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Costs and benefits of noise abatement measures

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Abstract

Environmental effects of traffic like noise are typically external and typically unpriced. This makes monetisation of these effects difficult. Much work has been spent the last few years on developing methods for monetising these (external) environmental effects. However, the application of these methods does fall short. This paper describes a cost-benefit analysis of a number of (possible) noise abatement measures in the Netherlands. Benefits are calculated according to consumer's preferences for dwellings, and values applied are derived from two different methodologies (hedonic pricing and contingent valuation). Costs are shown to be surpassed by benefits. Some weaknesses are also demonstrated in valuing noise, particularly where issues of equity, benefit transfer and embedding are concerned. Further research on these issues is recommended.

Keywords: Monetisation; Cost-benefit analysis; Transport

1. Introduction

Traffic causes such undesired environmental impacts as degradation of the landscape, and local and global air pollution and noise. Much effort has been put into minimising these effects. In the past decade this has led to a considerable reduction in the emissions, NO_x, SO_2, and PM10 from (car) traffic (RIVM, 2000). This article focuses on noise.

It has been estimated that around 20% of the European Union's population or close on 80 million people suffer from noise levels that scientists and health experts consider to be unacceptable. At these levels most people become annoyed, sleep is disturbed and adverse health effects are to be feared. An additional 170 million people are living in so-called 'grey areas', where the noise levels are such to cause serious annoyance during the daytime (European Commission, 1996).

Noise exposure is associated with a number of health effects (Berglund et al., 1999). First, we can distinguish socio-psychological responses, such as annoyance, sleep disturbance, disturbance of daily activities and performance, and secondly, physical responses, such as hypertension (i.e. high blood pressure) and ischemic heart disease. At low noise levels of 40 dB(A), for example, people may already be affected by noise exposure. This is especially the case in susceptible subgroups (children, elderly).

Despite numerous measures in the field of noise abatement at European, national and local levels (see Section 2 for details) there has not been a decrease in the noise-problem. In the Netherlands, 3–4% of the population is exposed to noise levels exceeding 65 dB(A). Without additional policy measures, more people in the Netherlands (5–6%) will be exposed to higher noise levels in the coming decades (Dassen et al., 2001). This is caused by factors like high population density, the increasing urbanisation and mobility of people, and the increasing goods transport. Other factors are the increase in recreational activities and the elevated possession and use of sound equipment (RIVM, 1997).

1.1. Cost-benefit analysis

The environmental policy is focussed on preventing and reducing undesired effects such as described in the above section. Budgetary constraints call for prioritisation of possible measures and projects to be undertaken. Several evaluation tools are available to support this process of

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priority-setting. One of the tools developed by economists is the cost-benefit analysis (CBA). Its principal feature is that all pros and cons of a project are translated into monetary terms.

The scientific evaluation of transport projects has a long history, dating back to mid-19th century France (Nakamura, 2000). At that time, only direct effects (e.g. travel time) formed part of the evaluation. Indirect effects (e.g. effects on the labour market) and external effects did not form part of the evaluation. External effects exist when an actor's (the receptor's) utility (or production) function contains a real variable of which the actual value depends on the behaviour of another actor (the supplier), who does not take this effect of his behaviour into account in his decision making process (Maddison et al., 1996). Environmental effects are typically external and typically unpriced, as no property rights and, consequently, no markets for these effects exist. This makes monetisation of the effects difficult. During the last decades, a lot of work was spent on developing methods for monetising (external) environmental effects. However, the application of these methods fell short of expectations (Dusseldorp et al., 2001). There is a consensus that environmental effects should be included in the appraisal, but no consensus as to how (Bristow and Nellthorp, 2000). Still, policy makers are becoming more and more interested in monetising both the costs and the benefits of particular (environmental) policy measures for large infrastructures. (Dusseldorp et al., 2001).

At the moment the Dutch government is reconsidering its noise policy and is thinking of implementing possible additional noise measures. In this light CBA of these measures might be helpful; it can contribute to the discussion on the desirability of the implementation of the noise measures. For this study we have focussed on a set of additional noise measures which eventually may be implemented in the Netherlands. These additional measures, all in the field of improving technical characteristics of road and railway traffic, have already been implemented on a small scale.

In Section 2 we will present a framework showing the different factors leading to adverse effects of noise and how noise policy may seize upon these factors. In Section 3 we map the effects of a set of noise abatement measures (additional to current noise policy) on noise exposure; we also present an overview of the costs and benefits involved. Furthermore, we discuss several aspects of the cost effectiveness of the measures involved. Section 4 discusses the results and recommendations for further research, focussing on weaknesses and gaps in the application of CBA in the field of noise.

2. Possibilities for noise policy

As mentioned in Section 1, noise policy aims at preventing and reducing the negative effects of noise.

