from ASEK 5 [1])

3   Results

The calculated SRMC in SEK (price level 2010) is illustrated for each km between Gothenburg and Stockholm in the map in Fig. 2. The area of each circle is proportional to the SRMC or transporting 1 ton of cargo for a 1 km section of the road or railway. The total distance is 3 % longer for the road than for the railway, see Table 2. Note that the SRMC is close to zero in rural areas, and it increases sharply where the population density is higher. For areas where no inhabitants live closer to the source than 1 km the SRMC is identical to zero.

The results are also given in Table 2 and Fig. 3. The average marginal cost is determined where the cost is high, i.e. more densely populated areas, which gives a skewed distribution where a big part of the road/railway network gives almost no contribution. The number of inhabitants within 1 km of the source is about equal for both corridors, but note that more inhabitants live closer to the railway. This is probably due to the central location of the railway in many of the urban areas it is passing through, which is in contrast to the road which often circles around the urban centers.
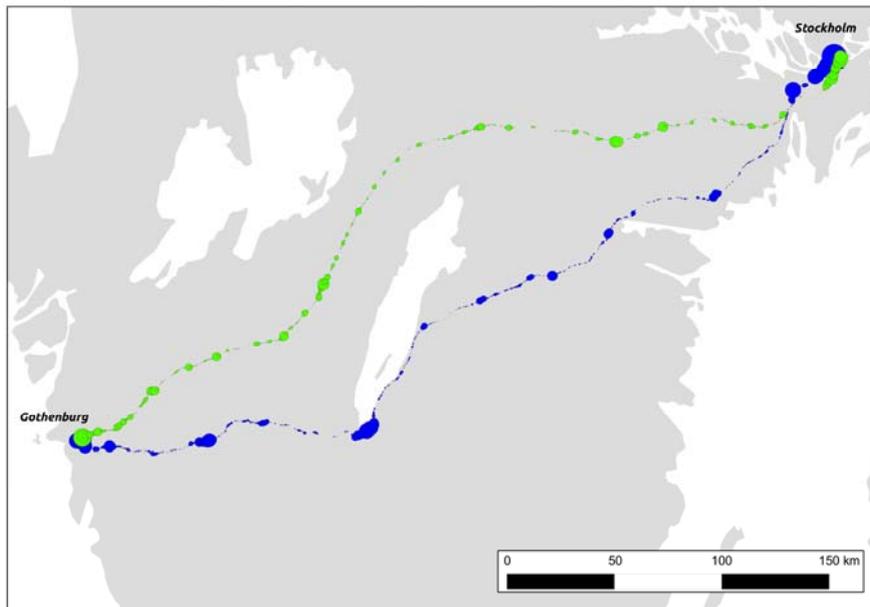

Fig. 2. Map of the marginal cost of transporting 1 ton of cargo between Gothenburg and Stockholm on railway (upper line, light gray) or truck (lower line, dark gray). The area of the circle is proportional to the SRMC.

Table 2. Description of the transport corridors and calculated SRMC

Parameter	Truck (road)	Freight train (railway)
Length [km]	471	458
Average traffic 24h	27 500	122
Population within 1km	409 000	400 000
Population within 250 m	61 000	88 000
Noise emission SEL at 25 m and 90 km/h [dB/ton]	71.9	75.1
SRMC 1 vehicle [SEK/km]	0.13	10
SRMC 1 ton [SEK/tonkm]	0.0031	0.0069
SRMC 1 ton median (max) [SEK/tonkm]	0.0002 (0.08)	0.0005 (0.20)
SRMC low noise 1 ton [SEK/tonkm]	0.00098	0.00069

The last line in Table 2 gives the result for a new calculation assuming a low noise variant of the vehicles. The freight train is assumed to be retrofitted with composite brake blocks (K-blocks) for an overall improvement of 10 dB, see [6]. The truck is assumed to be equipped with low noise mufflers and tires, giving an improvement of 5 dB according to [7]. For these low noise variants the railway transport has less marginal cost than road transport, showing the important potential for improvement of noise emission of freight wagons.
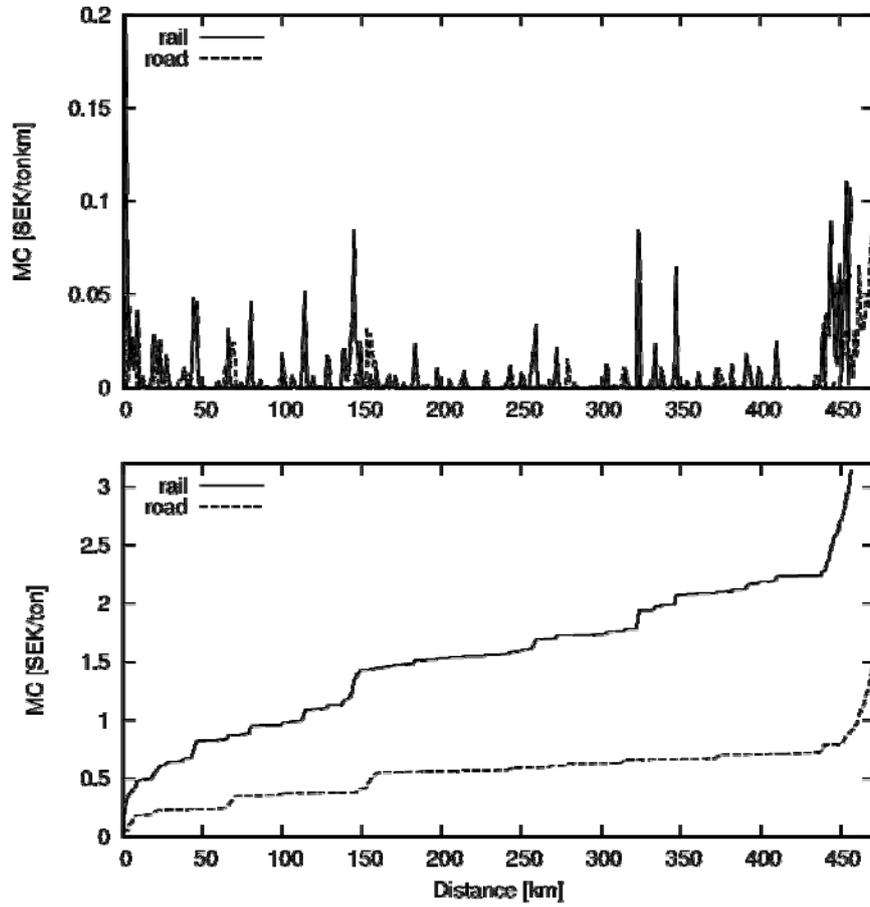
Fig. 3. SRMC for transporting 1 ton of cargo between Gothenburg and Stockholm. Upper picture is cost in SEK/tonkm, lower is accumulated cost in SEK/ton when starting from Gothenburg.

4 Discussion

The average marginal cost is approximately twice as high for rail transport of 1 ton of cargo. This is perhaps surprising considering that the valuation function gives a lower value for railway noise, but it turns out that the higher noise emission per transported ton together with the higher number of inhabitants close to the railway as compared to the road more than compensates for the lower valuation. The potential for reduction is demonstrated by the fact that railway transport gives lower marginal costs per ton if K-blocks are used. If a railway noise charge scheme is implemented where brake type is taken into account it would be a strong incentive for freight vehicle operators to retrofit their train sets using low noise technology. The same is of course true for truck transport.

Acknowledgements

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