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Value for money in road traffic noise abatement

Ingunn Milford[a], Sigve J. Aasebo[b], Kjell Strommer[c]

[a]Norwegian Public Roads Administration, Brynsengfaret 6, Oslo, Norway, *ingmil@vegvesen.no*
[b]*Ernst & Young AS, Dronning Eufemias gate 6, Oslo Atrium, P.O. Box 20, NO-0051 Oslo, Norway*
[c]*Swedish Transport Administration, SE-78189 Borlänge, Sweden, kjell.strommer@trafikverket.se*

Abstract

Noise from road traffic has over the years become a major problem in society. To investigate possible strategies for governments to pursue on noise abatement, and give a recommendation on which strategy will be most beneficial for society at large, this paper focuses on reducing noise annoyance and the cost effectiveness of different noise abatement measures when it comes to changing one “annoyed” by road traffic noise to one no longer “annoyed” by road traffic noise.

When viewed over a 20 years perspective, the cost of reducing the annoyance by one varies from 15 euros to 1800 euros per year depending on the measure chosen. Handling noise at source is the most cost effective approach to reduce noise annoyance, and especially to address the vehicle noise. The measures investigated are noise barriers, facade insulation, quieter road surfaces and development and production of quieter vehicles

Keywords: noise abatement; costs; annoyance; noise barriers; road surfaces; vehicle noise limits

1. Introduction

Road traffic noise has over the years become a major problem in society. The steady increase is mainly due to a constant growth in traffic, and in addition, noise caused by vehicles and tyres have not been reduced in recent years. Urbanization, and people moving from rural, quiet areas to noisier environments, also leads to increased exposure. The purpose of this paper is to provide support when strategies, plans and positions for future actions are discussed in order to reduce adverse noise effects more effectively.

This paper is the work of CEDR Project group Noise. CEDR, Conference of European Directors of Roads, is a non-profit organisation with 24 member countries. As road authorities, the CEDR Noise

Project Group has in this work not tried to go into details concerning vehicles and their noise behaviour, but strictly stick to information available in the TNO-report (TNO, 2011), assigned by the EU Commission, DG Enterprise and Industry.

The paper compares the effectiveness of different types of noise measures to reduce noise disturbance and adverse effects in relation to the cost of the measures. The measures investigated are noise barriers, facade insulation, quieter road surfaces and development and production of quieter vehicles.

2. Noise exposure in Europe

This paper is based on noise exposure data from the European Environmental Agency (EEA) and the European Topic Centre on Land Use and Spatial Information (ETC LUSI), on behalf of the European Commission. This is the latest noise exposure data for Europe..

For noise exposure affecting all people of Europe, we have adjusted the distribution of noise exposure of agglomerations (given in the EEA data) to reflect the fact that the total population of Europe are a little less noise exposed compared to people living in agglomerations. This approach is in accordance with the TNO report, where it is argued that 44 % of the people are exposed to noise levels above 55 dB in total. Data from EEA for agglomerations report that 51 % of inhabitants in agglomerations are exposed to noise above Lden 55 dB.. Some roads have restrictions or very low traffic flow, and as a consequence about 10 % of the population is hardly exposed to any traffic noise (TNO, 2011). In this paper no traffic noise exposure equate to exposure less than 40 dB.

There is currently no information regarding how the internal distribution between the three noise bands in the interval 40-54 are (40-44, 45-49, 50-54 dB). Hence, the choice has been to use an even distribution, see figure 1, which fits quite appropriately in with the more substantial noise interval data tends to be on the conservative side and surely does not overestimate the noise exposure. The noise exposure distribution of people (in percent) living in agglomerations is used for calculation of measures mainly implemented in agglomerations or densely populated areas. The noise exposure distribution for all people of Europe is used for the calculations of benefits for vehicles. This because vehicles influence the entire road network, not only agglomerations.