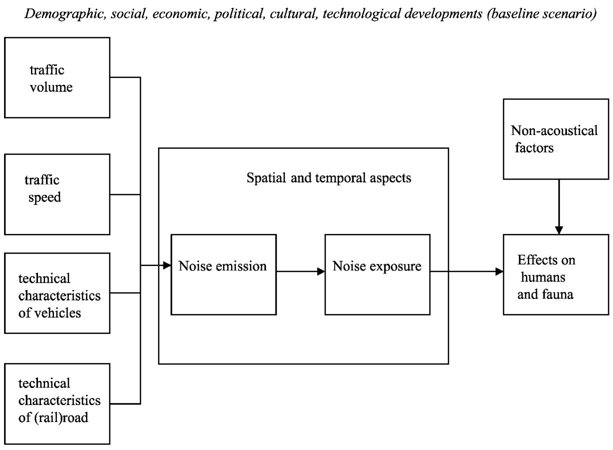

Fig. 1. Factors causing adverse effects of noise.

Noise abatement measures are usually aimed at influencing the major acoustical factor, noise exposure. This can be done, firstly, by reducing emission levels at the source (e.g. by introducing more low-noise kinds of cars or pavement, by reducing traffic speed or traffic volume). Secondly, noise can be abated by enlarging the distance between source and recipient,[1] thirdly, by hampering noise propagation in the construction of noise barriers and/or fourthly, by influencing the time of emission.[2] Ultimately, insulating outer walls is also a policy option.

Fig. 1 presents a schematic overview of factors leading to (adverse) effects of noise. Noise policy influences these factors. Source measures that reduce emission levels (inter)nationally are preferred to measures like insulation, which merely influence emission levels locally.

2.1. The Dutch situation

Since 1988, environmental targets at the national level (and the means to achieve them) have been set down in National Environmental Policy Plans. The Fourth National Environmental Policy Plan (Ministry of Housing, Spatial Planning and the Environment, 2001) sets targets for the year 2030 in terms of 'attaining an appropriate acoustical climate for different areas'. The different areas accommodate residential, natural, recreational and working areas. For different types of areas, different acoustical standards are set

[1] In spatial planning the Dutch government tries to arrange locations for labor, housing and transportation, for example, in such a way as to avoid exceeding current noise standards.

[2] Most European countries apply respective penalties of 5 dB(A) and 10 dB(A) for noise emissions in the evening (usually 19.00–23.00 h) and night (usually 23.00–7.00 h) to account for the annoyance caused by noise at that time of the day. Due to this system a noise emission at night equals 10, an 'equally loud' noise emission at daytime. Especially in traffic systems that can be regulated fairly well (traffic by air and rail), and where noise may be the limiting factor for transportation, ample care is taken to handle as much traffic as possible during daytime.

Table 1
Current noise standards

	Noise standard in dB(*A*)
Residential areas	50
Quiet nature areas meant for recreation	40
Nature	To be set before 2010

or are to be set before 2010. Table 1 shows the most common current noise standards for different types of areas in a simplified manner.

Despite the fact that the Dutch government has implemented numerous measures like more stringent requirements for noise emission by aeroplanes and cars, zoning of airport surroundings (including noise-insulation programmes), construction of hundreds of kilometres of noise barriers along roads and railways and the implementation of low-noise pavement, the noise problem will only increase due to rising traffic volumes and an increasing population (Ministry of Housing, Spatial Planning and the Environment, 1998). Solving the noise problem is a difficult task, in which new approaches and techniques, like the possible noise measures presented in this study may be called for.

3. Cost-benefit-analysis: The Dutch case study

To be able to weigh the different aspects of the noise abatement measures, all effects are valued and (where possible) monetised. To monetise the unpriced effects of the possible noise measures, effects are first described in physical terms (i.e. reduction in noise loads in different areas). In this study we follow the approach as described by Hanley and Spash (1993), in which a CBA usually comprises eight steps:

1. Defining the project (in relation to the baseline situation)
2. Identifying all effects
3. Identifying economically relevant effects
4. Physically quantifying these effects
5. Monetising the effects
6. Discounting the values
7. Comparing the sum of discounted costs and benefits
8. Doing a sensitivity analysis.

Defining the project (*in relation to the baseline-situation*). For this CBA, we want to evaluate a set of noise abatement measures, additional to current noise abatement practice. These measures, which might be implemented between 2000 and 2030 on a national scale, are presented in Table 2. The measures reduce road- and rail-traffic noise. Their effect on noise emission varies from 3 to 10 dB(*A*), (dB(*A*) being a logarithmic measure for the loudness of noise. A reduction of 3 dB(*A*) corresponds with cutting the noise intensity in half. Nevertheless, the human ear only perceives a halving of the intensity when the loudness is reduced by about 10 dB(*A*). The complex issue of physical loudness and the human perception falls somewhat outside the scope of this article. Since the reductions studied here are all found in the range of 10 dB(*A*), they are large enough to be perceived as considerable reductions. The total effect, 10–12 dB(*A*), of the road-traffic measures on highways is the sum of the individual measures, 4 dB(*A*) for low-noise tires and 6–8 dB(*A*) for low-noise pavement. For rail traffic the effect very much depends on the composition of trains and tracks. It is between 8 dB(*A*) (for passenger trains on well polished existing tracks) and 14 dB(*A*) (for freight trains with new brakes and therefore smoother treads on newly constructed

