The State-Of-The-Art on Economic Valuation of Noise

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1. BACKGROUND

Measures to reduce transportation and community noise are costly to implement, and an obvious question is whether the social benefits of reduced noise can justify these high costs. Thus, we need to know the social costs of noise to find the social optimal level of investments in noise reducing measures. Having an economic estimate of social benefits of reduced noise then allows us to identify the combination of measures providing highest social benefits per euro of costs, i.e. highest benefit–cost ratios.

The proposal for a Directive on the Assessment and Management of Environmental Noise (END) requires Member States to produce "strategic noise maps", by using noise indicators (L_{den}[1] and L_{night}[2])[3] assessing the number of people affected by noise, to inform the public about noise exposure and its effects, and to draw up "action plans" to reduce noise where necessary and to maintain environmental noise quality where it is good.

Both the EU and national policy makers need also to make a choice between the various measures available to mitigate noise. Further the Treaty requires that the costs and benefits of Community-wide environmental legislation be assessed. Therefore, the Directorate-General (DG) Environment of the European Commission (EC) seeks to develop a set of common tools to be used when carrying out the analysis of costs and benefits of noise mitigation measures.

Environmental valuation methods, both stated preference (SP) and revealed preference (RP) methods have been employed to estimate the economic value of changes in noise levels. Most studies have applied the RP approach of Hedonic Price (HP) to the housing market to analyse how differences in property prices reflect individuals´ willingness-to-pay (WTP) for lower noise levels. More recently there has been an increased interest in applying SP methods to value noise. Contingent Valuation (CV), Conjoint analysis (CA) and Choice Experiments (CE) have all been applied to value transportation noise.

In order to establish interim values for noise from different transportation modes (air, road, rail) to be used in cost-benefit analyses (CBAs) performed by the EC, there is a need for an overview and evaluation of the valuation techniques, empirical noise valuation studies and the potential for benefit transfer of noise values

2. AIM AND TASKS

The main aim of this paper is to provide the Commission services advice on the state-of-the-art on economic valuation of noise, and act as a basis for determining interim values for noise. More specifically the report will address the following issues/tasks:

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[1] L_{den} (day-evening-night indicator) : noise indicator for overall annoyance, defined in Annex I of the END

[2] L_{night} (evening-noise indicator) : noise indicator for sleep disturbance, defined in Annex I of the END

[3] These noise indicators relate to noise levels outside the dwelling. Differences between countries with regards to materials used in dwellings and the extent of noise reducing measures could produce different indoor noise levels for the same outdoor noise level. There is also differences between countries in terms time spent indoors (due to differences in climate and culture). In e.g. the Nordic countries indoor noise level is a more relevant noise measure. for predicting noise annoyance.

1) What should be the theoretical basis for estimating the value of noise? Is it defensible (and if yes: under what conditions) to use SP and RP methods to value noise?

2) Review economic valuation studies of noise from different transportation modes (air, road and rail) in both Europe and North America, covering both stated preference (SP) methods and revealed preference (RP) methods.

3) Are the existing noise value estimates fit for benefit transfer? If yes, under what conditions, and what benefit transfer methods should be applied?

4) What should be the cut-off point used for valuing noise? Should it be L_{den} 50¸ 55 or something else?

5) Beyond this cut-off point, what should the value of noise be per decibel (db) per person affected, in euros (2001 price level)?

6) Should the value of noise be different in different transport modes (air, rail, road)? If so, what should be the difference?

7) Should the value of noise be the same in different Member States or socio-economic groupings, as well as in accession countries?

8) What research gaps exist (e.g. value of night time noise vs. day time noise, more accurate information on noise from specific sources)?

The next eight sections (sections 3 through 10) of this paper will deal with each of topics 1 through 8 listed above.

3. THEORETICAL BASIS AND VALUATION TECHNIQUES

3.1. Damage Function Approach (DFA)

To calculate the total welfare loss from noise or the total increase in welfare due to noise reducing measures, a damage function approach (DFA) should be applied. A description of DFA applied to noise is given in figure 1. In the case of *reduced noise* emissions, which are described in figure 1, the damage function approach should rather be termed the *benefit* function approach.

The DFA for noise described in figure 1 is able to consider a number of complicating factors that have to be taken into account, including non-linear relationships in ERFs and value functions, and different initial noise levels, and the importance of context (e.g. characteristics of different noise sources). Figure 1 considers only the annoyance impact of noise, but the same framework can be used to consider other impacts in terms of endpoints from ERFs. In step 7 one must avoid double-counting as endpoints and/or economic values of endpoints might overlap, and lead to overestimation of economic benefits of noise reducing measures. Exclusion of impacts due to missing ERFs and/or economic values for their endpoints will lead to underestimation of the economic benefits.

Figure 1.

The Damage Function Approach (DFA) applied to noise. The DFA is divided into seven steps, where steps written in capital letters denote models/methods, while steps in small letters denote input and output to these models/methods.

For illustration "Percentage of persons highly annoyed (HA)" is used as the endpoint of the ERF for annoyance, but ERFs for each of the five annoyance levels defined in ISO (2001) should be used.

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1. ***Reduction in noise emissions*** due to noise mitigating measures, described in terms of change in time, location, frequency, level, and source of noise (and composition/contribution of noise sources if there are multiple sources)
2. NOISE DISPERSION MODEL
3. Noise dispersion models are used to estimate the ***changed exposures to noise*** at different geographical locations; measured in dB(A) and noise indicators (L_{den} and L_{night}) (presented in noise maps)
4. EXPOSURE–RESPONSE FUNCTIONS (ERFs), between decibel levels (measured by noise indicators like L_{den}) and levels of annoyance, ischaemic heart disease, subjective sleep quality and other impacts of noise. For annoyance the endpoint of the ERF could be "percentage exposed persons per year that are "highly annoyed" (HA)" (see appendix 5 for examples of such ERFs for noise from road, air and rail)
5. ERFs and information about the number of cases of each endpoint, e.g. the change in the total number of persons HA by noise per year, are used to calculate the ***overall change in noise impact.*** (Calculating the change in total number of person HA requires information about e.g. the number of dwellings, household size, and averting behaviour/existing noise mitigating measures (e.g. special insulation against noise and noise screens)).
6. ECONOMIC VALUATION TECHNIQUES are used to set an economic value for a "unit" of each endpoint of the ERFs , e.g. "euro per person HA by noise per year" . Two different valuation approaches can be used:
   - i) Transfer estimates from existing valuation studies (using benefit transfer techniques and literature review/databases on noise valuation studies), or
   - ii) Conduct a new, original study using environmental valuation techniques
7. **Economic benefits** of noise mitigating measures are calculated multiplying the economic value of each unit of the endpoint (e.g. "euro per person HA per year ", from step 6) with the calculated, corresponding impact (e.g. "change in number of persons HA per year"; from step 5); and aggregate over all endpoints from ERFs (but avoid double counting).

According to a literature review of ERFs for noise annoyance (Schomer 2001) "studies of community annoyance to numerous types of environmental noise show that L_{dn} is the best measure of impact. However, $L_{nignt.}$ would be a better noise impact measure in CBAs of noise mitigating measures affecting night noise only, e.g. night curfew at airports. Schultz (1978) showed a consistent relationship between L_{dn} and percentage of persons exposed that are "highly annoyed" (HA) by noise. This relationship, referred to as the "Schultz curve", has been reaffirmed and updated over the years (Fidell et al., 1991; Finegold et al., 1994), and more recently Miedema and Vos (1998, 1999) reported updated ERFs for road, rail and air based on an extensive meta-analysis of noise annoyance studies from several European countries (but none in Southern Europe), USA, Canada and Australia; representing an overall sample of 58.000 persons (see appendix 5). Using this same data set Miedema and Oudshoorn (2001) develop ERFs for road, air and rail between L_{den}, in addition to L_{dn}, and percentage "highly annoyed", "annoyed", or "(at least) a little annoyed". They use the "annoyance score" (AS), with a scale of 0-100, to define these three categories, with cut-off rates of 72, 50 and 28 for "highly annoyed", "annoyed" and "(at least) a little annoyed". These categories of AS are easier to value than each unit of AS (especially if the unit value is not constant). However, this categorization also implicitly assumes a specific weighting of the "annoyance index", and it requires Stated Preference (SP) studies that report values for these three annoyance categories. To my knowledge, no such SP study exists. However, results from the Contingent Valuation (CV) studies containing data on the respondents´ level of annoyance (Lambert et al 2001 and Navrud 2000b) could, at least theoretically, be converted to values for these three ERF endpoints for annoyance.

For the calculation of external costs of noise from transport, a "bottom-up/impact pathway approach (IPA)" was used by IER, University of Stuttgart, which is similar to the IPA for air pollution, developed in the EC project ExternE ("External Costs of Energy"). The IPA approach is equivalent to a DFA. The IPA was used to calculate marginal external costs of noise from road and rail transport in the EC project RECORDIT (Schmid et al. 2001) and for total and marginal external costs of road, rail and air transport in European countries (EU15, Switzerland, Hungary and Estonia) in the EC project UNITE (Bickel et al. 2001). Ten endpoints for economic valuation of health effects were identified and exposure-response-functions established, based on recommendations on adverse health effects for ischaemic heart disease, hypertension and subjective sleep quality (sleep disturbance) by Kluizenaar et al. (2001). Hunt (2001) provided the methodological basis for the economic valuation of endpoints. The values used for UNITE are given in Bickel et al. (2001). Other impacts from noise include: speech interference in offices (communication disturbance), annoyance[4], and psychological effects of noise on children (cognitive effects, and effects on memory, attention and motivation).

According to Hunt (2001) the starting point for the valuation of these end-points is the identification of the components that comprise changes in welfare. These components should be summed to give the total welfare change, assuming no overlap between categories. The three components include:

(i) *Resource costs* i.e. medical costs paid by the health service in a given country or covered by insurance, and any other personal out-of-pocket expenses made by the individual (or family).

[4] Annoyance is defined by TNO (2000), as a feeling of resentment, displeasure, discomfort, dissatisfaction, or offence when noise interferes with someone's thoughts, feelings or actual activities.

(ii) *Opportunity costs* i.e. the cost in terms of lost productivity (work time loss (or performing at less than full capacity)) and the opportunity cost of leisure (leisure time loss) including non-paid work.

(iii) *Dis-utility* i.e. other social and economic costs including any restrictions on or reduced enjoyment of desired leisure activities, discomfort or inconvenience (pain or suffering), anxiety about the future, and concern and inconvenience to family members and others.

The welfare changes represented by components (i) and (ii) can be proxied using market prices that exist for these items. In health valuation literature these components are summed to produce what is known as the "Cost-Of-Illness" (COI) measure of welfare. This measure - in best practice - needs to be added to a measure of the affected individual's loss of utility, reflected in a valuation of the willingness-to-pay/accept (WTP/WTA), to avoid/compensate for the loss of welfare associated with the illness.

Note that there is the possibility of overlap between components since, for example, the individual will include both financial and non-financial concerns in his/her assessment of loss of welfare. Financial costs are often not borne fully by the individual but are shared through health insurance and public health care provision. Thus, we assume here that the financial costs are separable and measured in component (i). If this is not the case, then a part of the dis-utility measured in the WTP estimate will be incorporated in the private medical costs associated with treatment (or prevention) of the health end-point, and the total valuation should be reduced by an equivalent amount.

Hunt op cit then derive country specific estimates and EU average for health care resource costs and the costs of absenteeism (i.e. components (i) and (ii)), and then use these estimates together with transferred estimates of the dis-utility (component iii) to estimate country specific and EU averages for myocardial infarction, hypertension, sleep disturbance, communication disturbance, and annoyance. Hunt op. cit notes that frequently the data for medical costs and absentee days do not exist in a sufficiently disaggregated form to be of use in deriving the cost element for individual endpoints, and thus crude approximations have to be made. In conclusion, considerable uncertainty is attached to the economic estimates of myocardial infarction, hypertension, sleep disturbance, and communication disturbance.

For annoyance the welfare component (iii) is thought to dominate, but opportunity costs (components (ii)) should also be added when applicable. Clearly it is difficult to isolate, what effects are covered when speaking of annoyance. Concerning health effects, there seems to be consensus among experts, that the general population is not aware of specific health impacts due to noise, and thus so the assumption of separation between health impacts and annoyance seems reasonable. For communication disturbance a separation is less clear, while for sleep disturbance a separation of ‘general annoyance’ and ‘annoyance during the night’ is possible, which would avoid double counting.

It can be argued that an economic estimate for annoyance (in their dwelling) can serve as an indicator of the overall impacts of noise, but most probably providing a lower economic estimate of noise impacts. This corresponds well with the suggested indicators for noise from air, road, train and industry, in the proposal for the Directive on the Assessment and Management of Environmental Noise (END), which focuses on the welfare loss from annoyance and sleep disturbance; measured by the noise indicators L_{den} and L_{night}, respectively.

Hedonic Price (HP) studies provide values in terms of the Noise Sensitivity Depreciation Index (NSDI) (and the same do expert assessments of real estate agents and assessors). NDSI was originally introduced by Walters (1975) and adapted for comparative purposes by Nelson (1980, 1982) in his major reviews of hedonic price studies of airport and traffic noise. HP studies use a DFA where there is a leap directly from step 3 to 6 (see figure 1). To use the complete DFA, Stated Preference (SP) studies (Contingent Valuation (CV), Choice Experiments (CE) and Conjoint Analyses (CA)) producing values for persons at different annoyance levels from noise exposure are needed in step 6. This could either be new, original studies for the specific context and site, or a benefit transfer exercise using existing SP studies on noise. Most of the existing SP studies, however, provide economic values pr dB, which means they also go directly from step 3 to 6. Using this unit of economic value in benefit transfer exercises means assuming the same economic value for the annoyance levels at the policy site (i.e. the site one transfers to) as found in the study site (i.e. the site the original valuation study was done). An economic value for a specific level of annoyance is most probably more transferable, as the level of annoyance is a measure of individual preference.

Section 3.2 will review valuation techniques that have been used to value welfare loss from noise, while 3.3 describes ways of transferring these noise value estimates (i.e. benefit transfer techniques).

3.2 Environmental Valuation Techniques

Both stated preference (SP) and revealed preference (RP) methods have been employed to estimate the economic value of reductions and increases in noise levels. The majority of valuation studies on noise are **Hedonic Price (HP)** studies. The main strength of this RP method, both in general and in applications to noise, is that it relies on actual behaviour in the housing market where individuals WTP for noise and other environmental characteristics of the house can be observed. General weaknesses are that the result of HP studies, in terms of the implicit price of the environmental factor (i.e. the Noise Sensitivity Depreciation Index (NSDI) which is the percentage change in house prices per dB increase in noise level), is very sensitive to modelling decisions and the conditions in the local housing markets, as shown in meta analyses of HP studies on air quality and aircraft noise; see Smith and Huang (1993) and Schipper et al (1996) for meta analyses of air quality and airport noise, respectively.