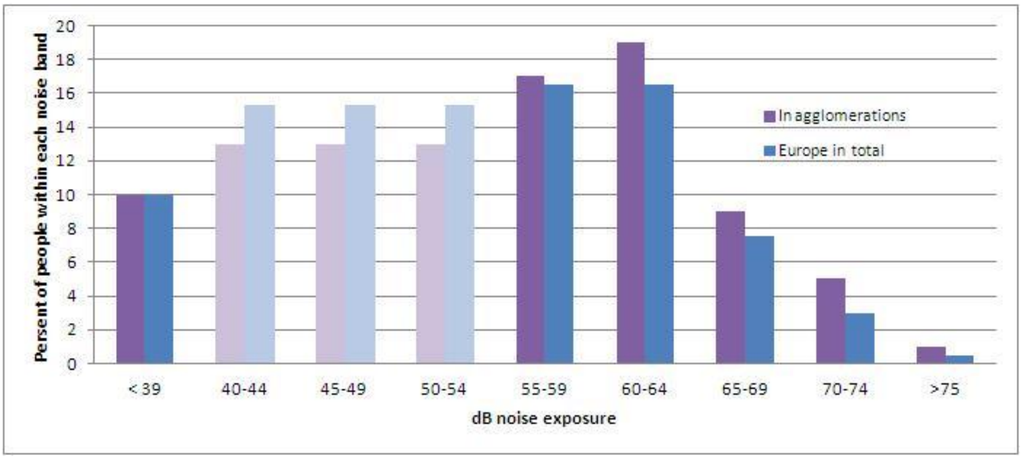

Figure 1. Distribution of people (in percent) in noise bands when inside agglomerations and for Europe in total.

3. Annoyance

To investigate possible strategies for governments to pursue on noise abatement, and give a recommendation on which strategy will be most beneficial for society at large, this paper focuses on reduction in annoyance. Out of the 514 million people in Europe in 2010 (EU27 + CH + NO) there are 98 million annoyed by road traffic noise. Any measure implemented will change the number of annoyed at a certain cost. The cost is divided by the number of the no longer "annoyed" as a result of implementing a certain measure. This is the cost of reducing the noise annoyance score by one.

3.1. Why annoyance?

It is not easy to find an exact monetary value when calculating the benefit of noise reduction, as it varies a lot between different countries. However, the degree of annoyance is less discussed. According to WHO (2011) noise annoyance is widely accepted as an end-point of environmental noise that can be used as a basis for evaluating the impact of noise on the exposed population. A definition of annoyance is given by the European Commission Noise Team (2000): *Annoyance is the scientific expression for the non-specific disturbance by noise, as reported in field surveys.* By choosing annoyance as our measurement for noise impact, we restrict the noise problem to concern only those negatively affected by noise at a given noise level.

3.2. How annoyance is calculated

The noise exposure data is used on the following annoyance equation for road traffic noise (Miedema and Oudshoorn, 2001):

$$\%A = 1{,}795.10^{-4}(L_{DEN} - 37)^3 + 2{,}11.10^{-2}(L_{DEN} - 37)^2 + 0{,}5353(L_{DEN} - 37)$$

where A is the percentage of the respondents who at a given noise level L_{DEN} will find traffic noise annoying.

For every measure evaluated we have first calculated the number of people affected by the noise reduction, and then the reduction in annoyance per noise band.

4. Method

4.1. Noise abatement measures

The measures investigated are:

1. Noise barriers
2. Facade insulation of dwellings
3. Porous road surfaces (single and double layer)
4. Thin layer surfaces (dense)
5. Vehicle noise limits for type approval

The 17 European countries participating in the CEDR Noise Project Group have been consulted, using questionnaires on noise measures, about effects and costs of the different measures. For most of the abatement measures, the Netherlands had the data with the highest precision level. These data where principally supported by the other countries, and jointly agreed upon. The data for changes in noise exposures and annoyance from vehicles is derived from the TNO report, 2011.

4.2. Assumptions

To reduce complexity and uncertainty some assumptions have been made:

- Accurate information on noise levels for all people in Europe exposed to road traffic noise is not available. Hence, a best estimate of noise exposure in 5 dB intervals has been used. As a point of reference, a representative value somewhat lower than the average for each interval is identified. This simplifies the calculation of annoyance, and gives a satisfactory accuracy for our purpose.
- Facade insulation (changing windows), which only has a noise reducing effect indoor, are given the same benefit (the same reduction in noise annoyance) as if the outdoor level was reduced. This gives an over estimation of the effect on noise annoyance for façade insulation.
- Noise reduction of porous asphalt varies quite much during its lifetime, and a representative value for the average noise reduction is therefore chosen. The average noise reduction also depends on what is used as a reference pavement, which can vary from country to country. This counts for both porous asphalts and thin layer surfaces.
- Noise barriers are assumed to be applied mostly along motorways, and are therefore given a height of 4 meters. However, both the height and the noise reducing effect varies for noise barriers in the field.
- A decrease in the type approval limit for vehicle noise will be implemented gradually and the effect will also be present beyond our planning horizon of 20 years. These effects are, however, not included in the calculations.