Table 2
Overview of measures, local emission reductions and costs (net present value 2000, discount rate 4%)

Measure	Emission reduction in dB(*A*)	Unit costs	Total extra cost, net present value (in millions of euro)	Source
Road traffic				
Silent tires	4	0	0	Blokland et al. (1999)
6500 km of silent pavement on all highways and on main provincial and urban roads	6–8	3.5 euro per m^2	860–1400	Blokland et al. (1999), KPMG (1999b)
Rail traffic				
Introduction of more silent passenger trains	5		100	Ministry of Housing, Spatial Planning and the Environment, expert session (1999)
Disc brakes instead of cast-iron brake blocks on existing freight trains, 6500 wagons; small additional adjustments	10	11,000 euro per pair of wheels	190	Jäcker and Friedrich (2000), KPMG (1998)
Polishing all existing tracks (ca. 3000 km)	3	2700 euro per km per year	80	KPMG (1998)
Silent tracks on planned new lines	4	110,000 euro per km	210	KPMG (1998)

tracks). These expected reductions, based on expert sessions in 1999, are well in line with findings of recent expert meetings on possible source measures, where comparable measures were assumed to have noise-reducing effects of 12 dB(A) for road traffic and 14–18 dB(A) for rail traffic (Ministry of Public Works, Water Management and Transport, 2002).

The implementation of the measures presented in Table 2 is supposed to take place in a certain/given societal context. We will call this the baseline scenario. The so-called European Co-ordination scenario of the Netherlands Bureau for Economic Policy Analysis (CPB, 1997) is used for this purpose. The scenario is characterised by an economic growth of 2.7% in the Netherlands, with the government playing a distinct role in a not completely liberalised market. The population grows from 15.5 million in 1998 to 18.3 million in 2030, while the average size of households continues to diminish from 2.5 in 1998 to 2.0 in 2030. The number of singles rises strongly. The same household size is assumed for the whole country. Developments in the construction of new houses differ per region and this has been taken into account. Traffic developments are characterised by a strong growth of road freight transport (in 2030 almost three times more vehicle-kilometres than in 1995). Air traffic is expected to grow by 65% (in terms of number of flights). Assumptions in the scenario are, in this case, not very crucial for the overall outcome.

Identifying all effects. As a result of the implementation of the measures described in Section 2, noise loads will decrease, having positive effects on the health and well-being of humans and fauna. For example, people will be less disturbed in their sleep, and the availability of nesting places for birds near (rail)roads will increase (Reijnen et al., 1995).

Identifying economically relevant effects. Because of lack of available data, this study focuses only on the effects of noise on human health and well-being. Positive effects of reduced noise loads, leading to improved human health and well-being may be expected in the human's living, working and recreational environment. Therefore, changes in noise loads will probably be reflected in changes of the valuation of the living, working and recreational environment. These changes in valuation reflect the price attributed to improved health and well-being.

Physically quantifying these effects. The effect of the additional measures on the noise levels in 1995 and 2030 has been calculated. We used an acoustic model linked to a GIS system, in order to estimate noise emissions from major roads, railroads and airports (Dassen et al., 2001; Jabben et al., 1999). The noise propagation by each source was also calculated, taking into account the characteristics of the surroundings. Noise emission and noise propagation were calculated using the calculation methods as prescribed under Dutch law. Finally, noise immisions in the Netherlands were calculated for each source and cumulated on a $100 \times 100\ \text{m}^2$ grid.

Table 3
Percentage of affected area with and without implementation of additional measures

	Noise standard in dB(A)	Year	Area above standard in percent (baseline scenario)	Area above standard in percent (baseline + additional noise measures)
Residential areas	50	1995	71	
	50	2030	80	37
Nature	40[a]	1995	33	
	40	2030	41	17
Quiet zones (recreation)	40	1995	19	
	40	2030	27	12

[a] For nature, where standards are to be set before 2010; the same standard that already applies for quiet zones is assumed.

Table 3 presents the percentage of affected area for the different types of areas in relation to their noise standard (i.e. the area where the noise load exceeds the noise standard for the specific type of area). The table shows, firstly, that the baseline scenario causes growing noise loads in 2030 in nature, recreational and residential areas; secondly, the additional measures cause decreasing noise loads in 2030, as compared to the baseline scenario in 2030 and to the present situation. The decreased noise loads lead, in turn, to decreases in the number of annoyed people and in the number of people with ischemic heart disease.

By implementing the additional measures, the noise nuisance in the residential areas will considerably lessen (see Fig. 2). The remaining bottlenecks are concentrated in the western part of the Netherlands, the so-called Randstad. This is partly due to the fact that Schiphol, the main Dutch airport, is located in this area and no additional measures for air traffic have been assumed.