Implicit prices are very sensitive to model specification (e.g. if other external effects of. transportation are not accounted for in the model, the estimated impact of noise on property prices could include these impacts as well), estimation procedures (including choice of functional form), the functional form (many HP studies rely on lognormal functions, while Box-Cox transformation have performed better where they have been used), the level of information about the noise level the respondent had when bidding for the dwelling, whether people can perceive marginal changes in the physical noise measure used, and whether there is perfect competition in the housing market, zero transaction costs and other strict assumptions (which often are not fulfilled). Finally, as theory would suggest, the empirical literature suggests that these implicit prices will vary from market to market depending on supply and demand in the markets. Only HP studies based on real market transactions data (and not the assessed value of house) should be used.

Expert assessment by real estate agents and assessors have also been conducted to estimate NSDI, see e.g. Strand and Vågnes (2001) and Ohm (2001) of train noise in Norway and road traffic noise in Estonia, respectively. Strand and Vågnes op. cit. conducted both a HP study and an expert assessment of real estate agents, and found the two approaches to give values of

similar magnitude. Frankel (1988) did the same for airport noise, comparing expert assessments of both realtors and appraisers with the HP estimates.[5]

Another RP technique which have been applied to noise is the **avoidance costs (AC)** approach. However, the main weakness of this method is, as in all applications, that only in certain circumstances the results can be interpreted as a proxy of welfare loss /gains from increased/decreased noise levels. Therefore, empirical applications of the AC approach to noise will not be reviewed here (see Hunt 2001 for examples).

One reason for the relatively few **Contingent Valuation (CV)** studies on noise could be the difficulties in constructing a good CV survey for valuing noise level reductions. A good CV survey would in general include the following sections: (a) an introductory section that helps set the general context for the decision to be made, (b) a detailed description of the good to be offered to the respondent, (c) the institutional setting in which the good will be provided, (d) the manner in which the good will be paid for, (e) a method by which the survey elicit the respondent's preferences with respect to the good; (f) debriefing questions about why respondents answered certain questions the way they did; and (g) a set of questions regarding characteristics including attitudes, and demographic information (Mitchell and Carson 1995). Particularly sections (b), (c) and (d) provides problems, i.e. describing the reductions in noise level in a scientifically correct and understandable way, institutional arrangements that makes respondents accept willingness-to-pay (WTP) questions (they easily protest WTP questions, since they think it is unfair that they should pay to reduce noise created by other), and a realistic and fair payment vehicle.

Many of the existing CE and CA studies value percentage reduction in noise levels (typically a 50% reduction) without checking whether people understand what this reduction in noise would mean to them (e.g. Sælensminde and Hammer 1994). Many early CV studies do the same (e.g. Pommerehne 1987), but more recent CV studies have instead described the noise reduction in terms that can be better understood by the respondents. Barreiro et al (2000) describe the change in noise level by referring to noise levels respondents experience at different times at different weekdays; e.g. "daytime noise would be reduced from the working day level to that of a Sunday morning". Vainio (1995, 2001) use a CV scenario of diverting traffic elsewhere or into a tunnel so that the "traffic volume would diminish considerably (the street would become a "residential street")" on the street that respondents had pointed out to cause them the most nuisance. Navrud (2000b) and Lambert et al (2001) both describe the noise reduction in terms of level of annoyance, i.e. elicit the WTP for a program of noise mitigating measures that eliminate annoyance. Navrud (2000b) also provide the respondents with a detailed list of avoided impacts in terms of discomforts, including sleep disturbance. They are then told that the program will eliminate noise annoyance indoors, provide a 50 % reduction of noise annoyance outside their dwelling, and eliminate noise in parts of an important recreational forest area nearby. Such "elimination of noise annoyance" - scenarios have the advantage of being directly linked to the ERFs for noise annoyance. If the respondents are asked about their current level of noise annoyance, economic estimates per person annoyed per year for different noise annoyance levels (preferably corresponding to endpoints of ERFs) can be estimated.

[5] Delphi studies applying Multi Attribute Decision Analysis have also been performed on road traffic noise, e.g. Wenstøp et al (1994)´analysis of representatives from the environmental, transportation and health authorities in Norway. Mean annual aggregate WTP to avoid "one person complaining about road traffic noise" was estimated at about 1000 euro. This method is not based on individual preferences, but on experts´ preferences.

Most SP studies do not seem to include questions about level of annoyance, and therefore such estimates cannot be estimated. Notable exceptions include Vainio (1995, 2001), Navrud (2000b), Lambert et al (2001) and Sælensminde and Hammer (1994) (see also Sælensminde 1999). However, the last study has the weakness of using an exposure-based scenario (i.e. describing the change as e.g. "50 % reduction in noise level") rather than the preferred annoyance-based scenario (i.e. describing the change as e.g. "eliminating noise annoyance"). The study by Sælensminde and Hammer op. cit. was used by the Norwegian Directorate for Public Roads to calculate economic values per person HA per year (by dividing the aggregated WTP on the number of persons HA in the sample) as a function of the change in noise level. Different unit values were used for reductions and increases in noise level, to reflect the results from this CA study showing higher WTP to avoid a percentage increase in noise level than for the same percentage reduction in noise level. This can be explained by "loss aversion" and risk aversion towards higher level of noise due to uncertainty about the increased annoyance they will experience (and whether you can take it or not, since high transactions costs and other reasons restricts the willingness and ability to move to a new house even if the noise annoyance becomes unbearable).

Realistic and fair payment vehicles should also be used to avoid large portions of protest zero answers observed in many SP studies on noise (e.g. Navrud 1997, Lambert et al 2001). Different elicitation methods, i.e. open-ended (with and without payment card), closed-ended (dichotomous choice, single or double bound) should be tested and compared with new approaches (e.g. Navrud 2000b, and Barreiro et al 2000) to see which elicitation method that works best for noise. The best approach in terms of payment vehicle and elicitation methods for noise could, however, differ between different noise sources and different countries due to e.g. different institutional settings, cultures and preferences.

Choice experiments (CEs) have been employed in the marketing, transportation and psychology literature for some time, and arose from conjoint analysis. CEs differ from typical conjoint methods in that individuals are asked to choose from alternative bundles of attributes instead of ranking or rating them. Under the CE approach respondents are asked to pick their most favoured out of a set of three or more alternatives, and are typically given multiple sets of choice questions. Because CEs are based on attributes, they allow the researcher to value attributes as well as situational changes. This approach can provide substantially more information about a range of possible alternative policies as well as reduce the sample size needed compared to CV. It also allows for simultaneous valuation of several characteristics/goods that naturally belong together, and thus has the potential of avoiding aggregation biases. However, survey design issues with the CE approach are often much more complex due to the number of goods that must be described and the statistical methods that must be employed. Also, lexicographic choices and other simplifying strategies employed by the respondent to choose between complex alternatives, could lead to biased results (Sælensminde 2000).

3.3. Benefit Transfer techniques

There are two main approaches to benefit transfer:

i) Unit Value Transfer Simple unit transfer
  - (a) Simple unit transfer
  - (b) Unit Transfer with income adjustments

ii) Function Transfer
  - a) Benefit Function Transfer
  - b) Meta analysis

3.3.1. UNIT VALUE TRANSFER

Simple unit transfer is the easiest approach to transferring benefit estimates from one site to another. This approach assumes that the utility or dis-utility experienced by an average individual at the study site is the same as that which will be experienced by the average individual at the policy site. Thus, we can directly transfer the mean benefit estimate from the study site to the policy site (or generalize from a local study site to a national policy site (i.e. average national values)

If the unit of benefit estimate is "euro per dB per person per year" or NDSI the obvious problem with transfer of this unit values is that individuals at the policy site may not value the same change in noise level the same as the average individual at the study sites. There are two principal reasons for this difference. First, people at the policy site might be different from individuals at the study sites in terms of level of annoyance from the same noise level (i.e. the proportion of the population at different annoyance levels is different for the same noise level), income, education, religion, ethnic group or other socio-economic characteristics that affect their demand for quietness. Second, even if individuals´ preferences for noise at the policy and study sites were the same, the opportunities to avoid noise might not be. A more robust unit of transfer could be "euro per person annoyed per year" with specific values for each annoyance level since we then at least would avoid making the strict assumption about the same distribution on annoyance levels for the populations at the two sites. For NDSI, one also has to make assumptions about equal local housing markets both in time and space.

In SP studies WTP is reported for one or more specified discrete changes in noise level, and not on a marginal basis. Therefore, the magnitude of the change, should be close, in order to get valid transfers of estimates of mean, annual WTP per household. Also the initial levels of noise should be close to avoid biases caused by non-linearity in the underlying physical impacts and/or economic estimate.

On the issue of units to transfer, one should also keep in mind that the valuation step is part of a larger damage function approach, where we are trying to find values for identified endpoints exposure-response functions for noise annoyance and other impacts from noise.

The simple unit transfer approach is not fit for transfer between countries with different income levels and standard of living. Therefore, unit transfer with income adjustments have been applied, by e.g. using Purchase Power Parity indices. However, this adjustment will not

take care of differences in preferences, environmental conditions, and cultural and institutional conditions between countries. Very few studies have tested for the impacts on valuation of these other factors (see e.g. Ready et al 1999 for an application to morbidity which observed transfer errors of ± 36-38 % between cities in five European countries).

3.3.2 FUNCTION TRANSFER

Function transfer could be transfer of the benefit function from one study (benefit function transfer) or transfer or a benefit function estimated from many studies (meta analysis).

Benefit function transfer
Instead of transferring the benefit estimates, the analyst could transfer the entire benefit function. This approach is conceptually more appealing than just transferring unit values because more information is effectively transferred. The benefit relationship to be transferred from the study site(s) to the policy site could again be estimated using either the HP method or SP approaches. For a CV study, the benefit function in its general form can be written:

$$WTP_i = b_0 + b_1 G_{ij} + b_2 C_i + e \qquad (1)$$

where WTP_i = the willingness-to-pay of household i, G_{ij} = the characteristics of the environmental good and site j, and C_i = characteristics of household i , and b_0 , b_1 and b_2 are parameters and e is the random error.

To implement this approach the analyst would have to find a study in the existing literature with estimates of the parameters b_0, b_1, and b_2. Then the analyst would have to collect data on the two sets/groups of independent variables at the policy site. The values of these independent variables from the policy site and the estimates of b_0, b_1, and b_2 from the study site would be replaced in the CV model (1), and this equation could then be used to calculate households´ willingness-to-pay at the policy site.

The main problem with the benefit function approach is due to the exclusion of relevant variables in the bid or demand functions estimated in a single study. When the estimation is based on observations from a single study of one or a small number of sites or a particular change in noise level, a lack of variation in some of the independent variables usually prohibits inclusion of them. For domestic benefit transfers researchers tackle this problem by choosing the study site to be as similar as possible to the policy site. The exclusion of methodological variables makes the benefit function approach susceptible to methodological flaws in the original study. In practise researchers tackle this problem by choosing scientifically sound original studies.

Meta-analysis
Instead of transferring the benefit function from *one* valuation study, results from *several* valuation studies could be combined in a meta-analysis to estimate one common benefit function. Meta-analysis has been used to synthesize research findings and improve the quality of literature reviews of valuation studies to come up with adjusted unit values. In a meta-analysis original studies are analysed as a group, where the results from each study are treated as a single observation into a new analysis of the combined data set. This allows us to evaluate the influence of the resources´ characteristics, the features of the samples used in each analysis (including characteristics of the population affected by the change in

environmental quality), and the modelling assumptions. The resulting regression equations explaining variations in unit values can then be used together with data collected on the independent variables in the model that describes the policy site to construct an adjusted unit value. The benefit function from a meta-analysis would look like equation (1), but with one added independent variable C_s = characteristics of the study *s* (and the dependent variable would be WTP_s = mean willingness-to-pay from study *s*).

While several literature reviews of noise valuation studies have been undertaken, I am aware of only two formal meta analyses. Schipper et al (1996) and Bertrand (1997) performed meta analyses of HP studies of aircraft noise and road traffic noise, respectively. These two analyses and meta-analyses of other environmental goods and health effects are not particularly useful for benefit transfer, because they focus mostly on methodological differences. Methodological variables like "payment vehicle", "elicitation format", and "response rates" (the latter used as an indicator of quality of mail surveys) in CV studies, and model assumptions, specifications and estimators in TC and HP studies, are not particularly useful in predicting values for specified change in environmental quality at the policy site. This focus on methodological variables is partly due to the fact that some of these analyses were not constructed for benefit transfer (e.g. Smith and Huang 1993), and partly because there were insufficient and/or inadequate information reported in the published studies with regards to characteristics of the study site, the change in environmental quality valued, and income and other socio-economic characteristics of the sampled population. Particularly, the last class of variables would be necessary in international benefit transfer, assuming cross-country heterogeneity in preferences for environmental goods. In most meta-analyses, secondary information was collected on at least some of these initially omitted site and population characteristics variables or for some proxy of them. These variables make it possible to value impacts outside the domain of a single valuation study, which is a main advantage of meta-analysis over the benefit function transfer approach. However, often the use of secondary data and/or proxy variables adds uncertainty

Most meta-analyses caution against using them for adjusting unit values due to potential biases from omitted variables and uncertainties in the measurement of included variables. To increase the applicability of meta-analysis for benefit transfer, one could select studies that are as similar as possible with regards to methodology, and thus be able to single out the effects of site and population characteristics on the value estimates. However, one would then have too few valuation studies of a specific environmental good to perform a Meta analysis. This is the case with SP studies for all noise sources, but probably not HP studies with both road traffic and aircraft noise.

Day (2001, p.98) shows that since marginal prices in hedonic markets are not necessarily constant, we would not expect any simple relationship to exist between marginal WTP for a property attribute and the quantity of that attribute presently enjoyed by a household., and thus meta-analyses of hedonic data that attempt to regress average implicit prices for environmental quality against average levels of environmental quality from various markets have no theoretical content. Therefore one should be cautious in using results from meta analyses of NSDIs (Schipper 1996 and Betrand 1997). Macroeconomic variables should be included in the meta analyses to try to correct for some of the observed differences.

3.3.3. CURRENT PRACTICE IN BENEFIT TRANSFER OF NOISE ESTIMATES

All these benefit transfer techniques have been used to determine noise values used by national transportation and environmental authorities. However, unit benefit transfer i.e. using unit values from one or a few (often recent) national valuation studies (CV; CE or HP), seems to be the dominating technique (see chapter 4). The benefit function approach, using simple regressions of WTP on initial noise levels and/or size and direction (increase/decrease) has also been used to some extent.

In his general assessment of HP methods Day (2001) conclude that implicit prices, like those for market goods, are market specific, i.e. they depend on the particular conditions of demand and supply that exist in that market. Since house prices and market are different between Member States, unit transfer of NDSI from one country to another, and from region to region within a country, will be highly uncertain.