4.3. Discussion on the cost calculations

To make the measures easily comparable, a total spending of € 6 billion in net present value is compared for each type of measure. This amount of money is chosen since the “option 5” in the TNO report on vehicle noise is estimated to cost about € 6 billion (2011). “Option 5” implies stricter noise limits for vehicles, giving an average noise reduction for the vehicle fleet of 3.1 dB when fully implemented. The “option 5” was in spring 2011 presented in EU working groups on noise as the recommended suggestions for new type approval limits for vehicles, and therefore represent an appropriate amount of money as basis for evaluation of different noise mitigation measures in the present study.

The additional costs of implementing measures are equal to the costs of the changes in level of annoyance. In the case of resurfacing the roads, only the additional costs of implementing a noise reducing surface and the additional costs for maintenance are included in the calculations. In the case of façade insulation, only costs due to noise considerations in the refurbishing a dwelling is used, and matched with the reduction in annoyance for the people living in the dwelling.

When implementing the different measures, the investment costs are mostly due in year one (immediately). The maintenance costs are distributed over the 20 years calculation period. This planning horizon fits the data accessible from the TNO report, and has been implemented when calculating all other measures. The cost distribution (investment and maintenance) over time is expected to vary. The measures without any maintenance costs or need for remaking in a 20 year period, will have all € 6 billion spent on the initial investment. But for vehicles, it is expected to be a five year research and development period followed by a larger production cost per vehicle when the new technology enters production

(TNO, 2011). Due to the large difference in cost profile between different measures, net present value (NPV) is calculated to make them comparable, using a discount rate of 4%.

4.4. People affected

The reduction in calculated annoyance, and the corresponding cost effectiveness of a noise barrier or a noise reducing road surface will depend on the number of people affected. This further depends on the type of road. Table 1 illustrates the variation between different road categories and the number of inhabitants per km alongside each category. The numbers of exposed people per km are estimates from noise mapping and demographic data. The data in table 1 is used to see the potential for different noise measures and to calculate how many people will be affected. For example, noise barriers will be most effective when used on urban motorways. When € 6 billion are spent it is possible to construct 2584 km of noise barriers. Assuming that the money is spent most effectively, i.e. alongside urban motorways, this gives 2584 km * 1000 people/km = 2 584 000 million people getting a noise reduction due to new noise barriers.

Table 1. Type of roads and how they are categorized (TNO report, 2011)

Road type	Residential (urban/ suburban)	Residential (urban/ suburban)	Main roads (urban/ suburban)	Main roads (urban/ suburban)	Arterial roads (urban/ suburban)	Urban motorways (urban/ suburban)	Rural motorways	Rural roads	Total
Traffic type	intermittent	free flow	intermittent	free flow	free flow	free flow	free flow	free flow	
Speed range	V<50	V<50	V<50	V<50	50<V<70	70<V<120	80<V<130	50<V<100	
Full road length(km)	581210	1180033	49818	101146	100643	5032	95610	2918633	5032125
Percentage of total road network	12%	23%	1%	2%	2%	0,1%	2%	58%	100%
Estimated avg. exposed inhabitants/km	250	250	500	500	500	1000	40	20	

After calculating the possible volume for each measure by spending 6 billion € and the number of people affected, these inhabitants are distributed in noise bands, in accordance with figure 1, and paired with the noise reduction they will get from the given measure. These figures are used to recalculate the number of people annoyed.

5. Results

Spending the same amount of money in Net Present Value (NPV) on each measure makes the different measures directly comparable when it comes to costs. This way, it is possible to only compare the benefits in making a cost benefit analysis. The initial investment on each measure will depend on the spending needed on maintenance, during the 20 year period used for comparison, to maintain the noise characteristics of the measure. This initial investment available is divided by the cost per unit to get the potential volume of each measure possible to produce. Then, the potential volume of each measure is multiplied by the number of people affected per unit of volume, to get the total number of people affected. A summary of the results is given in table 2.

For vehicles, all people exposed to traffic noise are affected, and they are distributed alongside roads as given in table 1.

Table 2. The initial investment costs for the different abatement measures leads to a given amount of noise barriers, new windows etc, and from this the number of people who gets a noise reduction is calculated.

	Initial investment in billion €	Cost per unit	Volume of abatement measure	People affected per unit	People affected (million)
Noise barrier	3,627	€ 1 600 per m	2 584 km	1000 per km	2, 6
Facade	6	€ 3000 per dwelling	2 mill dwellings	2,2 per dwelling	4, 4
Porous asphalt single layer	2,2072	€ 2,14 per m2	40 232 km	1000 per km	40, 2
Porous asphalt double layer	1,667	€ 10,45 per m2	6 380 km	1000 per km	6, 4
Thin layer	4,799	€ 1,5 per m2	177 740 km	500 per km	88, 9
Vehicle op. 5	5,993		All vehicles	All people exposed to traffic noise (> 40 dB)	463,0

The figures in table 2 are used for recalculation of the number of people annoyed in Europe, according to the annoyance formula used to calculate the initial annoyance. Table 3 sums up the calculated change in annoyance, and the cost of reducing the annoyance score by one, if € 6 billion in net present value is spent on any of the given measures.