Monetising the effects. The value of the effects on health and well-being caused by noise reduction as a result of the noise abatement measures was monetised for residential areas only, as only for these areas are methods and input data available. This clearly leads to an underestimation of the benefits. As there is no market for the effects on health and well-being caused by reduced noise loads, it is not possible to directly express these effects in terms of market prices. Nevertheless, to assign a monetary value to such goods and services, economists apply the willingness to pay (WTP): the maximum amount a person is willing to pay to obtain a good or service. It is a reflection of a person's preferences for one good relative to other goods. Among the various valuation methods available for estimating the WTP of effects such as noise reduction, the contingent valuation (CV) and hedonic pricing (HP) methods are most commonly used. Both methods have been applied in this study. The CV method estimates the WTP for a change in the quantity and/or quality of an environmental good such as noise by

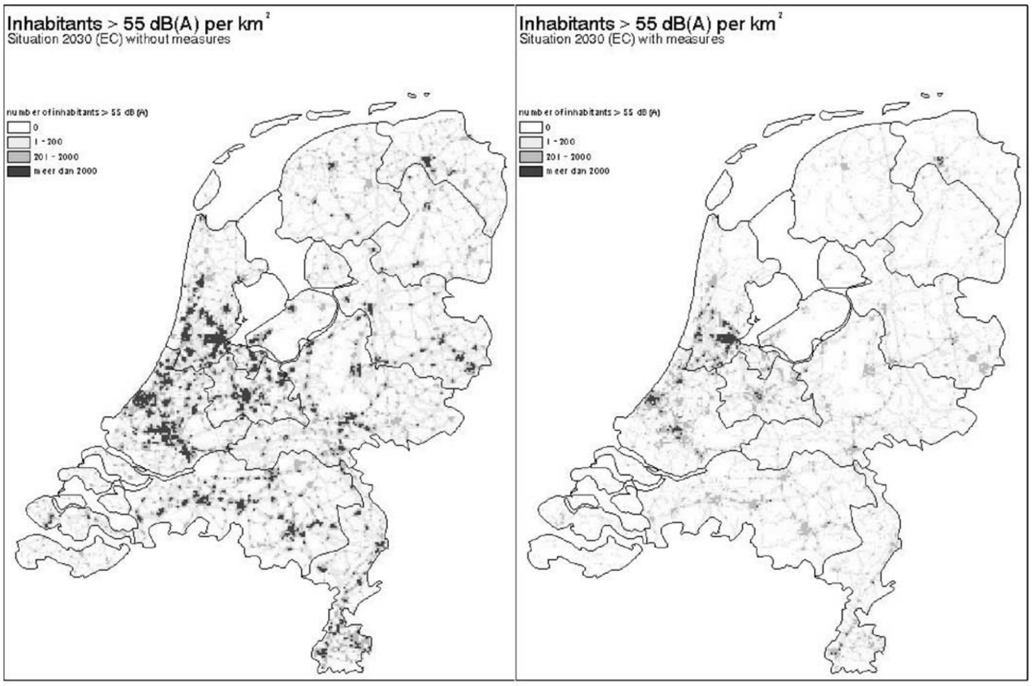

Fig. 2. Geographical distribution of Dutch inhabitants in areas with noise loads above 55 dB(A), with and without implementation of noise measures in 2030.

using survey techniques. In a questionnaire a hypothetical change is described and respondents are asked directly what their WTP would be for this change. The HP method uses data on house prices, noise loads etc. The idea underlying the HP method is that the price of a good is a function of its attributes, including environmental ones. In this case, house prices are seen as a function of characteristics of the house itself (e.g. number of rooms, heating system), neighbourhood characteristics (e.g. proximity to schools and shops) and environmental variables such as noise levels. Applying the HP method yields a price for noise-reduction derived from the difference in house prices. Along with this it is supposed that *ceteris paribus* a change in noise load will be reflected in a change in house price. The results of HP studies are summarised by means of a noise sensitivity depreciation index (NSDI). This is the percentage depreciation in house price for each decibel (dB(A)) of noise above a threshold level. A NSDI of 0.4% means that a house with a noise level of 75 dB(A) is worth 8% less to a house with a noise level of 55 dB(A) (Nelson, 1982).

3.1. Values used in this study

The actual NSDI value used in this study is 0.3% on the basis of a meta-analysis of a number of HP studies (Howarth et al., 2001). The CV method applied in this study uses a WTP value per person per decibel per year derived from other CV studies. In a literature review the default value was suggested to be around 15–20 euro per annum per excess dB(A) (Howarth et al., 2001). The original CV-questions on ‘halving the annoyance’ are ‘translated’ into ‘reducing the noise levels by 8 dB(A)’, using exposure-response functions of noise level and noise annoyance and assuming average initial noise levels levels between 55 and 65 dB(A). This study assumed a WTP of 15 euro per person, per annum per excess dB(A), presuming a linear relationship between the WTP and noise level. However, there is some discussion on the nature of the relationship between the WTP and the noise level. As part of the sensitivity analysis, the benefits were calculated according to a non-linear function as well.