Benefit transfer of unit values based on impacts in terms of level of annoyance (i.e. euro per person annoyed per year) seems to involve less uncertainty and fewer strict assumptions than the exposure-based unit values of NDSI and "euro per dB per person per year".

4. REVIEW OF NOISE VALUATION STUDIES

In order to get a complete overview of noise valuation studies (both revealed and stated preference methods) the existing databases for valuation studies (EVRI and ENVALUE) have been searched. Reviews of noise valuation studies prepared by national authorities have been collected, and academic journals publishing noise valuation studies have also been reviewed. Environmental valuation practitioners in Europe and North America have also been contacted in order to detect new and yet unpublished studies, and older "grey literature" in this field.

A search of the EVRI database (http://www.evri.ec.gc.ca/EVRI/) gives 12 hits on the word "noise". However, only three of these are transportation noise valuation studies, and all three are from Europe (Pommerehne 1988, Soguel 1994a and Vainio 1995). In addition, one study is related to noise from wind turbines in Denmark, and one study estimated the value of noise from tourism in a local community in Oregon, USA. The other studies were not related to valuation of noise. This clearly shows that the EVRI database, which was originally developed for water quality valuation studies, needs to add "noise" as a searchable predefined category to better represent noise valuation studies (see also the evaluation of the EVRI database; Navrud 1999a). The Australian ENVALUE database (http://www.epa.nsw.gov.au/envalue/) however, has four predefined categories of noise from different sources. A search of ENVALUE identifies 24 studies on airport noise (six from Europe), ten road on transport/traffic noise studies (none from Europe) and one specific rail transport noise study (not from Europe). No studies on industrial noise were found in any of the two databases. An overview of all these studies can be found in appendix 1. This search of the databases EVRI and ENVALUE clearly show the need for adding noise valuation studies to existing databases, which in practice means EVRI since ENVALUE is a "sleeping" database.

In addition to these databases, DETR (Department of the Environment, Transport and the Regions; now divided into DELR and DEFRA i.e. Department of Environment, Food and Rural Affairs) in the UK has constructed a list of environmental valuation source documents

for the UK (http://www.defra.gov.uk/environment/evslist/index.htm). However, this list includes only a few of the noise valuation studies listed in DETR´s review of noise valuation studies (DETR 1999; see also appendix 2).

National environmental and transport authorities in Europe have carried out literature reviews of noise valuation studies. Examples of institutions commissioning or conducting such literature reviews include; in the UK: DETR (DETR 1999, see appendix 2) and the Development Department of The Scottish Executive (SE) (Bateman et al 2000; see appendix 3); in Norway: Directorate for Public Roads (Veidirektoratet-VD) (Navrud 2000a, 2001) and Ministry of Environment (Navrud 1999b); in Sweden: the National Land Survey (Lantmäteriverket – LMV)) (LMV 1998); and in Denmark: Directorate for Public Roads (Vejdirektoratet) (COWI 2001) and the Rail Agency (Banestyrelsen) (COWI 1998). Most of the agencies mentioned above have also initiated and financed new, original valuation studies, in order to try to reduce the uncertainty in using transferred value estimates from previous valuation studies conducted a long time ago and/or in other countries. Summaries of the literature reviews performed by DETR and The Scottish Executive can be found in appendix 2 and 3, respectively.

These literature reviews have mainly been conducted to establish noise values for use in cost-benefit analysis (CBAs) of noise mitigating / traffic calming measures. However, The Scottish Executive, the Swedish National Land Survey and the Norwegian Directorate for Public Roads use, or aim at using, noise valuation studies to calculate compensation payments to land owners for welfare loss due to traffic noise, visual intrusion and other impacts from traffic on new roads and extension/widening of existing roads[6]. Noise valuation studies have also been used for environmental costing exercises of transport (e.g. COWI 2001 and the EC project UNITE) and even to calculate environmental taxes, e.g. noise charges for aircrafts (Thune-Larsen (1995) based on CV and CA studies, and Hoffman (1984) based on HP studies).

A review of the values used for noise in these four European countries (UK, Denmark, Sweden and Norway) shows that the methodological approach and unit used to measure the economic value of noise annoyance differ between countries, and even between different sectors/agencies in the same country. However, there seems to be two main approaches:

i) An economic value pr decibel per year; measured by the Noise Depreciation Sensitivity Index (NDSI), defined as the average percentage change in property prices per decibel.

ii) An economic value per year per person (or household) annoyed by noise. Two measures are used. a) value per person "highly annoyed" (HA), and b) value per person "annoyed", independent of the level of annoyance.[7]

[6] In the case of compensation payments for the overall annoyance of road building projects, the Hedonic Price method is ideal, as there is no need to isolate the different impacts of noise, accident risks, visual intrusion, local air pollution etc The noise level can be used as an indicator for overall annoyance. Since HP studies are based on actual behaviour in real estate markets the estimates will probably also hold up better in a court case than results from SP studies.

[7] Sometimes values are also expressed as per person *exposed* to noise levels above a certain level e.g. 55 db without referring to any annoyance level. This means that persons exposed to, but not annoyed by, noise will be included

The first approach is based on domestic Hedonic Price (HP) studies and/or a review of HP studies internationally; and in a few cases also expert assessments by real estate agents have been used. Nearly all of these studies report the results in terms of the Noise Depreciation Sensitivity Index (NDSI), which gives the average percentage change in property prices per decibel. To convert this capitalized value of expected future rents into an annual value, we have to make assumptions about time horizon and discount rate (which also vary between countries). To avoid making these assumptions, several authors (e.g. Palmquist 1981) have suggested using rental charges instead of sales prices as the dependent variable in HP regressions. Soguel (1991, 1994b) used the monthly rent (net of charges) as the dependent variable in his HP regression on dwellings in the town of Neuchatel in Switzerland. He found a value of SF 5.85 per db per household per month, which equals about 47 euro per year per household (1 SF = 0.675 euro). Furlan (1996) and Locatelli Biey (1994) also used monthly rent of apartments in their HP studies in the inner city of Paris and Turin (Italy), respectively. The last study used traffic volume as a proxy for the noise level, while Furlan op. cit had noise level data. However, neither of these two studies collected data on the income of households, and do not contain data on the average market price of apartments. Thus, no estimates of WTP per household can be constructed. One problem in using rental charges in HP studies is that the rental market could be controlled and therefore the difference in noise level often would not be fully reflected in differences in rental charges.

The second approach is based on Contingent Valuation (CV) and Choice Experiments (CE) like Conjoint Analysis (CA), and most of these valuation studies have been conducted over the last 5 – 10 years.

In addition to these two approaches, there have also been studies that try to calculate the national costs of noise annoyance in terms of percentage of Gross Domestic Product (GDP); see appendix 2 for the results from these studies. However, these results are not very relevant for benefit transfer to CBAs of noise reducing measures.

The recommended economic values for noise annoyance vary. This could be due to different initial noise levels, different income level, cultural differences, different methodological approaches (and the noise valuation unit used), whether other social costs than the annoyance costs are included etc. Below are a few examples on values and units used in some European countries that have many noise annoyance valuation studies, i.e. the UK, Norway, Denmark and Sweden.

DETR (1999) conclude their review of 64 noise valuation studies (including both original valuation studies and reviews of studies) by stating the range of results:

£15 - £30 (24 – 48 euro) per decibel per household per year (covering a total of 4 studies)
0.08-2.30 % change in property price per decibel (covering a total of 43 studies)
0.02-2.27 % GDP (covering a total of 15 studies)

DETR op. cit further note that "although it is difficult to compare between these different types of measurement without complete information about the population sampled, their properties and the noise levels to which they were exposed; the individual ranges they cover can provide helpful benchmarks for the magnitude of the external costs of noise. It is apparent that the studies sometimes make quite different estimates of the costs associated with noise. This can be due to a number of reasons - not only from methodological and sampling

differences, but also because studies often use different assumptions about baseline noise levels (e.g. using from between 30-65dB(A) as a zero-nuisance baseline) or use different time periods to identify average noise levels". For transport policy appraisal in the UK, DETR (1999) notes that HETA (Highways, Economics and Traffic Appraisal; a part of DETR) allows the use of £21.24 per household, for a one decibel noise improvement, based on Tinch's adaptation of the Soguel (1991, 1994) - study (see studies 8 and 27, appendix 2). However, given the uncertainties associated with transferring this value from its initial Swiss context, it is recommended that the estimate should be reported separately from other monetary values and that further UK-specific work should be carried out in future to improve upon this tentative value.

Environmental authorities in Norway (i.e. National Pollution Control Authority –SFT) use an ad hoc value of 10.000 NOK (1.250 euro) per person "highly annoyed" (HA) by noise. They further assume that with a 1 dB increase in the noise level an average person will be 2 % more highly annoyed. This results in a recommended value of 200 NOK (about 25 euro) per dB per person exposed per year (which is in accordance with the recommendations by ECMT 1998). The Norwegian Directorate for Public Roads use a noise value function which produces the higher value of 14.000 NOK per person HA per year for a 50 % reduction in the noise level; equivalent to a reduction in noise level of about 8 dB. This estimate is based on a combined CV and CA study (Sælensminde & Hammer 1994, Sælensminde 1999). They found a WTP of 17-35 euro pr dBA pr person per year (or 3.550 - 7.100 NOK, i.e. 440-890 euro, per year per annoyed person, i.e. counting and weighting equally both "somewhat" and "highly" annoyed persons; see Sælensminde (1999, table 10)). The Norwegian Air Traffic and Airport Management (Luftfartsverket) use a value of 3.900 per person HA per year. This clearly illustrates the use of different values for the same noise annoyance unit within the same country. SFT now wants to introduce a new valuation unit; i.e. the "annoyance score" introduced by Miedema and Vos (1998, 1999). The main advantages of this approach is that it also considers the welfare loss of persons at lower annoyance levels than HA by assigning different weights to the different noise annoyance level (i.e. higher weight to higher annoyance levels). However, it is still uncertain how the existing valuation studies can be used to estimate values per percentage unit of the annoyance score (without making rather arbitrary, simplistic, and unrealistic assumptions). The Norwegian Directorate of Public Roads, however, wants to keep "no. of persons HA" as the noise annoyance endpoint, and update and refine their value estimate for this endpoint.

In Denmark they report the economic value of noise in yet another unit; "highly annoyed dwelling". This value is based on two 20-25 year old Hedonic Price studies (one in Denmark (Hjort-Andersen 1978) and one in Sweden (Hammer 1974). These studies report NDSI as a function of the dB(A) level, e.g. Hammer (1974) report NSDI varying from 4.2 % at 57 dB(A) to 20.8 % at 71 dB(A). Using current mean prices for houses in Denmark, and adding an ad-hoc estimate of 50 % of this value to correct for other social costs of noise (than annoyance) the recommended value becomes (in 2000-prices) 49.752 DKK (6.675 euro) (COWI 2001).

In Sweden, the Directorate for Public Roads (Vägverket) now uses an economic value per person affected by noise varying from 0 at 50 dB to 13.890 1999-SEK (equal to about 1.480 euro) at 75 dB, which is based primarily on a HP study in Stockholm by Wilhelmsson (1997) (Johansson 2001).

In France, the Road Directorate applies an economic value of 963 FF (equal to about 147 euros) per person annoyed per year (Ministry of Transport - Road Directorate 1998; Lambert 2000).

The above overview of the use of noise values must be viewed as examples, and is in no way conclusive.

4.1. Road traffic noise

NSDIs for road traffic noise have been reported ranging from 0.08 % to 2.22 %, see appendix 3 (Bateman et al 2000). Bateman et al (2000) conclude that noise researchers have suggested that an "average" value lies somewhere in the lower part of this range. A simple mean of these studies suggests a NSDI of about 0.55. A HP study, not included in this review, using rental charges for apartments in Paris, (exposed to road traffic noise levels between 50 and 80 dB(A)) should also be mentioned. Furlan (1996) found a NSDI of 0.20 – 0.33 %.

Nelson (1982) reviewing 14 studies for the United States and Canada concludes that the average NSDI is around 0.4 % whilst more recent work by Bertrand (1997) suggests the average figure may be as high as 0.64 %. Betrand op cit used a meta-analysis to compare 16 estimates from nine different hedonic pricing studies of noise pollution carried out in the USA, Canada, Switzerland and Finland. Bertrand's results provide insights into how the hedonic price function varies from market to market. In line with expectations, the greater the average level of noise in a market and the greater the income of the market's households, the higher the implicit price that is paid for noise pollution reductions.

Bateman et al (2000), in their review of studies, point out that the use of a single statistic to compare studies conceals considerable heterogeneity in the exact method of their application. As an example, each of the studies deals with noise in a slightly different manner. Whilst the majority of studies have used the L_{eq} measure of noise (as shown in Column 4 of Table 5-2; appendix 3), the method by which the noise pollution impacting on a particular house is assessed can be very different from study to study. A number of studies adopt the noise contour approach whereby data from various monitoring points are used to construct bands of similar noise pollution across the urban environment. The noise pollution experienced by any particular property will depend on the band in which it falls. Studies using this approach include Gamble et al. (1974). More advanced measures of noise pollution can be achieved by using models that take account of the exact characteristics of a particular dwelling. Data from these models are likely to be much more accurate. Studies taking this approach include Pommerehne (1987), Soguel (1991) and Vainio (1995, 2001). Bateman et al (2000) also observe that studies vary considerably in the choice and accuracy of the explanatory variables used in the regression analysis and in the choice of functional form, and this affect the level of the observed NSDI.

Among studies that are not included in these review is the HP study in Glasgow reported in Bateman et al (2001). By using GIS (Geographical Information Systems) they are able to increase the number of independent variables in the HP function and measure them with greater accuracy (They had previously shown that GIS can accurately measure the visual exposure of properties to roads (Lake et al 1998)). They construct four different models where they start with traffic noise level and structural variables (i.e. characteristics of the house) only (Model I), and then add on neighbourhood variables, accessibility variables, and finally

also variables indicating the visual (dis)amenity of the land use surrounding the property (one being views of roads and traffic flows along them) for models II, III and IV, respectively. The implicit price for noise, i.e. NDSI, drops from 0.84 % in model I to 0.57, 0.42 and 0.20 in models II, III and IV, respectively. In model I the observed NDSI is an indicator for multiple environmental impacts of road traffic, while the much lower NDSI of the most complete specification of the HP function (model IV) is a much better representation of the isolate impact of noise annoyance by road traffic. Distinguishing the separate influence of noise may be relatively difficult though it is essential to include comprehensive measures of accessibility and the visual disamenity of roads. If this is not done then it is likely that the implicit prices estimated for noise will erroneously include the impacts of these factors.

Bateman et al (2001) also cites the study JMP Consultants Ltd. (1996) did for the UK Department of Transport valuing the nuisance from road traffic by asking the opinion of expert property valuators. Using a large sample they concluded that the best estimate of the NSDI was 0.29% per dB increase or decrease in noise pollution. This result falls in the range of values commonly reported from hedonic studies but is somewhat lower than the average of values reported in the hedonic literature.

