Best practice for cost/benefit based decisions on abatement of traffic noise

Bert Peeters[1], Gijsjan van Blokland[1]

[1] M+P consulting engineers, Vught, The Netherlands

Corresponding author's e-mail address: bertpeeters@mp.nl

ABSTRACT

Noise from road, rail and air traffic is a major source of annoyance, causing serious health issues in Europe. Noise abatement measures exist at all levels, such as noise barriers, rerouting or investments in silent vehicles. Decision makers implementing these measures need to balance the costs of the measures and the benefits for society. The EPA Network Interest Group on Traffic Noise Abatement (IGNA) has investigated several methods for decision making, based on cost/benefit analysis. A survey shows that well-defined, sophisticated methods exist in some countries, while other countries have no regulations for noise abatement decisions.

The key elements from existing systems are explained. We show what costs are included and how to calculate these. We demonstrate how to quantify the benefits in terms of annoyance and public health, and recommend values to be used. We present how costs and benefits are balanced, including other criteria that may influence the decisions. From these investigations, we propose a best practice which could be a guideline for countries and organizations that wish to increase transparency and fairness in noise abatement policy.

INTRODUCTION

Traffic noise has a severe impact on the EU population [1]. RIVM has estimated that about 21 million people in the EU are severe annoyed and about 14 million are severe sleep disturbed [2]. Moreover, the repeated excitation of the nervous system by traffic noise is found by the WHO to be related to frequent occurrence of ischaemic diseases leading to premature deaths. The impact in terms of lost healthy life years (DALY's) is estimated to be 640.000 per year. The results shown in Figure 1 [3] depict the impact of traffic noise on the EU33 population, living in the agglomerations as well as along the major traffic routes, and including the effects at noise levels below the reporting thresholds of the END.

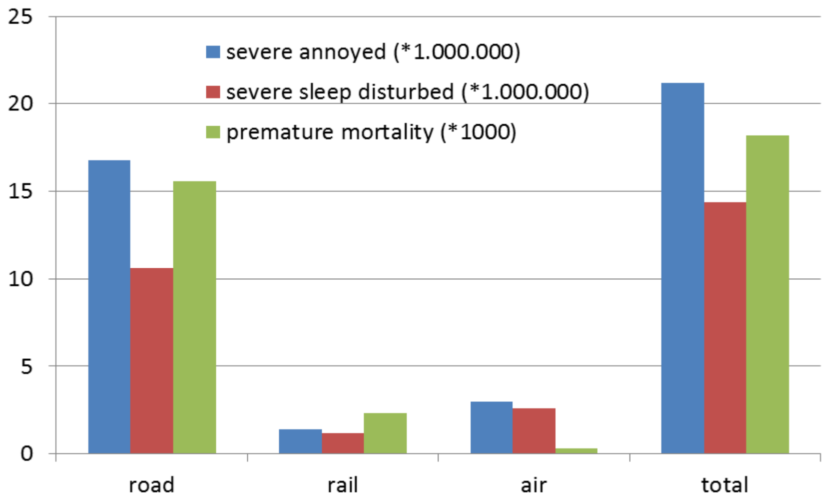

Figure 1: Impact of traffic noise on the European population: estimates of number of people affected in EU33, extrapolated to 100% coverage and including estimated impacts below 55 dB L_{den} / 50 dB L_{night}

The annoyance, sleep problems and health impact caused by traffic noise also has economic consequences. Besides the costs of treatment and medication, and the loss of productivity, an economic consequence is the loss of property value. People are willing to pay for a less noisy environment, or they may choose to accept to live next to a noisy road, but only because these dwellings are more affordable. The total costs of traffic noise, both directly related to health issues and indirectly related via the preference of people for a quieter environment, is estimated to be about 46 billion euro for the EU17 (price level 2000) [5].

The issue of traffic noise exhibits a strong international component. The technologies used for vehicles and infrastructure and the configuration of source and receiver show large similarities around Europe. The noise emission of the sources (planes, trains and automobiles) is regulated on European or worldwide scale. These international characteristics have led to international cooperation on the technologies and policies to control the emission of traffic noise and to suppress its impact on the population.

The European Network of the Heads of Environment Protection Agencies (EPA Network) have in 2010 started an Interest Group on Noise Abatement (IGNA). IGNA has since then published a series of four progress reports on noise abatement for road, rail and air traffic noise, available from the EPA web site (http://epanet.pbe.eea.europa.eu/). These studies are focused on the technologies involved and the technical regulations steering them.