In both the HP and the CV approaches the total benefits of a set of policy measures are calculated by subtracting the total WTP as a result of the additional set of policy measures from the total WTP calculated for the baseline scenario. It is assumed that during the 2000–2030 period people’s preferences with respect to noise will not change. For both approaches, a threshold level of 55 dB(A) was assumed. Below this level, no changes in a consumer’s preferences on the housing market due to changes in noise loads are expected to occur.

Calculation of the total benefits by means of hedonic property price approach is done according to the equation:

$$B(\mathrm{HP})_{\mathrm{total}}=[\mathrm{Exposed}(P_{\mathrm{House}})(\mathrm{NSDI})(\mathrm{dB(A)}_{\mathrm{actual}}-55)]_{\mathrm{ref}} \\ -[\mathrm{Exposed}(P_{\mathrm{House}})(\mathrm{NSDI})(\mathrm{dB}(A)_{\mathrm{Actual}}-55)]_{\mathrm{add}} \quad (1)$$

where $B(\mathrm{HP})_{\mathrm{Total}}$ is the total benefits of a set of policy measures calculated by means of the Hedonic Property Price approach; Exposed is the number of houses exposed to noise in a given noise band; P_{House} is average house price; NSDI is noise sensitivity depreciation index; $DB(A)_{Actual}$ is actual noise exposure level in dB(A); 55 is the assumed threshold noise exposure level; $[\ ]_{ref}$ is total noise damage in base-line situation; $[\ ]_{add}$ is total noise damage after implementation of additional measures.

The average house price is assumed to be 158,000 euro. This is the average price of existing private property in the Netherlands in 1999 (Dutch real estate agents association, NVM). Furthermore, it is assumed that the house prices in real terms will remain constant until 2030. The NSDI was the same for the several noise levels and noise sources.

Calculation of the total benefits by means of contingent valuation:

$$B(\mathrm{DV})_{\mathrm{Total}} = [\text{Exposed HH size WTP}_{\mathrm{excessdB}}(\mathrm{dB}(A)_{\mathrm{actual}} - 55)]_{\mathrm{ref}} - [\text{Exposed HH size WTP}_{\mathrm{excessdB}}(\mathrm{dB}(A)_{\mathrm{actual}} - 55)]_{\mathrm{add}} \quad (2)$$

where $B(\mathrm{CV})_{\mathrm{Total}}$ is total benefits of a set of policy measures calculated by means of contingent valuation; Exposed is the number of houses exposed to noise in a given noise band; HH size is average household size; $\mathrm{WTP}_{\mathrm{excess\ dB}}$ is WTP per excess decibel value derived from contingent valuation studies, expressed as Willingness to pay per person per annum per excess decibel[3]; $\mathrm{dB}(A)_{\mathrm{Actual}}$ is actual noise exposure level in dB(A); 55 is the assumed threshold noise exposure level; $[\ ]_{ref}$ is total noise damage in base-line situation; $[\ ]_{add}$ is total noise damage after implementation of additional measures.

Discounting. The total benefits are converted to net present values, obtained from the total benefits taken from Eqs. (1) and (2), respectively, by applying a discount rate of 4%, the standard rate used in CBAs for infrastructural projects in the Netherlands (Eijgenraam et al., 2000).

Comparing the sum of discounted costs and benefits. Table 4 shows the estimated costs and benefits, both of which are discounted. The costs are derived from recent research (Blokland van et al., 1999; Elbers, 1998; KPMG, 1998; 1999). Minimum and maximum values are presented. The benefits are calculated as described in the above sections. Table 4 shows that the benefits are higher than the costs in all cases. The table also shows that the use of different methods, i.e. hedonic pricing and contingent valuation, eventually leads to similar results. This at least enhances confidence in the robustness of the results.

Sensitivity analysis. The sensitivity of the results to several assumptions was examined by testing one assumption at a time, *ceteris paribus*. The assumptions examined were the selected threshold value, the development in the prices of dwellings, and the value of the NSDI and WTP chosen.

Table 4
Costs and benefits of the noise measures (net present value 2000)

	Costs (billions of euro)		Benefits (billions of euro)	
	Minimum	Maximum	Hedonic pricing, NSDI = 0.3%	Contingent valuation, WTP = 15 Euro
Road traffic	0.8	1.4	3.4	4.4
Rail traffic	0.6	0.6	0.8	1.0
Total	1.4	2.0	4.4	5.7

Regardless of the method used, threshold values have a negative non-linear relationship with the benefits (see Fig. 3). Here it is seen how the choice of the threshold value is important for the outcome.

In this study, as in most, a threshold value of 55 dB(A) is assumed. Below 55 dB(A) no effects on the housing markets are observed (Vainio, 1995) and consequently no benefits can be taken into account. However, below 55 dB(A) effects on health and well-being can be expected as well (Berglund et al., 1999). A recent study of Miedema and Oudshoorn (2001) showed that people may experience annoyance at levels around 40 dB(A) because of noise exposure. So consumer behaviour towards noise exposure differs from the effect of noise exposure on human health and well-being.