Pommerehne (1988), Soguel (1991,1994a) and Vainio (1995) have used the contingent valuation approach to produce results that they can compare with those derived from their hedonic analyses. The Pommerehne (1988) study in Basel, Switzerland produces remarkably similar results. Estimating households' WTP to reduce noise pollution by half, the hedonic price method returns a result of 79 CHF per month (1 euro = 1.47 CHF) compared to a value of 75 CHF per month derived from the CV survey. In a similar manner, the Soguel study in Neuchatel, Switzerland produces highly comparable results. Again valuing households' WTP to reduce noise pollution by half, the research estimates a value of 60 CHF per month from the hedonic pricing method (Soguel, 1991) and a value of between 56 and 67 CHF per month from the CV survey (Soguel, 1994a).

The Vainio (1995, 2001) study in Helsinki, Finland is not so favourable. Applying the HP and CV methods to the same population sample in Helsinki (Finland), he found that the HP method produced 2 to 3 times higher values than the CV study (see Vainio (2001) which presents re-calculated results from the original study). The HP study was based on 1522 transactions and the CV mail survey had a 60 % response rate producing 418 useable responses. Based on the mean price of a dwelling unit Helsinki in 1991, Vainio (2001) calculates mean WTP per dB reduction in noise level (above 55 dBA) as a lump sum at 365 euros (2001 price level) per household. At a 6 % discount rate and indefinite time horizon this corresponds to reports a mean WTP of 22 euros per dB per household per year. The corresponding estimates from the CV study is 6 and 9 euros; assuming that reported WTP per person in the CV survey represents the WTP of the overall household and one person only, respectively.

In a nationwide CV survey of a random sample of about 1.000 households, Navrud (1997) found significantly different WTP for persons HA compared to those that were little or not annoyed. Mean WTP per household per year was 335 and 101 1996-NOK (1 NOK = 8 euro) for these two annoyance groups, respectively. Only 6 % of the households in this random sample were HA. Thus, mean WTP for the overall sample was 115 NOK/household/year.

Navrud (2000b) found a mean WTP per household per year of 1.520 – 2.200 NOK (equivalent to 165-275 euro) for the elimination of the noise annoyance from road traffic in

Oslo. This is assumed to be equivalent to a reduction in experienced noise level of 10 dB(A), All households interviewed were exposed to noise levels of 65 dB and above. No significant difference in WTP was found for the four different annoyance levels respondents classified themselves in, nor between WTP and the noise levels respondents were exposed to.

In a CV survey of 331 households living along highways in the Rhône-Alpes Region in France, Lambert et al (2001) found significant different WTP for a public program that would eliminate noise annoyance at home for respondents that classified themselves in five different annoyance levels (in accordance with the new annoyance levels; ISO 2001). While the overall mean WTP per household per year was 73 euros, the corresponding values for the annoyance levels “not at all”, “slightly”, “moderately”, “very” and “extremely” annoyed were 47, 61, 78, 101 and 130 euros, respectively. This is currently the only SP study using the new annoyance level classification according to ISO (2001). The results can be compared to SP studies using the previous annoyance level classification with four levels, since HA corresponds to the aggregating the two levels “very” and “extremely” annoyed.

Thune-Larsen (1995) used CV to value road traffic noise in the same area and for the same respondents as described in more detail chapter 4.2. (since valuation of aircraft noise was the main aim of the study). Mean WTP per household per month for a 50 % reduction in noise level was valued at 78 NOK per household per month (which was lower than the corresponding value for the same percentage reduction in aircraft noise from the same CV study). Assuming a 8 dB reduction in noise level, this corresponds to an annual WTP per household pr dB of 14 euros (1994 price level)-.

Wibe (1997) performed a CV study of 4000 randomly selected person in Sweden, asking for their WTP in terms of increased rental charges for their dwelling to eliminate noise from all sources. A response rate of 58 % in this postal survey gave 2322 useable observations. 50 % stated zero WTP, while the remaining 50 % were willing to pay 400 SEK per month per household. Thus, the overall WTP for the sample was estimated at about 200 SEK per month per household (1 euro = 9.22 SEK), or about 6.5 % of the mean monthly rental charge. Assuming a 10 dB reduction in noise level, this corresponds to an annual WTP per household pr dB of about 25 euros. Questions about level of annoyance from different noise sources (including noise from neighbours) were also asked.

Arsenio et al (2000) and Sælensminde and Hammer (1994) / Sælensminde (1999, 2000) both apply CE to road traffic noise in Lisbon (Portugal) and the counties of Oslo and Akershus (Norway), respectively. Arsenio et al (2000) interviewed 412 households in Lisbon in June-November 1999, and also performed noise measurements in the building the respondents´ apartments were located. Assuming that 10 dB represent a doubling of the noise level, preliminary results show a mean WTP per month per household of 7900 PTE per month per household (1 euro = 200 PTE). This corresponds to 474 euro per dB per household per year. This estimate is much higher than reported in the other studies reported here. This could (partly) be explained by the risk of overestimating annual WTP when the valuation question elicit monthly WTP, the methodology used to elicit unit values for noise and other assumption made, and the fact that “loss aversion” and risk aversion lead people to place a higher value on avoiding an increment in noise levels compared to the same percentage reduction in noise level.

Sælendminde (1999, table 9) reports a WTP per household per year of NOK 45-90 pr percentage point reduction in noise levels. For a 50 % reduction in noise level,

assumed to be equivalent of an 8dB reduction in noise level, the WTP is NOK 2250-4500 per household per year, and NOK 280-560 per dBA per household per year (1 euro = 8 NOK).

Garrod et al (2001), Scarpa et al (2001a) and Scarpa et al (2001b) reports results from a combined CE and CV (discrete choice) study of local residents in three English towns for traffic calming measures. Scarpa et al (2001b) conclude that there is no significant difference between estimated WTP from the two SP methods, and see these results as encouraging as the survey instruments in the two methods were quite different. Economic values separate for noise and other impacts of the traffic calming scheme were estimated from the CE study. The estimated mean WTP from the mixed logit models is in the range of 1.38 - 2.26 £ per household per year (1 euro = 0.61 GBP), i.e. about 2 – 4 euros per db per household per year. (The CE experiments had three noise levels; 60, 70 and 80 dB)

Barreiro et al (2000) performed a CV telephone survey of a sample of 600 households in the city of Pamplona in Northern Spain. They found a mean WTP per household per year of 4675 ESP (1 euro = 166 ESP) for the CV scenario "daytime noise would be reduced from the working day level to that of a Sunday morning". This is assumed to be equivalent to eliminate noise annoyance, although some respondents might think it would not do so. This would bias the WTP downwards. The positive image of Sunday mornings could bias the WTP upward. The net impact of these to effects is difficult to predict.

Weinberger (1992) conducted a CV study of a random sample of 7000 persons in Germany in 1989 asking for their WTP to "live in a quiet area". The monthly WTP (euro) was estimated at 0.85 L_{Aeq} – 36.6 , i.e. 10 euros per dB(A) per person above 43 db(A) (J. Lambert pers. comm.. 2002).

Due to the lack of data on average property prices in the HP studies and the uncertainties introduced by modeling assumptions and transfer of HP values over time and location (with different housing markets), we will put most emphasis on the SP studies of road traffic noise. Among these studies, only studies presenting results in terms of values for different levels of annoyance can be used if all steps of the DFA should be followed. However, since there are too few such SP studies to construct mean values for the EU Member States, a "second best"-approach would be to convert the results from existing SP studies into values per dB per household per year.

In order to calculate economic values per dB from SP studies we need to translate the SP scenarios into corresponding changes in dB levels. This involves using exposure-response functions and a set of strict assumptions. For a SP scenario of e.g. "50 % reduction in noise levels" we have to assume that:

(i) the respondents interprets the scenario as a 50 % reduction in noise *annoyance*,
(ii) a 50% reduction in noise annoyance is assumed to be equivalent with a 50 % reduction in the proportion of people strongly annoyed by noise as shown by exposure-response functions of noise level and noise annoyance (from an assumed average initial level of noise (since the reduction in dB corresponding with a 50 % reduction in noise annoyance will increase with a lower initial noise level),
(iii) the respondent states the WTP only for him-/herself and not others affected by the change in noise level, and

(iv) respondents interpret the SP scenario not as an instant reduction in noise level (which is a possibility that cannot be excluded), but as a reduction in the accumulated annoyance from noise over a year.

Assuming that the annual "average" initial noise level is in the area of 60-65 dB, exposure-response functions give the following approximate reductions in dB-level, which have then been used to produce the results shown in table 1.

(a) "getting a 50 % reduction in noise level" is equivalent to about 8 dB
(b) "getting a 100 % reduction in noise annoyance" is equivalent to about 10 dB
(c) "avoiding a 100 % increase in noise levels" is equivalent to about 10-15 dB

Table 1 summarizes results from SP studies on road traffic noise expressed in economic values per dB reduction in noise level**.** The table clearly shows the wide rage of values per dB per household per year from the existing studies. This large variation in values should be expected since one or more of the strict assumptions listed above will most probably not be fulfilled for all SP studies.

If we exclude older SP studies (done before 1995 and using exposure-based scenarios), and include studies valuing *reductions* in noise levels only (i.e. excluding the Arsenio-study), the higher WTP values are excluded and the range is reduced to 2-32 (2001) euro per dB per household per year. This range of values reflects a combination of differences in methodological and modeling approaches (and implicit assumptions made), and differences in preferences, sites, institutions, culture and contexts. A meta analysis of these studies could have tested the significance of these explanatory factors, but there are still too few of these SP studies to perform a comprehensive meta analysis.

To conclude, calculating economic values per dB per year from SP studies (and implicitly skipping many steps of the damage function approach and making simplified assumptions[8]) introduces a large degree of uncertainty, which is clearly reflected in the empirical results in table 1. This makes it difficult to recommend a specific interim value for road traffic noise from the range indicated by this "second best" – approach. Rather a quite broad range of values should be used until more SP studies linking annoyance levels and WTP have been conducted.

[8] A main assumption introducing uncertainty is the conversion of WTP for a specified discrete change in noise level described in the SP study into marginal WTP in terms of an economic value per db. Economic values per annoyed person for the different annoyance levels should also be much more stable across space and time than dB values.

Table 1.

Results from Stated Preference (SP) studies (Contingent Valuation (CV) and Choice Experiments (CE)) of *road traffic noise*; as experienced inside the dwelling. Willingness-to-pay (WTP) per decibel (db) per household (hh) per year, reported in national currencies in the year of the study and converted to 2001 - euro. The euro values have been calculated using exchange rates as of January 2002 and adjusting to 2001–value using GDP deflators (used by the European Commission) for the respective countries where the studies were conducted.

Study (Valuation Method)	**Site (Scenario description) / Year of study**	**WTP /dB/hh/year** (Original estimate in national currency in year of study)	**WTP /dB/hh/year in euros** (in 2001 price level)
Pommerehne 1988 (CV)	Basel, Switzerland (50 % reduction in experienced noise level) / 1988	112 CHF (= 75 CHF/month for 8dB)	99
Soguel 1994a (CV)	Neuchatel, Switzerland (50 % reduction in experienced noise level) / 1993	84 – 100 CHF (= 56-67 CHF/month for 8 dB)	60 - 71
Sælensminde & Hammer 1994, Sælensminde 1999 (CV and CE)	Oslo and Akershus counties, Norway (50 % reduction in experienced noise level) / 1993	281 – 562 NOK (=2250-4500 NOK/year for 8 dB)	47 – 97
Wibe 1995 (CV)	Sweden – national study (Elimination of noise annoyance) / 1995	240 SEK (= 200 SEK/month for 10 dB)	28
Vainio 1995, 2001 (CV)	Helsinki, Finland (Elimination of noise annoyance) / 1993	33 - 48 FIM	6 - 9
Thune–Larsen 1995 (CV and CE)	Oslo and Ullensaker, Norway (50 % reduction in experienced noise level) / 1994	117 NOK (= 78 NOK/month for 8 dB)	19
Navrud 1997 (CV)	Norway – national study (Elimination of noise annoyance) / 1996	11 NOK (= 115 NOK/year for 10 dB)	2
Navrud 2000b (CV)	Oslo, Norway (only hh exposed to > 55 dB) (Elimination of noise annoyance) / 1999	152 – 220 NOK (= 1520 – 2200 NOK / year for 10 db)	23 - 32
Arsenio et al 2000 (CE)	Lisbon, Portugal (Avoiding a doubling of the noise level) /1999	9,480 PTE (= 7900 PTE / month for 10 – 15 dB)	50
Barreiro et al 2000 (CV)	Pamplona, Spain (Elimination of noise annoyance) / 1999	476 ESP (= 4765 ESP / year for 10 db)	2 - 3
Lambert et al 2001 (CV)	Rhones - Alpes Region, France (Elimination of noise annoyance) / 2000	7 euros (= 73 euros /year for 10 dB)	7

4.2 Aircraft noise

Gillen and Levesque (1989) in their review of 15 HP studies on aircraft noise (and one combined HP and Expert assessment) in mainly U.S. cities found NDSI in the range from 0.4 to 1.1 % per dB, with a median value of 0.5-0.6 %. Another review, including also recent HP studies, Bateman et al (2000) found reported NSDIs (i.e. the percentage decrease in housing prices following a 1 dB increase in noise pollution) in the range from 0.29% to 2.3% for

aircraft noise (see appendix 3 for an overview of these studies). The variety of NSDI values should not come as any surprise. Theoretically, we would not expect different housing markets to have the same hedonic price function and, therefore, would not expect applications of the hedonic pricing technique in different cities in different years to return identical results. Schipper (1996) has carried out a more formal statistical test of these results using meta-analysis. He finds that the implicit price of aircraft noise pollution is influenced by a number of factors including the timing, country and specification of the original noise studies. His findings suggest that as a baseline the NSDI is around 0.33%, whilst for studies in the United States this rises to 0.65%.

Among HP studies not included in the literature reviews mentioned above are Gillen and Levesque (1991). For runway expansions at the Persons International Airport in Toronto, Canada they found NSDIs of 0.48 and 0.21 % for single/semi-detached houses and condominiums, respectively. Gillen and Levesque (1990) report another HP study regarding the establishment of the same airport, with estimated NSDIs of 0.43 and 0.08 % for single family homes and condominiums, respectively. They point out that these impacts should be corrected for the positive impact of accessibility (estimated as elasticity for house value with distance equal to –0.02 and –0.04 for single family homes and condominiums, respectively) to calculate the net effect of the airport.

Bateman et al (2001) in their HP study in Glasgow (see chapter 4.1) also valued aircraft noise. The most comprehensive model (Model IV), in terms of number of independent variables, produced a NSDI of 0.25 %, which is higher than the corresponding value for road traffic noise (0.20 %) in the same HP study. Hiron (1999) reports a recent French HP study.