The IGNA notes that not only the availability of technology is of relevance for an abatement measure to be applied, but also the balance between costs and benefits: are the costs of the measures balanced by the benefits, in terms of lower noise exposure and improved wellbeing of the population? A recent report of the IGNA therefore focuses on how the costs of measures can be evaluated and in which ways the benefits can be defined. The report also addresses the different ways the cost/benefit ratio is taken into account in the government's decisions to implement a mitigation measure.

The need for cost/benefit based decision methods

The IGNA study on cost/benefit methods included a survey around the EEA's EIONET network members, which include the national Environmental Protection Agencies from 33 countries in Europe.

The survey results demonstrated that although traffic noise is an international issue, the approach to it is mainly national. There exists no European harmonized limit value, as is the case for air quality. There is no European law, or funding, that might coordinate national policies. Each country has its own noise laws and shows different attitudes in terms of how serious the issue is taken, what types of measures are applied, what budgets are made available to reduce the noise exposure and by which procedures and policies the budgets are attributed to specific projects.

Part of the issue observed in the survey is the fact that the negative effects of noise are intangible subjects and difficult to quantify. For instance, annoyance and health are individual effects: a noise level of 60 dB L_{den} may seriously bother one person, while somebody else is unaffected by it. Also, rail traffic with the same L_{den} level as road traffic will generate less annoyance, while air traffic at that same level will be considerably more annoying than road traffic. Even within a transport category a distinction is found between the noise sensitivity in inner city and rural areas [6].

These issues make it difficult for decision makers clearly explain to the public where they should spend money, and what effects can be expected from these investments. The responses to the IGNA survey indicate that many governments wish to have a clear and objective method for determining costs and benefits, as well as a best practice to evaluate the ratio of costs/benefits and how decisions can be based on that.

In this paper the methods that can be used to balance costs and benefits will be explained. Methods on how costs are to be defined and calculated, and how the benefits can be quantified in term of health and financial consequences will be presented. Finally suggestions for best practice methods will be given.

METHODS

Five decision methods for noise abatement measures have been identified. In a previous paper [9] these methods have been explained and compared. The methods mainly differ in the type of criterium used for the decision and in the method (and unit) used to quantify the benefits.

Three of them, given in Table 1, are treated in this paper. The two methods listed below, have also been identified previously, but are left outside the scope of this paper because they are not considered 'best practice':

- <u>cost minimization</u>: this strategy aims to find the cheapest option that fulfils the legal or desired noise limits. It is not considered best practice because it contains no consideration of increasing or diminishing returns: it could be that with a little extra budget, a great additional noise reduction could be obtained. Or it could be that a lot of budget needs to be spent to bring the very last dwelling below the limit. This last disadvantage has been reported by some countries in the survey to lead to disproportionally high costs;
- <u>multi-criteria design analysis</u>: in theory, MCDA could be a very good solution for cost/benefit decisions, because (i) it allows to include other criteria that are difficult to quantify, such as aesthetic or socio-cultural values, and (ii) it increases public involvement and participation, which in turn may increase acceptance and reduce annoyance. Since, however, we have not been able to find any good, recent applications of MDCA methods for noise abatement, we will not recommended as best practice.

Table 1: Overview of three decision methods treated in this paper

method	decision criteria	remarks
cost-effectiveness (CEA)	optimal ratio between noise reduction and costs	for noise, the output parameter is usually the noise reduction (in dB * persons)
cost-utility (CUA)	optimal ratio between public health (utility) parameter and costs	the health impact contains various endpoints; the impact is expressed in DALY/QALY units
cost-benefit (CBA)	optimal ratio between multiple, monetarized criteria, summed to a single value, and costs	every benefit is translated to monetary units, e.g. using WTP or VSL for health effects

Cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA) are commonly used for decisions on costs and benefits of noise abatement. For the best practice evaluation, cost-utility analysis (CUA) is also included as an alternative, mainly for decision makers that want to express the direct public health benefits instead of addressing these only as an economic issue.

COSTS OF MEASURES

In almost all cases taking measures implies creating costs. These can be direct costs that are attributed to the measures itself and carried by the one taking the measures, or indirect costs that are caused by the measures but carried by other parties.

A clear example of direct costs are the investment costs of a noise barrier but also the maintenance costs over the life time of the barrier, defined as Net Present Value. Indirect costs can be related to longer traveling time or travelling distance by users of the infra structure. But besides costs, savings can also be identified. A recent study by M+P showed, as an example, that noise barriers lower air drag of large trucks by reducing cross wind components.

We have questioned 33 European parties on their implementation of costs of measures. We received 19 responses, coming from 15 different countries. The results concerning definition of costs are presented in Figure 2.