The development of the prices of dwellings is crucial to the calculation of benefits. Here, it is assumed that the prices of dwellings do not change over the years, so the price of a dwelling in real terms in 2030 will, on average, be the same as the price of a dwelling in 1998, i.e. 158,000 euro. This is probably a low estimate of the expected house price, as house prices in the Netherlands, as in most western countries, tend to rise. As in all HP studies, it is assumed that consumers are able to choose from a complete range of price levels and house characteristics, and that the housing market is a completely open one, or at least open enough not

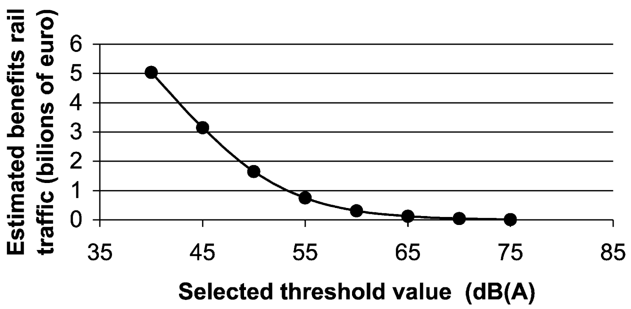

Fig. 3. Benefits as a function of threshold-level. Benefits are calculated for rail traffic measures, by means of the hedonic pricing method using an NSDI of 0.3%.

[3] Using the WTP per excess decibel value makes it possible to compare the results of the calculation using the contingent valuation approach with the results of the Hedonic pricing approach. In fact, the WTP derived from contingent valuation studies is converted to an increase in the house price.

to influence consumer's choices on houses with different noise loads.

The value of the NSDI chosen is crucial for the total benefits. In the literature, various values of the NSDI are presented. The value of the NSDI used in our study (0.3%), complies with recent studies from Bateman et al. (1999) for the UK and Vainio (1995) for Finland, but is considerably lower than (older) estimates from Weinberger et al. (1991) for Germany, for example, and Soguel (1994) for Switzerland. Their estimates range from 0.5 to 1.3%. In a recent meta-analysis an attempt was made to find an explanation for these observed variations (Schipper et al., 1998). It appeared that studies in which samples with a higher relative average house price were used attained a higher NSDI. This complies with observations of Bertrand (1997). Furthermore, the choice of variables included in the regression model (e.g. age, income, house characteristics) of the HP studies also proved to affect the study outcome (Schipper et al., 1998). These observations call for caution when transferring one of these values as a 'suitable' estimate to a new location.

Contingent valuation usually applies a linear relationship between willingness to pay and excess noise level. Bertrand (1997) argues that in reality such a relationship is more complex and dependant on the actual noise level and income.

In the equation:

$$\mathrm{MWTP} = e^{(2.3148+0.509\times10^{-5}\ m+0.497\times10^{-1}\ N)}$$

where m is yearly income in US dollars; N is noise level in dB(A); MWTP is marginal willingness to pay per excess decibel per person per annum.

This equation shows that the value of quiet surroundings rises with rising income, as may be expected in the economic baseline scenario used. For an average yearly Dutch income of 21,700 euro (CBS) in 1999, this would mean a total benefit of 15.2 billion euro, considerably higher than using a linear relationship with a WTP of 15 euro/person/yr, as proposed by Howarth et al. (2001) and as used in this study. It clearly shows that estimates of external costs for transport noise strongly depend on the assumptions made. An obvious research conclusion is that much more research is needed to identify the reliability and applicability of the various valuation techniques. The sensitivity analysis shows a number of parameters (the threshold value, the prices of dwellings, the value of the NSDI and the WTP chosen) to be crucial for the overall outcome of the CBA. In this study, these parameters have been chosen in such a way that the estimates of the benefits are relatively low.

3.2. Cost-effectiveness

The most cost-effective measure is the introduction of low-noise tires, as this would have considerable effect and no side-effects. Furthermore, this measure would cost next to nothing since it merely consists of banning the noisiest tires on the market today by introducing emission limits. It would therefore not require any new technology. The cost-effectiveness of (double layered) low-noise pavement is less than that of low-noise tires, but could at least be improved if it were to be constructed on noise-sensitive spots only (e.g. near residential areas, near nature or recreational areas). It would be interesting to look at the cost-effectiveness of (combinations of) measures more in detail. Some measures (low-noise tires, low-noise brakes on freight trains, see Fig. 4) have rising returns with a rising degree of implementation, whereas others (low-noise pavement, polishing existing tracks) have a diminishing return by rising degree of implementation. The latter type of measures is best applied on acoustical hot-spots only, whereas the former type could be best applied on a bigger, (inter)-national scale. However, in this research, this point is not addressed and all measures are calculated as if they were all implemented simultaneously on a national scale.

For rail traffic, improving the brakes of freight trains is the most cost-effective measure, whereas the construction of low-noise tracks on new railway lines is the less cost-effective one. Nevertheless, improving the brakes of freight trains is only cost-effective when it is done on a large scale, retrofitting the vast majority of wagons. Fig. 4 shows that the maximum total emission reduction of 7 dB(A) will be reached when 100 % of the freight wagons have low-noise brakes. If this Fig. is only 50%, a reduction of only 2 dB(A) is achieved.