Few SP studies have been conducted on aircraft noise, and to my knowledge none that present WTP in terms of annoyance levels. The very first of these CV studies seems to be Opschoor (1974), which by current standards would be considered a low quality CV. Pommerehne (1988) conducted parallel HP and CV studies on aircraft noise in Basel, Switzerland, and found a mean WTP per household per month of 22 and 32 CHF (1 euro = 1.47 CHF), respectively. Navrud (2000b) conducted a CV survey of persons exposed to aircraft noise and other sources (road, train and rifle range) in the communities of Oslo and neighbouring Ullensaker (where the Oslo Airport is located). Thune-Larsen (1995) performed in-person interviews of 473 respondents around the Oslo Airport Fornebu (now closed, and replaced by the new Oslo Airport Gardermoen) using both CV and CA techniques to value aircraft noise. Scenarios with percentage reductions in noise levels were used (varying percentage change scenarios in the CA, and a 50 % reduction scenario only in the CV question). Mean WTP per household per month of 91-460 NOK and 104-353 NOK (1 NOK = 8 euro) were estimated for the CA and CV method, respectively.

Baarsma (2000) conducted a study of aircraft noise in 1998 around the Schiphol airport outside Amsterdam (The Netherlands) using Conjoint analysis (CA) and two other, new valuation methods (i.e. the welfare evaluation method and the well-being evaluation method). Baarsma op. cit concludes that the “well-being evaluation method”, based on the Cantril measure of well-being that is based on the respondents´ answers to a “ladder-of-life questions”, works the best in terms of significant relationships with the measure for noise nuisance used (i.e. Kosten units (Ku)[9]; an “objective” measure of aircraft noise nuisance

[9] The measure of noise nuisance levels from aircraft noise differs between countries, e.g. the US use Noise Exposure Forecast (NEF), the UK use Noise and Number Index (NNI), and the Netherlands use the Kosten unit (Ku).

developed in the 1960s for the Netherlands by the Kosten Committee, named after the chairman: late professor Kosten). The results are presented in terms of the compensation required per household per month if noise nuisance increase. For households with a net monthly income of 5000 DFL (1 euro = 2.20 NLG) living in a house with no noise insulation, a rise in noise level from 20 to 30 Ku would require a compensation of 215 NLG per month. The corresponding value based on information about living expenses (1,500 NLG/month) and asking price for the dwelling (400.000 NLG) instead of household income, is 357 NLG.

Table 2.

Results from Stated Preference (SP) studies (Contingent Valuation (CV) and Choice Experiments (CE), including Conjoint Analysis (CA)) of *aircraft noise*; as experienced inside the dwelling. (Based on the same assumptions as for road traffic noise; chap.4.1 and table 1)
Willingness-to-pay (WTP) per decibel (dB) per household (hh) per year, reported in national currencies in the year of the study and converted to euros. The euro values have been calculated using exchange rates as of January 2002, and adjusting to 2001–value using GDP deflators (used by the European Commission) for the respective countries where the studies were conducted.

Study (Valuation Method)	**Site (Scenario description) / Year of study**	**WTP /dB/hh/year** (Original estimate in national currency in year of study)	**WTP /dB/hh/year in euros** (in 2001 price level)
Pommerehne 1988 (CV)	Basel, Switzerland (50 % reduction in experienced noise level) / 1988	48 CHF (= 32 CHF/month for 8dB)	43
Thune-Larsen 1995 (CV and CA)	Residents around Oslo Airport Fornebu, Norway (50 % reduction in experienced noise level) / 1994	NOK 1.092 - 5.520 NOK (=91-460 NOK/month and 104-353 NOK/month for 8 dB; from CV and CE, respectively)	190 - 959
Faburel 2001 (CV)	Residents around the Paris-Orly airport (Elimination of noise annoyance) / 1999	8 euro (84 euro/year for 10 dB)	8

Note:
Results from two SP studies could not be reported in terms of WTP/dB/hh/year: Baarsma (2000) reported willingness-to-accept compensation (WTA) for an increment in the Dutch aircraft noise measure Ku, and Navrud (2000b) elicited WTP for a package of measures reducing aircraft noise and other types of transportation noise (and thus WTP for airport noise only cannot be separated out). These two studies are, however, described in the text above the table.

Faburel (2001) conducted a CV study of the benefits from eliminating aircraft noise annoyance around the Paris-Orly airport in France by a public program involving modification of flight paths. More than 600 residents were interviewed in 1999. In the most noise exposed areas (L_{Amax} > 80 dBA), the annual, mean WTP per person was estimated at 83 euros while in the least exposed areas (L_{Amax} between 70 et 75 dBA), the WTP was 11 euros. L_{Amax} was used since this noise measure had the highest correlation with annoyance. Noise exposure, noise annoyance as well as non-acoustic variables as level of education, sensitivity to noise, had a significant effect on WTP.

Deriving household WTP (84 euros per year in average), benefits of the elimination of aircraft noise annoyance around Paris-Orly airport was estimated to 1.8 millions euros per year.

Table 2 compares the results of three of these SP studies in terms of the economic value per dB per household per year, which shows an even bigger variability in values than reported for road traffic noise in table 1. However, one should note that the results from these studies are not directly comparable as a change in noise level of e,g. 10 dB measured as maximum noise level L_{Amax} (used by Faburel (2001)) and average noise level L_{Aeq} (versions of this used by Pommerehne 1988 and Thune-Larsen 1995) are not directly comparable.

Due to the low number of SP studies on aircraft noise, and the wide range of values for both aircraft and road traffic noise, one cannot say whether aircraft noise is valued higher than road traffic noise, or vice versa.

4.3. Rail noise

Only two original valuation studies on rail noise have been identified; both of them HP studies. However, the CV scenario, annoyance level questions and noise exposure data of Navrud (2000b) also include railway noise.

In the Gamlebyen region in Oslo (near the Oslo Central Railway Station) Strand and Vågnes (2001) used both HP and a Delphi study (using a Multi Criteria Analysis technique) of real estate brokers to value rail noise. Using distance to the rail tracks as a proxy for noise level the HP study found that a doubling of the distance to the tracks would mean a 10 % increase in property prices. In the Delphi study, a mean WTP of 2.000 1996 NOK per meter increased distance to the track. All results are for apartments. For single family and detailed houses the impact is 20-27 % higher than for apartments.

A HP study on railway noise in Sydney, Australia (Holsman and Paparoulas 1982) found that the occurrence of railway noise in areas with no benefits from increased accessibility reduce property prices by 10 %.

4.4. Industrial noise and other types of noise

No valuation studies on specifically on industrial noise have been identified. However, the HP study of Oosterhuis & Van der Pligts (1985) looked at both road traffic noise and industrial noise. They found a NSDI of 0.4 % for the combined impact of the two noise sources. The CV scenario, annoyance level questions and noise exposure data of Navrud (2000b) also included rifle range noise and industrial noise (but no noise exposure data for the latter).

5. THE POTENTIAL FOR BENEFIT TRANSFER OF EXISTING STUDIES

The noise valuation literature is dominated by HP studies (most of them old) on road traffic and aircraft noise of varying quality. However, NDSI estimates from HP studies seem to be problematic to transfer, both theoretically and in practice (Day 2001).

There is an increasing number of SP studies on road traffic noise, but only a few present WTP in terms of "euro per annoyed person per year" for different annoyance levels, which correspond to endpoints of ERFs. Due to the low number of studies that can be used for this approach, a "second-best" alternative is to evaluate all these SP studies with regards to quality (e.g. avoid using studies with scenarios based on changes in exposure rather than annoyance and health impacts), choose the best ones, and calculate a value in terms of "euro per dB per person per year". The number of high quality European studies on road traffic noise might be sufficient to establish a EU value based on this approach. For noise from air, rail and industry there seem to be too few SP studies to evaluate whether the same values as for road traffic noise can be used. Due to the different characteristics of these four types of noise, one would expect that these exposure-based values would differ between different noise sources (while the preferred annoyance based unit value would probably not be so sensitive to the source of noise). Another uncertainty the pr. dB – approach faces is the conversion of WTP values for relatively large discrete changes in noise valued in SP studies to marginal values assuming linearity. Benefit function transfer might be used to reduce this uncertainty.

In addition to benefit transfer in space, one might also have to transfer values in time. This is usually one using the consumer price index (CPI) as a proxy. However, it is still an open question whether the CPI of the study country or the policy country that should be used. Also, one should consider whether the CPI is representative of the change in value over time for noise annoyance.

Conversion of values expressed in national currencies to euro is also somewhat more complicated than simply using of financial exchange rates. Environmental goods and health are most closely analogous to a consumable, i.e. it is something that respondents would "buy" with disposable income, in order to generate welfare or utility. The decision whether to "buy" the environmental and health improvement at the price given is therefore critically dependent on the prevailing prices at which other consumable goods can be purchased. However, for many reasons, similar market goods cost different amounts of money in different countries. These price differences must be considered when converting values from one currency to another. Purchasing Power Parity (PPP) exchange rates that reflect differences in the national average prices for the standardized bundle of goods provides a practical solution to theoretically correct conversions between currencies. OECD publishes average annual PPP indexes (with US $ as the baseline) for all OECD-countries.[10] However, it is not known whether such corrections with Purchase Power Parity (PPP) indices and adjustments with national or EU-average Consumer Price indices (CPI), would reflect the change in noise valuation over time and space.

[10] These PPP indices are national averages (EU15 average values are also reported). If the study area of the valuation study is a large city, where price levels tend to be higher than the respective national average, using national average PPP values would overestimate the value.

6. WHAT SHOULD BE THE CUT-OFF POINT FOR VALUING NOISE ?

When using economic values per dB, practice among transportation authorities in Europe and the US has been to use different cut-off points for different modes of transportation. Typically a “bonus” of 5 dB is given to rail, compared to road and air to correct for the fact that rail noise at the same noise level is less disturbing than road traffic and aircraft noise. This means cut-off points of 55 dB for air and road, and 60 dB for rail, which means zero damage costs of noise below these levels.

Exposure-response functions for transportation noise show that people are annoyed by noise at levels below 55 dB (Miedema and Vos 1998, 1999 and Finegold et al 1994), and that elimination of noise annoyance occurs at 37-40 dB (and theoretically even lower, but in practice other noise sources, e.g. noise from neighbours, would dominate at lower levels of transportation noise). The review of valuation studies also shows that people exposed to noise levels below 55 dB and/or are not annoyed by noise have a positive willingness-to-pay (WTP) for noise reducing measures like noise absorbing road covers and improved tires (see e.g. Navrud 1997). To avoid underestimation of benefits of such measures, which reduce road traffic noise for both high and low levels of initial noise (as opposed to e.g. noise screens in locations with high noise levels), the cut-off point for noise should be below 55 dB. However, both ERFs and economic value estimates for annoyance become very uncertain below 50 dB due to few empirical studies at these low noise levels. Thus, L_{den} 50 could be used as an interim cut off point for economic valuation. However, even this cut-off point will most probably produce conservative estimates (underestimates) of benefits from reduced noise annoyance, which could lead to “wrong “outcomes” of CBAs of noise reducing measures which also have a positive impact on a high number of houses with low initial levels of noise.

7. WHAT VALUE SHOULD BE USED BEYOND THE CUT-OFF POINT?

Ideally, interim economic values for noise should be based on results from high quality valuation studies only, i.e. valuation studies using state-of–the-art methodology and preferably constructed with benefit transfer in mind.

There seems to be two alternative units in which interim values for noise could be presented: (i) Economic value per person annoyed per year; with separate values for each level of annoyance (in accordance with endpoints from ERFs), and (ii) Economic values per dB per person (household) per year

Both alternatives should be based on results from SP studies. This will avoid the problems isolating the value of noise annoyance in HP studies, making all the uncertain assumptions by converting NDSI values from HP studies to values per dB per person per year, and avoid the problems of benefit transfer of HP studies noted by Day (2001).

Alternative i) is the preferred one, as marginal values needed for benefit transfer are elicited directly from SP studies (also containing questions about the respondents current level of annoyance). This eliminates the need for many strict and unrealistic assumptions needed to construct marginal values (pr. dB) from values for discrete changes in noise levels and noise annoyance (see page 20). Values per annoyed person per year at different annoyance levels are also thought to be more stable (and easier and more transparent to adjust) across time and space, since it is based directly on a measure of individual preference (instead of the indirect, technical measure of dB).

However, since there are currently few SP studies reporting economic values per annoyed person per year (see sections 3 and 4), alternative ii) could be considered when constructing interim values. The value per dB per person per year would have to vary with different initial noise levels (Most of the existing SP studies have initial noise levels in the 55-65 dB range). Tables 1 and 2, summarizing the results from SP studies on road traffic and aircraft noise, respectively, clearly shows the large variability in estimates of WTP per dB per household per year. It is difficult to narrow these ranges of values down to specific, reliable interim values, but an interim range of 2-32 euro per household per dB per year seems reasonable for road traffic noise. For aircraft noise there are too few studies to defensibly narrow the large range shown in table 2. For other noise sources the empirical evidence is close to non-existent.

8. SAME VALUE FOR NOISE FROM DIFFERENT TRANSPORTATION MODES?

The noise measure L_{den} corrects for different distribution of noise over time, but not the content and composition of noise. An example: A classical music concert and a rock music concert might have the same L_{den} level, but the noise have very different contents and composition, and the enjoyment/annoyance of these two concerts would vary between individuals according to their preferences (An important difference between this example and transportation noise is that the latter noise source individuals in most cases are involuntarily subjected to).

Aircraft noise is often considered to be the worst since it is characterised by infrequent events with very high noise levels. Rail noise has the same characteristics, but opposed to aircraft noise you can hear the train coming well in advance and prepare for the high noise level when it is passing. Also it is easier to find effective noise reducing measures against rail noise, while it is more difficult to protect households from air noise (i.e. noise coming through the roof). However, if there are few or no restrictions on night traffic, train noise cause high levels of sleep disturbance. In situations with restrictions on rail noise during the night, road traffic noise is ranked higher in terms of noise annoyance than rail, but lower than air. Road traffic is characterised by more frequent and constant levels of noise than air and rail noise. The annoyance from industrial noise will vary dependent on the type of industry and noise. Single tone component noise is more disturbing than noise over a wide spectre, and sharp increases in noise levels (e.g. hammering) is more disturbing than a constant noise level (e.g. ventilation system, fans). Thus, the same L_{den} level for different sources gives different levels of annoyance. This is also reflected in ERFs for noise from different sources (see appendix 5).

Results from a recent HP study in Glasgow including data on both aircraft and road traffic noise in Glasgow also indicate that reductions in aircraft noise are valued higher than road traffic noise (Bateman et al 2000; table 9-3).