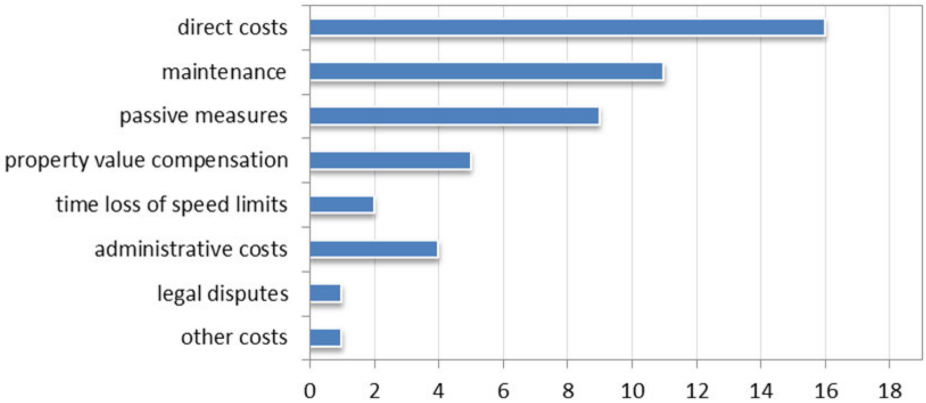

Figure 2: Cost categories included in the cost considerations. The direct survey responses are included; the number indicates the amount of responses that included the cost category.

The graph shows the variation in components that are taken into account. Nearly all questioned parties use direct costs. About 2/3[rd] also include maintenance of the measures. Only a few parties take indirect costs, such as increased traveling costs, and secondary costs like administration and legal procedures into account.

About half take passive measures, such as façade insulation, into account when balancing costs and effects. It is supposed that in a number of situations, the noise exposure of the facade is the objective of the measure and thus sound insulation may be regarded as an extra. This measure has an interesting aspect though. Taking the measure implies costs for the owner of the house or infrastructure manager. In several cases it may result in better heat insulation and thus costs saving for the user of the house and included in the calculation as negative indirect costs.

In five cases the cost definition includes a compensation for the loss of property value or reduced living quality. Although not directly a cost of a measure, it is included in the cost part since one might regard it as the cost of a zero measure. In the balancing of measures against each other, it becomes clear that also a zero measure has costs attributed to it.

VALUING THE EFFECT

The three methods taken into account in this paper differ in the definition of the targeted effect. The cost-effectiveness uses a rather fixed definition of the effect of the measure. The cost-benefit is more open, as long as the effects can be defined in monetary terms. The cost-utility is, usually, more direct in that it expresses the direct health effects, and more open in the sense that it may include any health effect, as long as a unambiguous measure can be applied.

Benefits in cost-effectiveness analysis

Application of the cost-effectiveness analysis implies a clear definition of the target of the measure and its effect. Different countries use different definitions. In Denmark the Noise Exposure Score is used, based on a noise level related factor (noise exposure unit, NEU) per dwelling times the number of dwellings. The NEU is highly non-linear, 0.1 for 60 dB L_{den} and more or less doubling every step of 5 dB. The Dutch cost-effectiveness measure is also the number of dwellings times a noise level related factor, but this factor is linear with a small incremental step at 65 dB, giving some more emphasis on dwellings > 65 dB L_{den}. It is clear that the Danish method will favor measures aimed at reducing the highest levels, more so than the Dutch method.

The Danish method can be traced back to monetary terms. One Noise Exposure Unit equals the sum of the nuisance costs of € 1,862,-/yr and health costs of € 1.907,-/yr to a total of € 3,770,-/yr, but since the target is fixed and defined as an abstract value, it should be considered as a cost-effectiveness method. For the Dutch method, there is no direct link between the noise related factors used and the monetary, economic value.

Effects in cost-benefit analysis

Cost benefit analysis is applied when the effects of the measures are defined in monetary terms, as are the costs. Germany, Switzerland, United Kingdom and others apply such a system to evaluate the effect of measures against the costs and to decide on the application of the measure. The method can involve the application of a strict definition of the noise costs as is the case for Germany, or a range, as is the case in the UK.

The German guideline uses a fixed figure of € 30,- per person/dB/yr. The UK applies a level related cost factor of about £ 50,-/household/dB/yr for road traffic noise at 50 dB L_{den} to £ 180,-/household/dB/yr at 80 dB L_{den}. Surprisingly, the figures for air traffic noise are lower while the annoyance versus noise level curve is steeper. The Swiss guideline takes the ratio of the costs and the benefits in monetary terms into account (defined as ‘efficiency’) but in addition also measures how much of the target is realized (effectivity). The higher the percentage of realization, the lower the allowed efficiency is allowed to be: the efficiency times the effectivity is the decision parameter.