As freight carriages, as opposed to passenger carriages, tend to belong to many different companies in many different European countries and tend to ride all over Europe, this measure will only be effective if it is carried out in international cooperation. For our study, this international cooperation was assumed to be the case. The costs presented here are the costs for the (6500) freight carriages owned by Dutch companies.

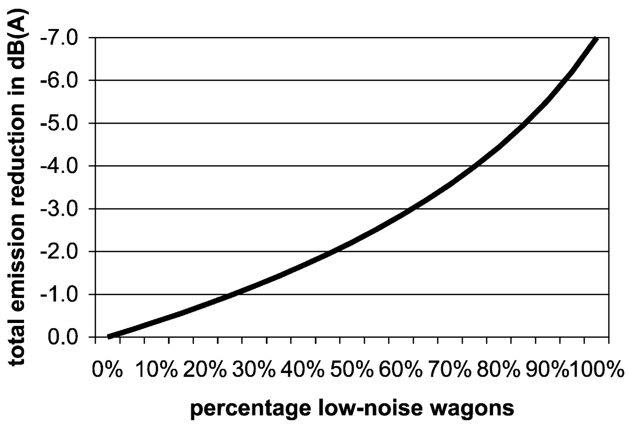

Fig. 4. Overall noise reduction as a function of the percentage of freight wagons with a low-noise brake system (source: KPMG, 1999a).

Recent studies on cost-effectiveness of noise abatement measures on Dutch railroads suggest a better performance of source measures compared to measures like noise barriers and window insulation (KPMG, 1999a; Elbers, 1998). Oertli (2000) states that the optimal mix of noise abatement measures is dependent on the available financial resources. In his Swiss case study, the optimal mix consists for 65% (of the available budget) of source measures, for 30% of noise-control barriers and for 5% of window insulation. What the optimal mix in the Dutch situation would be is unknown. Research of Lenders and Hecq (2002) on the cost-effectiveness of noise abatement measures for railways suggests that, in general, measures on rolling stock are more cost-effective than measures on tracks, but again, the optimum probably lies in a combination of both types of measures.

4. Discussion

This study was meant to contribute to an ongoing discussion on the desirability of implementing a set of noise control measures for road and rail traffic in the Netherlands. The results show that implementing these measures will considerably improve the noise situation in the residential, recreational and nature areas (Table 3). As a consequence human health and well-being will be improved too.

From Table 4 we can conclude that the additional measures are not only effective in terms of reduction of noise levels and improvement of the human health and well-being, but also, once these effects are monetised, in economic terms. The estimated benefits (4.4–5.7 billion euro) largely exceed the costs (1.4–2.0 billion euro) of the measures. Therefore, from a national welfare point of view, it would seem advantageous to implement these measures. Yet, further research on the most cost-effective mix of measures is recommended.

In this study, care has been taken not to overestimate the (monetary) potentials of abatement measures, so the benefits presented are likely to be an underestimation of the full benefits. This is even more so, as only effects on human well-being in residential areas could be monetised. Effects on well-being in recreational and natural areas have not been monetised, nor have effects on fauna. Further research on developing valuation methods for these issues is recommended.

Monetisation includes estimating a number of variables (WTP, NSDI, house price, threshold value). It is inevitable that data from previous studies will have to be used, where focus is on a different region or time period. Therefore it is important to know when data from other studies can be used and under what conditions. Benefit transfer is an application of monetary values (e.g. NSDI or WTP) from a particular valuation study to an alternative secondary policy-decision setting, often in another geographical area than the one where the original study was performed (Beukering van et al., 1998). This study did not account for this very well. We used a NSDI that represented the result of a meta-analysis of studies abroad. Dutch consumer behaviour, however, may be different from the observed behaviour in the meta-analysis, which would result in different NSDI values. The same goes for the WTP used, which was derived from a meta-analysis of CV studies. No recent or reliable Dutch values are available. There is a need for research on estimating present Dutch values for NSDI and WTP.

This research used geographically detailed data on traffic and the locations of dwellings, which were used to calculate noise loads. The data on income and house price, used to calculate the willingness to pay were national averages and did not take regional or local differences into account. Three aspects of unequal spatial distribution of the population with different effects on the calculated benefits seem particularly relevant.

First, one can say that the noise problems are greatest in the Randstad. This is the densely-populated area with a lot of infrastructure. Therefore the number of houses with reduced noise loads due to the noise abatement measures in the Randstad is relatively higher than in other parts of the country. At the same time, house prices in the Randstad are higher than average Dutch house prices in 2000, when the average house price in the Randstad was 186,000 euro; in the northern provinces it was 145,000 euro (Marlet, 2001). Therefore since many of the benefits are gained in the Randstad and house prices in the Randstad are underestimated in this study, the benefits as presented are likely to be an underestimation.