In a situation where individuals are exposed to *multiple sources of noise,* measures to reduce one dominating source (especially if the decibel level is below 65dBa) or one out two equal noise sources will have little effect on the level of annoyance as the other sources will take over and dominate. (e.g. shutting down an airport makes people at some distance from the airport more aware of and annoyed by nearby roads traffic noise). Therefore, action plans towards noise must consider all noise sources (especially when the noise level is below 65 dB(A); at higher noise levels there is a more significant effect of reducing one noise sources, and they may be treated source by source). Also, the effect on total annoyance by different environmental factors might be little affected by a measure to reduce noise from one or several sources if e.g. levels of air pollution (causing health impacts and visibility effects),

visual intrusion and accident risks are constant. Therefore, one should shift the focus from noise alone to look at the total annoyance level and welfare effect of all environmental factors that affect households.

If we use annoyance level - based units of value, we should be able to use the same value for all noise sources (since the difference between noise sources is “taken care of” in the different ERFs between noise levels and noise annoyance), while noise exposure - based values would have to be different for different noise sources to correct for their different characteristics and level of annoyance at the same dB level

9. SHOULD THE VALUE FOR ALL MEMBER STATES AND ACCENSION COUNTRIES BE THE SAME?

Economic values per dB per person per year, estimated from SP studies or NDSIs found in HP studies could certainly vary both between socio-economic groupings (e.g. income groups) within a EU country and between EU countries. A meta analysis of HP studies on road traffic noise suggests that the implicit price of noise (NDSI) will be higher in property markets where households are relatively wealthier and where the general level of pollution is relatively higher (Bertrand, 1997). Smith and Huang (1995) found the same results for air pollution in a meta analysis of HP studies.

The level of annoyance from the same decibel level measured outside the house (L_{den}) could be different in different countries because of: different building traditions and climates (wood, brick, insulation, double glazing in cold climate protects against low temperature and noise), activity level outdoor and proportion of time spent indoors/outdoors (e.g. in the Nordic countries garden activities are mainly in the summer), the kind of activity (i.e. different activities are differently affected by noise), and income level in the country (seem to be less annoyed by noise in low income countries - e.g. give priority to other effects). Even the economic value of specific noise annoyance levels (believed to be less subject to benefit transfer error) could vary between countries according to income, although there is little empirical evidence of this effect. CV studies using “road traffic noise annoyance elimination scenarios” found mean annual WTP per household to represent 0.35, 0.32 and 0.19 % of the mean annual income of the population interviewed in the Rhone-Alpes region in France (Lambert et al 2001), Helsinki, Finland (Vainio 1995, 2001) and Pamplona in Northern Spain (Barreiro et al 2000), respectively. The lower value of Barrerio op. cit could, at least partly, be explained by the fact that they used a CV scenario that could be interpreted as not eliminating noise annoyance completely.

Thus, there seems to be some empirical support for a lower value in the ascension countries (and EU15 countries with below average EU15 per capita incomes) than other EU 15 countries, if we use an exposure based unit for the economic value of noise, but less so for annoyance based units. Using lower economic values in ascension countries implies accepting higher noise emissions in these countries. Following the same procedure as recommended in the case of mortality values for CBAs with the EC, this means adjusting the noise value with PPP indices. However, there are also reasons to argue for the use of the same value in all EU countries The first reason for recommending the same central values for all EU15 and ascension countries is purely ethical. EU countries do not discriminate within their own

populations on the basis of income and it is not right that the EU should do so either. Secondly, whilst, theoretically, willingness to pay varies with income, it also varies with a number of cultural and social factors and their influence may be greater than that of income alone. (People in ascension countries might be even more annoyed than people in EU 15 countries at the same noise level due to serious health problems and financial/social problems). Therefore, without hard empirical evidence it would be misleading to adjust between populations solely on the basis of income. The proposal for a Directive on the Assessment and Management of Environmental Noise (END annex III) recommends that specific ERFs should be presented for different climates and different cultures, which also would reduces the need for different economic values for the same annoyance level.

10. RESEARCH GAPS

A number of research gaps have been identifies, and are discussed below (in random order):

1) In order to apply the Damage Function Approach to value welfare loss from noise annoyance, there is a need for more Stated Preference studies. These studies should include questions about annoyance levels in order to improve economic estimates per person per year for each annoyance level (including "not annoyed at all", to capture pure altruistically motivated WTP). The annoyance level questions should be based on an international standard, which should be checked for the potential of misunderstanding when translating the questions from English to other languages. The annoyance levels also have to correspond with endpoints of existing ERFs for noise annoyance.

   There is also a need for improved scenario descriptions both in CV and CE studies, focusing on impacts and level of annoyance instead of change in exposure. This means avoiding the typical "50 % reduction in noise level" – description, and instead using e.g. a "elimination of noise annoyance" – scenario (Note that this is elimination of noise annoyance and not the noise, which, at least outdoors, would be an unrealistic impact of most noise reducing measures)

   Conducting the same SP study in several European countries at the same time would provide a test on the validity of benefit transfer of noise values between countries (see Ready et al 1999 for such a test of the value of respiratory illnesses caused by air pollution).

2) The noise measure L_{den} is based on a weighted average of the noise level during the day (12 hours), evening (4 hours) and night (8 hours) (with default values 07.00-19.00, 19.00-23.00 and 23.00-07.00 hours local time, respectively). 5 and 10 decibel (dB) is added to the actual noise level for evening and night, respectively, to correct for differences in annoyance at the same dB level during day, evening and night. However, we do not know if the affected persons value noise during day, evening and night in the way assumed by these weights in all Member countries, and whether valuation of noise annoyance at different times of the day correspond with these weights. There is therefore a need for a comparative Stated Preference valuation study of noise annoyance in the Member countries (or a "representative" sample of them), which should also include standard questions on level of noise annoyance.

3) DETR (1999) in their review of studies note that: "almost all the studies identified are limited to valuations of road and air traffic noise exposure in the home only. While very little data on alternative sources and exposures to noise currently exists, the measurement of noise costs in different contexts is crucial, and exposure to different types of noises at work, at home, at leisure and while travelling all need to be considered if the effects of noise pollution are not to be understated". More studies are therefore needed on rail and industrial noise.

   All economic valuation studies focus on noise annoyance. Therefore, there is a lack of valuation studies for other social benefits from noise reducing measures, e.g. sleep disturbance. Improved exposure response functions (ERFs) are also needed for noise annoyance, especially for rail and different types of industrial noise, and for other impacts of noise e.g. ERFs between L_{night} and sleep disturbance for all transportation modes and industrial noise. If we move from using noise annoyance values as an indicator of total welfare loss of noise to value each impacts (along the lines suggested by Hunt 2001), we also need studies of whether (and to what extent) people include welfare loss due to sleep and communication disturbances when asked to value noise annoyance in SP studies, to avoid double counting and overestimation.

4) Annoyance ERF studies and valuation studies should also look at the effect of noise reducing measures in situations with multiple noise sources and also consider noise in the broader context of all environmental factors affecting peoples well-being (Klæboe et al 2000).

5) New CV and CE studies should be constructed to provide values for endpoints of exposure- response functions (ERFs) of noise annoyance in terms of values per person highly annoyed (HA), or rather values from the new five-level annoyance scale which should be used in new CV and CE studies. More research is also needed to include welfare loss for people exposed to lower annoyance levels. One option is to construct ERFs and economic values for each annoyance level. However, the evidence is mixed with regards to whether one can produce economic estimates that are significantly different for each annoyance level (While Lambert et al (2001) found a significant effect in France (Rhône-Alpes Region) for road traffic noise, Navrud (2001) did not in Norway for road traffic in Oslo and for multiple noise sources in an area around the Oslo Airport).

   An alternative could be to try to construct economic values for the "annoyance score" (AS) constructed by Miedema and Vos (1998, 1999) or the three categories (annoyance levels) constructed from the same index (Miedema and Oudshoorn 2001). This could either be based on existing CV and CE studies and use weights they (implicitly) apply to the different annoyance levels, or better; based on new empirical studies which also test the validity of these weights (i.e. to test whether individual preferences correspond with expert assessments by noise annoyance researchers).

   SP studies of scenarios involving reductions in night noise only are needed in order to calculate unit values for people annoyed by changes in the $L_{night.}$

6) The natural unit of economic value in CV and CE studies is the household (since financial decisions in a household are taken on a household level rather than at the individual level), while ERFs use "persons annoyed" as their endpoint. More research is needed to establish rules and factors of conversion between economic values per person and per household.

Persons within the same household exposed to the same noise level could also be annoyed to different degrees. Therefore, the practical procedure of using the average number of persons per household as the conversion factor is a simplification that needs to be tested.[11]

7) Different noise annoyance scales are used both in noise annoyance studies and SP studies. This makes it difficult to construct general ERFs for annoyance, general economic values for annoyance and to link endpoints of ERFs with the economic estimates. Work to standardize the annoyance scale is now undertaken (as a technical specification under the ISO system; see ISO 2001), but standard conversion factors between the different scales used are also needed to take advantage of the large number of existing studies.

8) ERFs, level of noise annoyance and economic values at noise levels below L_{den} 50 are very uncertain, and more empirical studies are needed to be able to set a lower cut-off point and avoid underestimation of social benefits of noise reducing measures affecting low noise levels. Note that even if the economic benefit per exposed household is lower for households at lower initial noise levels (compared to very high noise levels), there are many more households affected at low noise levels. Thus, aggregated benefits over all affected individuals could be just as a high for measures reducing noise at low noise levels (e.g. low noise tires) compared to measures implemented only for households at high noise levels (e.g. noise screens). However, one should check for situations where other noise sources take over when the dominating noise source is reduced or eliminated, and control for this in order to avoid overestimation of social benefits from measures reducing noise from the initially dominating source.

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[11] Evidence from CV studies on morbidity shows that adults value avoidance of respiratory symptoms to their children higher than to themselves and (Navrud 2001), and it is still an open question whether this is the case for children annoyed by noise. This will obviously affect the conversion from economic value per person to per household. Navrud op cit also found that willingness-to-pay (WTP) to avoid respiratory symptom days for all members of the household was 1.6-1.8 times higher than WTP to avoid own symptom days (which is lower than the average household size in Norway of 2.22 persons, which is again slightly higher than the EU average of 2.16 persons per household).

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APPENDIX 1
SEARCH FOR NOISE VALUATION STUDIES IN THE DATABASE *ENVALUE*

http://www2.epa.nsw.gov.au/envalue/

(Click the author(s) to see details of each study, as listed in ENVALUE)

ENVALUE presents studies in four different transportation noise categories (see below):

ENVALUE - Airport Noise Valuation Studies

Author	Year	Country	Location	Method
<>Abelson (1978)	1972-73	Australia	Sydney,	Hedonic Price Method
<>BIS Shrapnel Pty Ltd (1990)	1988	Australia	Sydney,	Hedonic Price Method
<>Burns & Associates (1989)	1988	Australia	Adelaide,	Hedonic Price Method
<>Coleman (1972) in Pearce (1978)	Not reported	United States	Los Angeles,	Hedonic Price Method
<>Collins and Evans (1994)	1985-1986	United Kingdom	Stockford, Manchester International Airport, Manchester	Hedonic Price Method
<>de Vany (1976) in Nelson (1980)	1970	United States	Dallas,	Hedonic Price Method
<>Dygert (1973) in Nelson (1980)	1970	United States	San Francisco and San Jose,	Hedonic Price Method
<>Emerson (1972) in Nelson (1980)	1967	United States	Minneapolis,	Hedonic Price Method
<>Gautrin (1975) in Nelson (1980)	1968-69	United Kingdom	Heathrow,	Hedonic Price Method
<>Hoffman (1984) in Barde & Pearce (1991)	Not reported	Norway		Hedonic Price Method
<>Holsman & Aleksandric (1977)	1959-73	Australia	Sydney,	Hedonic Price Method
<>Levesque (1994)	1985-1986	Canada	Winnipeg International Airport	Hedonic Price Method
<>Mark (1980)	1969-70	United States	St. Louis,	Hedonic Price Method
<>Maser (1977) in Nelson (1980)	1971	United States	Rochester,	Hedonic Price Method
<>Mason (1971) in Streeting (1990)	1971	Australia	Sydney,	Hedonic Price Method
<>McLure (1969) in Pearce (1978)	Not reported	United States	Los Angeles,	Hedonic Price Method
<>Mieszkowski & Saper (1978)	1969-73	Other Country	Etobicoke & Mississauga in Toronto, Canada,	Hedonic Price Method
<>Mitchell McCotter (1994)	1993	Australia	Sydney,	Hedonic Price Method
<>Nelson (1978) in Nelson (1980)	1970	United States	Washington DC,	Hedonic Price Method
<>O'Byrne, Nelson & Seneca (1985)	1970-72,79-80	United States	Atlanta,	Hedonic Price Method
<>Opschoor (1986) in Pearce & Markandya (1989)	Not reported	Netherlands	Amsterdam,	Hedonic Price Method
<>Pennington, Topham and Ward (1990)	1985-1986	United Kingdom	Manchester International Airport, Manchester	Hedonic Price Method
<>Roskill (1971) in Pearce (1978)	Not reported	United Kingdom	Heathrow and Gatwick,	Hedonic Price Method
<>Uyeno, Hamilton and Biggs (1993)	1987-1988	Canada	Vancouver International Airport,	Hedonic Price Method

ENVALUE- Road Traffic Noise Valuation Studies

Author
Year
Country
Location
Method

<>Allen (1980) in Nelson (1982)
1977-79
United States
Tidewater, North Virginia,
Hedonic Price Method

<>Anderson & Wise (1977) in Nelson (1982)
1969-71
United States
North Springfield, Towson and Four areas (pooled),
Hedonic Price Method

<>Bailey (1977) in Nelson (1982)
1968-76
United States
North Springfield,
Hedonic Price Method

<>Hall, Breston & Taylor (1978) in Nelson (1982)
1975-77
Other Country
Toronto, Canada,
Hedonic Price Method

<>Holsman & Bradley (1982)
1980
Australia
Sydney,
Hedonic Price Method

<>McCalden & Jarvie (1977)
1962-74
Australia
Newcastle, NSW,
Hedonic Price Method

<>Nairn, Segal and Watson (1994)
1994
Australia
Melbourne, Victoria
Hedonic Price Method

<>Nelson (1978) in Nelson (1982)
1970
United States
Washington DC,
Hedonic Price Method

<>Palmquist (1980) in Nelson (1982)
1958-78
United States
Kingsgate, North King County and Spokane,
Hedonic Price Method

ENVALUE – Rail Transport Noise Valuation Studies

Author
Year
Country
Location
Method

<>Holsman & Paparoulas (1982)
1972-81
Australia
Sydney,
Hedonic Price Method

ENVALUE – Road Traffic Noise Valuation Studies (Noise Measured as traffic volume)

Author
Year
Country
Location
Method

<>Hughes and Sirmans (1992)
1985-1989
United States
Baton Rouge metropolitan area, Louisiana
Hedonic Price Method

APPENDIX 2

Review of Studies on External Costs of Noise
prepared by Rhian Hawkins, Environment Protection Economics Division
DETR July 1999

Disclaimer

This review was carried out for limited circulation within the DETR and for the information of the members of the DETR Group on Environmental Costs and Benefits. It has not been subject to peer review or circulated for comment to the authors of the studies which it reviews. The Department has agreed to make the paper available to a wider audience in the hope that it stimulates others to add to the information it contains on noise values.