Table 3. Overview of how an investment of € 6 billion will affect the reduction in noise annoyance, and the cost of reducing the annoyance score by one (cost per year)

Measure	Noise reduction (dB)	People affected (million)	Reduction in annoyance	Cost of reducing annoyance by one (per year in €)
Noise barrier	8 – 1	2,6	165 000	1800
Façade insulation	8	4,4	764 000	400
Porous double layer	4	6,4	330 000	900
Porous single layer	2	40,2	1 086 000	280
Thin layer asphalt	2	88,9	2 400 000	125
Vehicle noise	3,1	463,0	19 664 000	15

6. Discussion

The CEDR Noise project group has compared the costs of different abatement measure which can be used to reduce the noise annoyance in Europe. This has been conducted by comparing data from a report on vehicle noise limits and noise emission from vehicles (TNO report, 2011) with the experience of noise abatement costs and effectiveness of measures used traditionally by road authorities (represented by CEDR Noise project group). This information is then used on noise exposure data and formulas for calculation of annoyance.

The most cost effective measure to reduce noise annoyance is to reduce the vehicle noise. It is more than eight times more costly to improve the road surfaces. Noise reducing road surfaces (with the exception of double layer porous asphalt) are about half the price of facade insulation, in the form of window upgrade. The most expensive measure is noise barriers. The noise barriers are, however, as distinct from façade insulation, also helping to reduce noise in the outdoor areas.

The chosen unit, noise annoyance, is not always the most appropriate unit to use when choosing noise abatement measures. Sometimes a severe noise reduction is required, and local measures are the only alternative. Such measures are of importance for adapting to local needs. Local measures, like noise barriers and façade insulation, will always be of great importance when helping those exposed to the highest noise levels, where e.g. 2 dB is not enough to give a satisfactory noise level and/or comply with a regulation.

It should be stressed that assumptions have been made to simplify the calculations. There will be further work to e.g. to look at the effect of façade insulation, and the consequence of reducing only the indoor noise level compared to the outdoor noise levels. Still, the findings seem to be very robust and the simplifications and limitations are not enough to invalidate the conclusions.

6.1. Ongoing discussion on European regulations and directives

Noise emissions of four-wheel motor vehicles are addressed by Directive 70/157/EEC and the equivalent UN/ECE Regulation No. 51. These regulations are now under revision, after almost 20 years of no changes to the limit values. A proposal for a new EC regulation on sound level of motor vehicles was released in December 2011, and will presumably be treated in the European Parliament and the Council during spring/summer 2012. At a meeting in Brussels in March 2011, the Commission presented a proposal for the CARS 21 working group 4 which is in line with "Option 5" in the TNO report (2011). Hence, this option has been the basis for this work in CEDR Project Group Noise

7. Conclusions

To investigate possible strategies for governments to pursue on noise abatement, and give a recommendation on which strategy will be most beneficial for society at large, this paper focus on reduction in noise annoyance and the cost of it. Table 4 lists the main results of the work of the CEDR Project Group Noise, showing, that seen in a 20 years perspective, the cost of reducing the annoyance score by one varies from € 15 per year to € 1800 per year depending on the abatement measure chosen. In conclusion, handling noise at source is by far the most cost effective measure to reduce noise annoyance. In this respect, addressing the noise emission from vehicles is most effective. Although assumptions have been made to simplify the calculations, the findings are very robust. There is ongoing work in the EU and ECE to update the current vehicle noise emission standards, and the present results illustrates that more stringent standards to reduce noise from vehicles will give very good value for money.

Table 4. Possible noise abatement measures, their most important attributes and the cost of making one less annoyed by road traffic noise for one year

Measure	Noise reduction	Reduction in annoyance score	Limitations on use	Cost per reduction in annoyance (per year)
Vehicle noise reduction	3 dB	19, 7 mill	None	€ 15
Thin Layer asphalt	2 dB	2,4 mill	Not motorways (with high speed and density)	€ 125
Porous asphalt single layer	2 dB	1,1 mill	Only motorways (high speed)	€ 280
Façade insulation (2 windows)	8 dB	0,8 mill	None (indoor effect only)	€ 400
Porous asphalt double layer	4 dB	0,3 mill	Only motorways (high speed)	€ 900
Noise barrier	8-1 dB	0,2 mill	Not in city streets (city center?)	€ 1800

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