A characteristic of the cost-benefit method is the variability in valuing benefits. Literature shows a wide range of figures found for such items as the willingness-to-pay (see [8]) or the value of lost healthy life years [7]. The UK method accounts for this by letting the user choose between a low, medium and high estimate.

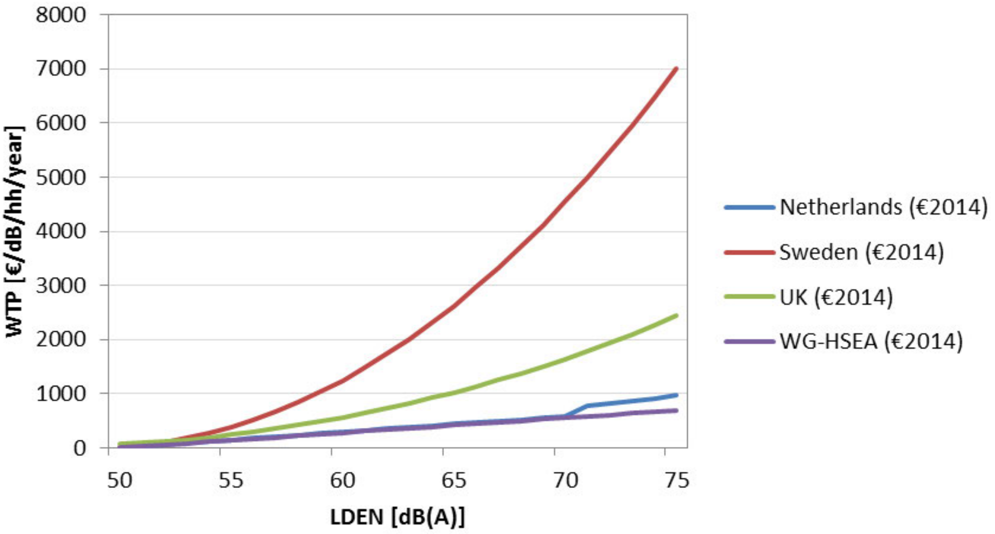

Figure 3: Examples of monetarization values used in different countries; values indicate the WTP for the total noise costs (annoyance plus health costs) [3].

Yield in cost-utility analysis

This method uses a virtual health related quantity as yield of a measure or a policy. Usually this is the DALY (Disability Adjusted Life Years) or the QALY (Quality Adjusted Life Years). These quantities combine all relevant health effects due to noise exposure. The World Health Organization has published an overview of such health effects and has formulated a method to interpret these health effects in loss of DALY's [4]. To account for the fact that different diseases and disturbances have less impact on the overall human health, the number of DALY's is found by multiplying the number of highly sleep disturbed or highly annoyed people, for instance, by the Disability Weighting factor (DW) for that effect. As an example: 1000 highly annoyed people with a DW of 0.02 present the loss of 20 DALY's. The uncertainty in predicting health effects due to noise annoyance or sleep disturbance is addressed by giving a lower, medium and higher estimate for the DW. For the two most important effects, annoyance and sleep disturbance, the range in values for DW's is given in Table 2. It is common to present not only the results using Medium DW's, but to report also higher and lower results.

Table 2: Disability Weighting for sleep disturbance and for annoyance due to environmental noise. Given is a lower, medium and higher estimate.

	Disability Weighting (DW)		
	Lower DW	Medium DW	Higher DW
Highly sleep disturbed	0.04	0.07	0.10
Highly annoyed	0.01	0.02	0.12

The DW for ischaemic heart diseases and acute myocardial infarction is in the order of 0,4 with less variation, but for these endpoints there is more uncertainty in the dose-effect relations. The average increase in the chance suffering that type of disease is about 20%, but the reported uncertainty ranges from minus 20% to plus 60%.

Since more evidence is coming available on this topic, it is expected that the WHO will update this publication in 2017 or 2018. The reader is certainly advised to use the latest WHO guidelines and values, as soon as these are available.

BEST PRACTICE EVALUATION

The best practice is evaluated based on the six properties listed in Table 2. For each of the three methods a rating of the method for that property is given.