At present the Department does not regularly use monetary values of noise in the appraisal of transport schemes or policies. The Department's approach to appraisal is set out in Guidance to the New Approach to Appraisal (NATA) on the Department's website at www.roads.detr.gov.uk/roadnetwork/heta/hetapubs.htm. The tabulated result of the appraisal shows the number of dwellings experiencing changes in noise above a certain threshold. At present the appraisal methods used do not require putting a monetary value on those changes.

Introduction

1. The purpose of this paper is to provide a brief summary of the studies undertaken to date which estimate the external costs associated with noise. There is a large literature on the valuation of noise, and in this paper, a total of sixty four relevant studies have been identified. These studies have derived estimates using a variety of valuation techniques. Hedonic pricing is the most popular valuation method, but studies have also used contingent valuation, abatement costs, avoidance costs and productivity loss to estimate the external costs of noise.

2. The different methodologies used in the studies often give rise to different measurements of valuation. Most hedonic studies tend to produce results based on the Noise Depreciation Sensitivity Index (NDSI) which gives the average percentage change in property prices per decibel. Other studies quote costs in terms of billions per annum or percentage of GDP, whilst others still use cost per decibel of noise. Given the complexity involved in translating results from one form to another, without complete information, these different measures of valuation can make comparisons between the studies extremely difficult. The most useful measure for the purposes of policy evaluation is damage in terms of cost per decibel - however, this measure is not available for many of

the studies. Where several different measures of the results are available, these have been provided.

3. The paper first concentrates on noise valuation studies undertaken in the UK, and then broadens the scope of the survey to include further studies undertaken in the EU, the USA and finally any studies undertaken in the rest of the world. Within each section, the main details of the studies identified are outlined in a summary table and then the key studies are discussed briefly in the accompanying text.

UK Studies

4. Ten of the studies identified were based on UK data, or adapted from overseas data for UK use. See Table 1 for summary details of each of these studies.

#	Study	Location	Type of noise	Means of valuation	Results
1	Gautrin (1975)	London Heathrow	Aircraft noise	Hedonic house pricing	0.62 NDSI
2	Pennington *et al*. (1990)	Manchester	Aircraft noise	Hedonic house pricing	0.47 NDSI
3	RCEP	Review of existing studies	Noise and vibration	Review of existing studies	£1.2 - £5.4 billion per annum
4	Pearce *et al* (1993)	UK	Noise	Avoided cost	£0.6 billion per annum
5	CSERGE / EFTEC (1994)	Review of existing studies	Traffic noise	Hedonic house pricing	0.67 NDSI £2.6 billion per annum
6	Collins & Evans (1994)	Manchester - Terrace - Flat - Semi (small) - Semi (medium) - Semi (large) - Detached	Aircraft noise	Hedonic house pricing	 0.71 NDSI 0.65 NDSI 0.74 NDSI 0.83 NDSI 1.28 NDSI 1.05 NDSI
7	ECMT Task Force	Based on Soguel's (1994) Swiss data but adapted for UK use.	Traffic noise	Adapted from hedonic rent pricing study	ε1.72/dB(A) per person per month
8	Tinch report (1995)	Review of existing studies	Noise	Adapted from hedonic pricing and contingent valuation studies.	£7.75/dB(A) per person per annum £21.24/dB(A) per household per annum 0.31% GDP
9	JMP report (1996)	UK	Traffic nuisance	Hedonic house pricing Contingent valuation	0.29 NDSI £24-£30 per person per month for six different noise policies
10	Yamaguchi (1996)	London Heathrow London Gatwick	Aircraft noise	Hedonic house pricing	1.51 NDSI 2.30 NDSI

Note: NDSI stands for Noise Depreciation Sensitivity Index and represents average percentage change in property prices per decibel.

5. It can be seen that most of the UK studies use HP and measure noise damage either in terms of the NDSI or in terms of total cost to the country per year. Overall, the studies produce results ranging from **0.20-2.30% of property prices per decibel** and estimate an annual cost to the country of between £0.6bn (now discredited) and £5.3bn.

6. Studies 7 and 8 measure noise damage in terms of cost per decibel. Study 7, a report by the ECMT Task Force, is based on the results from a study by Soguel (1994 – see Study 27 for more details). It includes an estimate of ?1.72/dB(A) per person, per month

(equivalent to approximately £13.42/dB(A) per person, per year) for the UK shadow price for noise damage. The study also shows that the variation in noise valuation is less than the variation in real incomes, implying a fairly low income elasticity for noise. Assuming an average of 2.2 people per household, this is approximately equivalent to **£30/dB per household per annum.**

7. Study 8, by Tinch (1995), was commissioned by DoT and is based on a review of existing studies. The recommended values are largely based on two studies: a HP study by Soguel (1994 – see Study 27 for more details) and a CV study by Sælensminde & Hammer (1994 - see Study 28 for more details). Tinch provided recommended estimates for a number of different types of measurement. These include an overall cost to the UK of £3.06 billion per annum (equivalent to 0.5% of GDP) and damage per decibel costs of **£7.75 per person**, and **£21.24 per household, per annum**. In addition to best estimates, Tinch also suggested low and high estimate ranges of £5.50-£10.00/dB(A) per person per annum and £2.17-3.95 billion per annum.

8. The JMP report (Study 9) was also commissioned by DoT to value road traffic nuisance using both stated preference and revealed preference techniques. The stated preference work relied upon valuation of six different noise mitigation policies (eg halving of traffic volumes, HGV ban, traffic humps etc). This had the unfortunate result that respondents placed a high value (£24-£30 per person per month) on decreases in road traffic nuisance, regardless of magnitude. The revealed preference work relied on expert valuation (rather than actual behaviour) by a small sample of District Valuers about the percentage reduction in house prices due to the presence of noise. The survey found that house prices fell by 0.29% for each 1 dB(A) increase in noise. In view of the methodological difficulties with JMP's work, HETA did not recommended that these values be used in UK appraisal.

9. Given the different types of measurement used in the studies, it is difficult to provide a valuation range that represents the UK study estimates. The estimate presented in the Tinch report, however - £7.75/dB(A) per person per annum - is the figure that HETA have previously suggested might be used in policy appraisal of transport measures (DETR Appraisal Group Paper No. AG(98)7) and which REF have used for rail appraisal work. It is considered to compare well with the results of other studies from around the world. However, as noted in the disclaimer to this paper, these values are not in general use for project and policy appraisal purposes.

European Studies

10. A wide range of European-based studies exist, covering a variety of valuation techniques. These are summarised in Table 2, below.

Table 2: European studies estimating external costs of noise

#	Study	Location	Type of noise	Means of valuation	Results
11	Hammar (1974)	Stockholm, Sweden	Traffic noise	Hedonic house pricing	0.8 –1.7 NDSI
12	IRT (1983)	France	Traffic noise	Insulation costs	0.30-2.27% of GDP
13	Kanafani (1983)	Review of existing studies	Traffic noise	Review of existing studies	0.10-0.20% of GDP
14	Ringheim (1983)	Norway	Traffic noise	Hedonic house pricing Loss of sleep Existing protection Potential vehicle protection	0.20% of GDP 0.17% of GDP 0.07% of GDP 0.12% of GDP
15	Grupp (1986)	West Germany	Traffic noise	Hedonic house pricing	0.02-0.05% of GDP
16	Lambert (1986)	France	Traffic noise	Hedonic house pricing	0.04% of GDP
17	Pommerherne (1986)	Switzerland	Traffic noise - 30 dB(A) - 70 dB(A)	Hedonic house pricing	 1.00 NDSI 1.40 NDSI
18	Opschoor (1987)	The Netherlands	Traffic noise	Hedonic house pricing	0.02 % of GDP
19	UIC (1987)	The Netherlands	Traffic noise	Government expenditure	0.02 % of GDP
20	Wicke (1987)	West Germany	Traffic noise	Productivity losses Hedonic house pricing	0.15 % of GDP 1.45 % of GDP
21	Bleijenberg (1988)	The Netherlands	Traffic noise	Prevention costs and remaining loss in property values	0.03-0.08 % of GDP
22	Pommerherne (1988)	Basel, Switzerland	Traffic noise	Hedonic house pricing	1.26 NDSI
23	Iten & Maggi (1990)	Zurich, Switzerland	Traffic noise	Hedonic house pricing	0.9 NDSI
24	Dogs *et al* (1991)	West Germany	Transport noise - roads - rail 	 Contingent valuation Avoidance cost Contingent valuation Avoidance cost	 0.52 % of GDP 0.03 % of GDP 0.22 % of GDP 0.03 % of GDP
25	ExternE (1991)	Europe	Traffic noise - car - bus - HGV		 0.2 pence per vehicle mile 1.6-6.1 pence per vehicle mile 1.6-6.1 pence per vehicle mile
26	INFRAS/IWW (1994)	EUR15 plus Norway & Switzerland	Transport noise - cars - buses - rail - air - two wheelers - road freight - rail freight	Contingent valuation	0.65% of GDP 0.29 pence per passenger km 0.27 pence per passenger km 0.20 pence per passenger km 0.20 pence per passenger km 3.92 pence per passenger km 0.83 pence per passenger km 0.31 pence per passenger km
27	Soguel (1994)	Neuchatel, Switzerland	Traffic noise	Hedonic house rents	0.91 NDSI SF 5.85/dB(A) per household per month
28	Sælensminde & Hammer (1994)	Oslo & Akershus, Norway	Noise experienced on journey to work	Conjoint analysis	NOK 225-400/dB(A) per household per year
29	Tinch report (1995)	Review of existing studies - Finland - Norway - Sweden - Denmark - France - Germany - Switzerland	Noise	 Time cost of disturbance Ad hoc value Hedonic house pricing x 2 Hedonic house pricing Review of other studies Mitigation costs Hedonic house pricing Avoidance cost calculation	 £570 per person per annum £665 per person per annum £555 per person per annum £3890 per household per annum £88 per person per annum £33 per window SF 819 million per annum SF 556-927 million per annum
30	Vainio (1995)	Helsinki, Finland	Traffic noise	Hedonic house pricing	0.36 NDSI
31	Renew (1996)	Brisbane, Australia	Traffic noise	Hedonic house pricing	1.00 NDSI
32	Grue *et al* (1997)	Oslo, Norway – *Obos* – *Flats* – *Houses*	Traffic noise	Hedonic house pricing	 0.24 NDSI 0.21 NDSI 0.54 NDSI

11. Overall, the above studies provide a range of values from 0.21-1.7 percentage change in property price per decibel and 0.02-2.27% of GDP. Other types of measurements also exist, from value per person per annum (Study 29) to pence per unit distance for different types of transport (Studies 25 & 26). However, very few studies quote their results in terms of cost per decibel, which is the most useful measurement for policy evaluation.

12. One of the few studies which does provide results in terms of cost per decibel is a key study by Soguel, mentioned earlier as the basis to the ECMT Task Force (Study 7) and Tinch's (Study 8) valuation estimates. Soguel's study of residential noise levels in Neuchatel in Switzerland is considered to represent the state of the art in noise valuation. The study estimates the willingness of the inhabitants of Neuchatel to pay for a halving of their exposure to road traffic noise, by examining the link between noise and property rents in this area. It was found that noise had a highly significant impact on rents, which fell on average by 0.91% per decibel of noise increase. Other Swiss results are of a similar magnitude: Iten & Maggi (Study 23) estimated 0.9% for Zurich and Pommerehne (Study 22) found 1.26% for Basle.

13. Using this initial result, Soguel then went on to calculate the WTP for a one decibel noise reduction per household per month, according to noise level and income. Although WTP did increase slightly with the level of existing noise, the change was not statistically significant and suggested that existing noise levels could be ignored when valuing changes in noise. On average, Soguel found that the monthly WTP for a one decibel noise reduction was SF 5.85. This is equivalent to about £21 per household per year.

14. Another key study which produced damage estimates in terms of cost per decibel, was that of Sælensminde & Hammer (Study 28). This study elicited average annual WTP values of NOK 225-400 for a one decibel noise improvement, using conjoint analysis. These values are roughly equivalent to £15-26/dB(A) per household per year, and hence correspond well with Soguel's results.

US Studies

11. The twenty-one US based noise studies which have been identified by this review are summarised in Table 3, below.

Table 3: US Studies estimating external costs of noise

#	Study	Location	Type of noise	Means of valuation	Results
33	Emerson (1969, 1972)	Minneapolis	Aircraft noise	Hedonic house pricing	0.58 NDSI
34	Paik (1972)	New York Los Angeles Dallas	Aircraft noise	Hedonic house pricing	1.9 NDSI 1.8 NDSI 2.3 NDSI
35	Gamble *et al* (1974)	Bogotoa Rosendale North Springfield All three areas	Traffic noise	Hedonic house pricing	2.22 NDSI 0.24 NDSI 0.21 NDSI 0.26 NDSI
36	Price (1974)	Boston	Aircraft noise	Hedonic house pricing	0.83 NDSI
37	Vaughan & Huckins (1975)	Chicago	Traffic noise	Hedonic house pricing	0.65 NDSI
38	De Vany (1976)	Dallas	Aircraft noise	Hedonic house pricing	0.8 NDSI
39	Dygert (1976)	San Francisco San Jose	Aircraft noise	Hedonic house pricing	0.5 NDSI 0.7 NDSI
40	Langley (1976)	North Springfield	Traffic noise	Hedonic house pricing	0.22 NDSI
41	Anderson & Wise (1977)	Towson North Springfield	Traffic noise	Hedonic house pricing	0.43 NDSI 0.14 NDSI
42	Bailey (1977)	North Springfield	Traffic noise	Hedonic house pricing	0.30 NDSI
43	Maser *et al* (1977)	Rochester, N.Y. – city – suburban	Aircraft noise	Hedonic house pricing	 0.88 NDSI 0.61 NDSI
44	Nelson (1978)	Washington	Traffic noise	Hedonic house pricing	0.87 NDSI
45	Nelson (1978)	Washington	Aircraft noise	Hedonic house pricing	1.06 NDSI
46	Nelson (1979)	San Francisco St. Louis Cleveland New Orleans San Diego Buffalo	Aircraft noise	Hedonic house pricing	0.58 NDSI 0.51 NDSI 0.29 NDSI 0.4 NDSI 0.75 NDSI 0.52 NDSI
47	Allen (1980)	North Virginia Tidewater	Traffic noise	Hedonic house pricing	0.15 NDSI 0.14 NDSI
48	Nelson (1980)	Review of existing studies	Aircraft noise	Hedonic house pricing	0.62 NDSI
49	Palmquist (1980, 1981)	Kingsgate North King County Spokane	Traffic noise	Hedonic house pricing	0.48 NDSI 0.30 NDSI 0.08 NDSI
50	Nelson (1982)	Review of existing studies	Traffic noise	Hedonic house pricing	0.40 NDSI
51	Kanafani (1983)	Review of existing studies	Traffic noise	Review of existing studies	0.06-0.12 % of GDP
52	O'Byrne *et al* (1985)	Atlanta (1980) Atlanta (1970)	Aircraft noise	Hedonic house pricing	0.69 NDSI 0.64 NDSI
53	Levesque (1994)	Winnipeg	Aircraft noise	Hedonic house pricing	1.3 NDSI

12. It can be seen that almost all of the US based studies which have been identified use hedonic house pricing to produce an NDSI measurement for traffic or aircraft noise. These studies provide a range from 0.08 to 2.3 per cent change in property price per decibel. Nelson (1980&1982) (Studies 48&50) undertook comprehensive reviews of existing valuation studies for both traffic and aircraft noise – these reviews included some studies from overseas, but were mainly US based. As a result of this review, Nelson recommends the use of an NDSI of 0.40 for traffic noise and 0.62 for aircraft noise.