Secondly, richer people tend to live more than average in more expensive houses in quieter areas, poorer people tend to live more than average in less expensive houses in noisy areas, see Fig. 5. The benefits of the noise abatement measures as calculated in this research only occur in noisier areas, i.e. above the threshold value of 55 dB(A). Therefore noise reductions relevant to calculated benefits will occur more than average in poorer areas with house prices less than average. Therefore the benefits as presented here are likely to be overestimated.

Thirdly, there is likely to be an element of self-selection, with people less averse to noise choosing to live in noisy areas. This might reduce the value attributed to noise reduction in those areas. It would at the same time raise the value attributed to quiet living surroundings in the case of new infrastructure or a sudden rise in noise levels due to re-routing of traffic, for example.

Further research on the issue of uneven spatial distribution of the population and its effects on the overall outcome is recommended.

In the CV method it is assumed that respondents are fully aware of all effects of noise on health and well-being. Yet it is doubtful whether other health effects than annoyance are included in most CV studies. If not, the WTP as derived from those studies tends to be underestimated. The same line of thinking applies for the HP

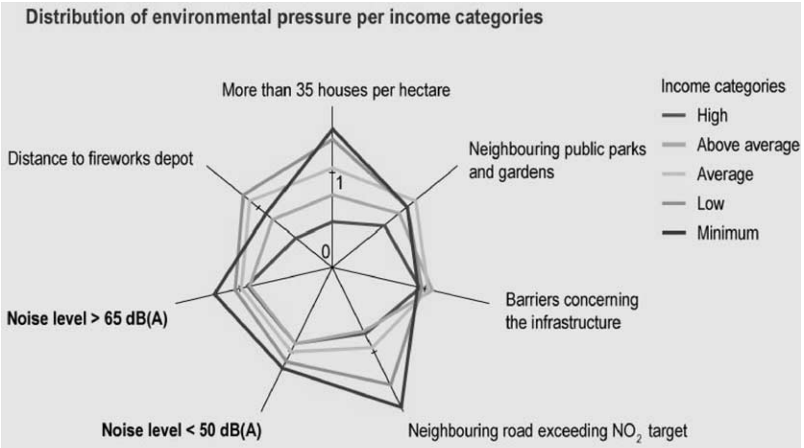

Fig. 5. Distribution of environmental pressure per income categories. Index 1 is the average of the total population, a value smaller than 1 is favourable (source: RIVM, 2002).

method. It is unlikely that the majority of consumers (i.e. house buyers) are aware of other effects than annoyance. Again, this would lead to an underestimation of the NSDI, and thus of the benefits of abatement measures.

On the other hand, the problem of 'embedding' may lead to an overestimation of the benefits of noise abatement measures. Embedding occurs when it might be difficult to separate component values from more broadly defined goods (Maddison et al., 1996). Thus when respondents are asked for their WTP to reduce noise levels by 20%, they may give responses that are based on the assumption that road traffic (and all its other external effects) is reduced by 20%. The scope for double counting is obvious. Embedding might just as well occur using the HP method. Due to noise abatement measures, for example, house prices may rise, a fact often attributed to reduced noise levels only, whereas, at the same time, other externalities like reduced number of accidents, improved (feeling of) safety, reduced air pollution etc. should be considered. In conclusion, the valuation of the effects of noise abatement measures by reducing the noise from the source (and not changing traffic load, air pollution etc.) may be overestimated in this study. Further research on the issue of embedding is recommended.

Other weaknesses of the CV method have not been addressed in this study either, but should be kept in mind when applying data derived with CV, as the CV-method itself is prone to several forms of bias (besides embedding). Getting strategic responses is one of them. Another methodological problem exists in discriminating between people who do not value the environmental good, so WTP is really zero, and those who object to the nature of the economic valuation of environmental goods and therefore express a WTP of zero, the so-called protest bids (Maddison et al., 1996). Furthermore, it is not always clear if respondents are all fully aware of the meaning and the implications of, for example, a 10 dB(*A*) reduction of noise.

This only supports the conclusion from Section 3 that much more research is needed to identify the reliability and applicability of the various valuation techniques. CBA has met much criticism. The key criticism relevant for this project is that environmental impacts are typically unpriced and necessarily receive too little attention in CBA because 'Money speaks louder than words' (Hoevenagel, 1994). However, this study once again shows, as others before it, that it is possible to incorporate unpriced externalities like noise in a CBA, even though uncertainties remain. Another point of criticism is the unsolved equity problem: costs are carried by groups in society (e.g. railroad companies) different to those who will eventually be the beneficiaries (e.g. people living along railroad tracks). This represents one of the major obstacles for which the solution will be far more a political challenge than a scientific one. Although there is a call for inclusion of equity aspects into CBAs, it is usually left vague in practice (Lee, 2000). It is not addressed in this study either. Welfare transfers from one societal group to another remain hidden in this CBA, representing an incompleteness of the study. The present CBA (as most CBAs) cannot be the sole basis for policy-making, but can be used as an input for a more comprehensive multi-criteria-analysis, in which such aspects as equity, fairness and sustainability might be included as well.

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