- The implementability is considered highest for the cost-effectiveness method, since it only requires to specify how to calculate the effectiveness measure. The Dutch or Danish examples may serve as a guideline. Cost utility has a low rating since the utility part is still subject to nonstandard approaches. Also, the margins in disability weightings are difficult to cope with in legal implementations.
- Simplicity is positive for both cost-effectiveness and cost-utility since both method follow well prescribed procedures with standard factors. The cost-effectiveness requires a non-standard monetarization method for each item included. The low rating of cost-benefit on the property “simplicity” is caused by the complexity to evaluate the cost savings of the measures in monetary terms.
- Accuracy is considered highest for the cost-effectiveness method, since the reliability of the outcome remains an issue for both cost-utility and cost-benefit. The factors used for the disability weighting, as well as for the willingness-to-pay, show large variations, which need to be dealt with in the results. The cost-benefit calculation procedure used in the UK for evaluation noise measures (see [10]) includes this variation and allows the user to choose the high, middle or lower range.
- Flexibility is considered highest for the cost-benefit method, since it allows to include, in principle, any costs, benefits or other criteria. As long as these can be related to monetary terms, they can be included on both the cost and benefit side.
- Objectivity is considered best for the cost-benefit method. Since a single parameter is used to evaluate both costs and benefits, it is the most straightforward approach. The limitations lie of course in the amounts attributed to different aspects. Even in the direct costs of measures, some freedom is there to choose how much extra maintenance shall be attributed to the measure, or what interest rate is used for the net-value calculation
- Plausibility is also considered highest for the cost-benefit method. Since the costs and savings of different alternatives can be shown, the outcome is clear and understandable for anyone. The utility part is harder to explain, because one needs to explain such terms as DALY’s. The cost-effectiveness method is less plausible for the public because it uses an abstract measure of effectiveness that is less transparent and explainable.

Table 3: Advantages and disadvantages of decision methods

property	cost-effectiveness	cost-utility	cost-benefit
implementability: How well can it be prescribed and legally implemented?	+	-	0
simplicity: How easily can it be used?	+	+	-
flexibility: Can other criteria be easily included?	-	-	+
accuracy: How reliable is the outcome?	+	-	-/--
objectivity: Is the outcome independent on judgment and policy choices?	-	0	+
plausibility: Will people understand and accept the outcome?	-	+	+

CONCLUSIONS AND RECOMMENDATIONS

The three methods presented in this paper all have the objective to balance the costs of a measure, or different sets of measures, with the positive effects of the measure on society. The methods differ in their approach and the way the benefit, or the yield of the measure, is defined. All methods are used in practice but one can distinguish situations where one method will perform better than the other. The following best-practice is advised to choose the appropriate method:

- Cost-benefit analysis is the only method that translates the benefits into monetary units. It is the only method to give an *absolute* answer to the question “What is the effect of noise on economy?”. It is most suitable for *large-scale projects or (inter)national policy decisions*. It is complex and quite inaccurate, so the result requires documentation and clear indications of the monetary values used and the bandwidths around them.
- Cost-effectiveness analysis is about fair and transparent *distribution* of budget. It can be implemented in regulations (as is done in several countries) and once implemented, it is fairly simple to use. It is most suitable to apply in *large or small scale projects*, to make sure that people experiencing the same noise levels receive an equal treatment. The absolute height of the budget needs to be set by policy makers, using other means, which makes it less objective. Also, it uses some arbitrary measure of effectiveness that cannot be directly related to health and annoyance, which people may not understand and accept.
- Cost-utility analysis results in direct health benefits, either as separate health endpoints or in DALY units. Using DALY’s, the outcome may be used to compare the noise to other health-related aspects, such as air quality. It may even be integrated in full life cycle assessment methods, such as the recently updated ReCiPe [11], although until now noise has not yet been included. It is objective, since it is based on commonly accepted international studies by the WHO. It could in principle be used for legal implementation, but one should realize that values and outcome will change over time as research in the field progresses.

In any application of these methods, it is highly recommended to be clear and specific about the method, the outcome and the uncertainties. For any decision or study, a written report should state the values used: cost-benefit decisions should include the willingness-to-pay, health costs or VSL values used. Cost-utility decisions should include (references to) dose-effect relations and values for the disability weights. And for any method, it should be clearly stated which items are included on the costs side (direct and indirect costs, maintenance, administrative costs, etc.). It is also recommended to be clear and realistic about the accuracy of the outcome, especially in cost-benefit and cost-utility applications.

Finally, as was highlighted in this paper, good examples of existing cost-effectiveness and cost-benefit systems exists in several EU countries (e.g. UK, CH, NL, DK, DE). Member states and decision makers that want to develop or implement a system should consult their EU colleagues, possibly through EPA-IGNA, for experiences and advice.

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