13. The only alternative measurement given for noise damage in the US, is Study 51, by Kanafani (1983). Kanafani undertook reviews of existing studies in both Europe and the US and found that damage caused by noise is worth 0.06-0.12% of GDP in the US,

compared to 0.1-0.2% in Europe (see Study 13). This differential between US and Europe appears to correspond with other studies.

Other Studies

14. Studies on noise valuation have also been undertaken in several other countries, such as Canada, Australia and Japan, or have been based on reviews of a wide range of studies from around the world. These are summarised in Table 4, below.

Table 4: Other studies estimating external costs of noise

#	Study	Location	Type of noise	Means of valuation	Results
54	Hall *et al* (1978)	Toronto, Canada	Traffic noise	Hedonic house pricing	1.05 NDSI
55	Mieskowski & Saper (1978)	Toronto, Canada	Aircraft noise	Hedonic house pricing	0.52 NDSI
56	Abelson (1979)	Marrickville, Australia Rockdale, Australia	Aircraft noise	Hedonic house pricing	0.40 NDSI 0.50 NDSI
57	McMillan *et al* (1980)	Edmonton, Canada	Aircraft noise	Hedonic house pricing	0.51 NDSI
58	Hall *et al* (1982)	Toronto, Canada *– Arterial* *– Expressway*	Traffic noise	Hedonic house pricing	 0.42 NDSI 0.52 NDSI
59	Quinet (1989)	Review of existing studies	Traffic noise	Productivity loss and annoyance	0.1% of GDP
60	Hidano *et al* (1992)	Tokyo, Japan	Traffic noise	Hedonic house pricing	0.70 NDSI
61	Quinet (1993)	Review of existing studies	Noise pollution	Review of existing studies	0.20-2.00 % of GDP
62	Uyeno *et al* (1993)	Vancouver, Canada - detached houses - condominiums - vacant land	Aircraft noise	Hedonic house pricing	 0.65 NDSI 0.90 NDSI 1.66 NDSI
63	INRETS (1994)	Variety of countries	Noise exposure - 1970s - 1980s	Hedonic house pricing	 0.3-0.8 NSDI 1.00 NSDI
64	Pearson *et al* (1994)	?	Traffic noise - cars - bus - motorbike - HGV		 0.41 pence per passenger km 0.09 pence per passenger km 1.18 pence per passenger km 1.96 pence per passenger km

15. Again, hedonic pricing studies are the dominant method of valuation, producing a 0.3-1.66 range of percentage change in property prices per decibel. Two reviews of existing studies by Quinet (Study 59 and 61) estimate noise damage to be between 0.1 and 2.0 % of GDP.

16. The study by Pearson *et al* (Study 64) attempts to give an alternative measure of damage by allocating noise costs from road transport to particular modes. It estimates that HGVs produce the most noise damage, at 1.96 pence per passenger per kilometre, with motorbikes, cars and buses causing damages of 1.18, 0.41 and 0.09 pence per passenger per kilometre respectively. When adjusted to consistent forms of measurement, this ranking compares reasonably well with Studies 25 and 26 which also give values in cost per unit distance travelled for different transport modes.

Conclusion

In conclusion, it can be seen that the literature on noise valuation is extensive and provides a wide range of damage estimates in different forms of measurement. Overall, the range of results produced are as follows:

- £15 - £30 per decibel per household per year (covering a total of 4 studies)
- 0.08-2.30% change in property price per decibel (covering a total of 43 studies)
- 0.02-2.27% GDP (covering a total of 15 studies)

Although it is difficult to compare between these different types of measurement without complete information about the population sampled, their properties and the noise levels to which they were exposed; the individual ranges they cover can provide helpful benchmarks for the magnitude of the external costs of noise.

It is apparent that the studies sometimes make quite different estimates of the costs associated with noise. This can be due to a number of reasons - not only from methodological and sampling differences, but also because studies often use different assumptions about baseline noise levels (eg using from between 30-65dB(A) as a zero-nuisance baseline) or use different time periods to identify average noise levels.

For transport policy appraisal in the UK, HETA currently allows the use of £21.24 per household, for a one decibel noise improvement, based on Tinch's adaptation of the Soguel valuation (Studies 8 and 27). However, given the uncertainties associated with this transferring this value from its initial Swiss context, it is recommended that the estimate should be reported separately from other monetary values and that further UK-specific work should be carried out in future to improve upon this tentative value.

Finally, it should be noted that almost all the studies identified are limited to valuations of road and air traffic noise exposure in the home only. While very little data on alternative sources and exposures to noise currently exists, the measurement of noise costs in different contexts is crucial, and exposure to different types of noises at work, at home, at leisure and while travelling all need to be considered if the effects of noise pollution are not to be understated.

Abbreviations (used within UK DETR)

DoT UK Department of Transport, now part of DETR.

HETA, Highways Economics and Traffic Appraisal, part of DETR.

REF, Railways Economics and Finance, part of DETR.

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APPENDIX 3

Review of Road traffic and air traffic noise valuation studies

<u>Source:</u> Bateman et al (2000, tables 5.2 and 5.3)

Table A3-1: Hedonic pricing studies of loss in property value from *Road Traffic* noise (% depreciation in house prices per 1 dB(A) increase in noise level)

Source Study	Study Year	Study Area	Noise Measure	NSDI
Allen, 1980†	1977-79	North Virginia, Va., USA	L_{10}	0.15
	1977-79	Tidewater, Va., USA	L_{10}	0.14
Anderson and Wise, 1977†	1969-71	Towson, Md., USA.	NPL	0.43
	1969-71	North Springfield, Va., USA	NPL	0.14
Bailey, 1977†	1968-76	North Springfield, Va., USA	Log of Distance	0.3
Gamble et al., 1974†	1969-71	Bogotoa, N.J., USA	NPL	2.22
	1969-71	Rosendale, Md., USA	NPL	0.24
	1969-71	North Springfield, Va., USA	NPL	0.21
	1969-71	All three areas	NPL	0.26
Grue et al.,1997		Oslo, Norway – *Obos*	L_{eq}	0.24
		Oslo, Norway – *Flats*	L_{eq}	0.21
		Oslo, Norway – *Houses*	L_{eq}	0.54
Hidano et al., 1992*		Tokyo, Japan	L_{eq}	0.7
Hall et al., 1978†	1975-77	Toronto, Canada	L_{eq}	1.05
Hall et al., 1982		Toronto, Canada – *Arterial*	L_{eq}	0.42
		Toronto, Canada – *Expressway*	L_{eq}	0.52
Hammar, 1974		Stockholm, Sweden	L_{eq}	0.8 –1.7
Iten and Maggi, 1990		Zurich, Switzerland	-	0.9
Langley, 1976†	1962-72	North Springfield, Va., USA	NPL	0.22
Nelson, 1978†	1970	Washington, D.C., USA	L_{dn}	0.87
Palmquist, 1980, 1981†	1962-76	Kingsgate, Wa., USA	L_{10}	0.48
	1958-76	North King County, Wa., USA	L_{10}	0.3
	1950-78	Spokane, Wa., USA	L_{10}	0.08
Pommerherne, 1988	1986	Basel, Switzerland	L_{eq}	1.26
Renew, 1996a		Brisbane, Australia	L_{eq}	1.0
Soguel, 1991	1990	Neuchatel, Switzerland	L_{eq}	0.91
Vainio, 1995		Helsinki, Finland	L_{eq}	0.36
Vaughan & Huckins, 1975†	1971-72	Chicago, USA	L_{eq}	0.65

† Reviewed in Nelson (1982)

* From Bertrand (1997) who notes that figure is presented with caution

Table A3-2: Hedonic pricing studies of loss in property value from *Aircraft Noise* (NSDI = % depreciation in house prices per 1 dB(A) increase in noise level)

Source Study	Study Year	Study Area	NSDI
Abelson, 1979†	1972-73	Marrickville, Sydney, Australia	0.4
	1972-73	Rockdale, Sydney, Australia	0.5
Collins and Evans, 1994	1985	Manchester, UK	-
De Vany, 1976†	1970	Dallas, USA	0.8
Dygert, 1976†	1970	San Mateo, San Francisco, USA	0.5
	1970	Santa Clara, San Jose, USA	0.7
Emerson 1969, 1972†	1967	Minneapolis	0.58
Gautrin, 1975†	1968-69	London Heathrow, UK	0.62
Levesque, 1994		Winnipeg, USA	1.3
McMillan et al., 1980†	1975	Edmonton, Canada	0.51
Maser et al., 1977†	1971	Rochester, N.Y., USA – *City*	0.88
	1971	Rochester, N.Y., USA – *Suburban*	0.61
Mieskowski & Saper, 1978†	1969-73	Etobicoke, Toronto, Canada	0.52
Nelson, 1978†	1970	Washington, USA	1.06
Nelson, 1979	1970	San Francisco, USA	0.58
	1970	St. Louis, USA	0.51
	1970	Cleveland, USA	0.29
	1970	New Orleans, USA	0.4
	1970	San Diego, USA	0.75
	1970	Buffalo, USA	0.52
O'Byrne et al., 1985	1980	Atlanta, USA	0.69
	1970	Atlanta, USA	0.64
Paik, 1972†	1960	New York, USA	1.9
	1960	Los Angeles, USA	1.8
	1960	Dallas, USA	2.3
Pennington et al., 1990	1985	Manchester, UK	0.47
Price, 1974†	1960-70	Boston, USA	0.83
Uyeno et al., 1993	1987	Vancouver, Canada	0.65
Yamaguchi, 1996	1996	London Heathrow, UK	1.51
	1996	London Gatwick, UK	2.30

† Reviewed in Nelson (1980)

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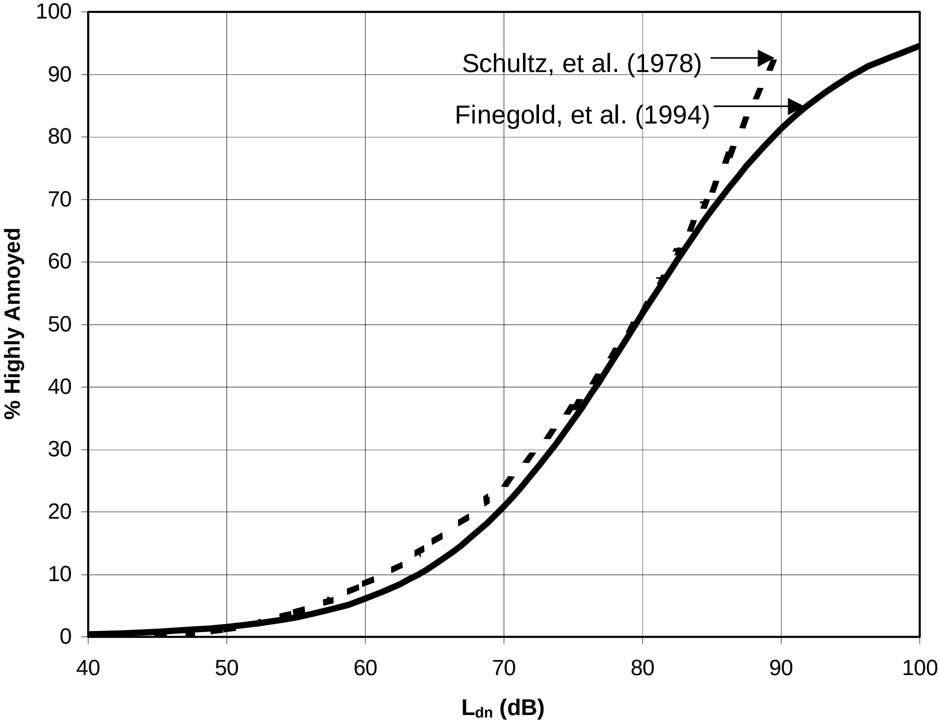
Figure 4-1. Public Annoyance versus L_{dn}



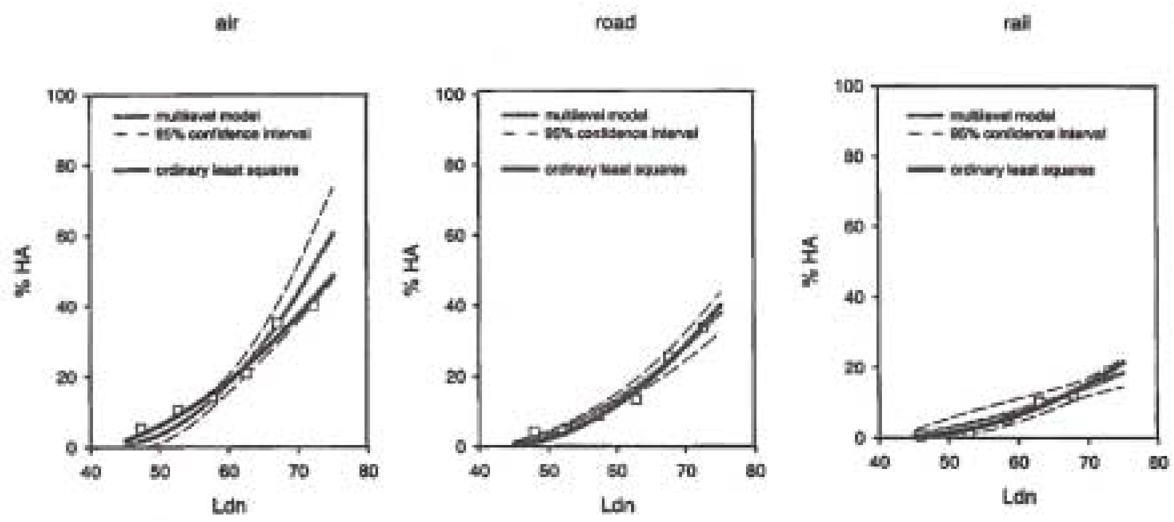


Figure 7. A recent meta-analysis of noise annoyance versus sound level by Miedema and Vos (1998) using all applicable world-wide noise attitudinal survey data.