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Introducing willingness-to-pay for noise changes into transport appraisal – an application of benefit transfer

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Abstract

Numerous research studies have elicited willingness-to-pay values for transport-related noise, however, in many industrialised countries including the UK, noise costs and benefits are still not incorporated into appraisals for most transport projects and policy changes (Odgaard *et al*, 2005; Grant-Muller *et al*, 2001). This paper describes the actions recently taken in the UK to address this issue, comprising: primary research based on the city of Birmingham; an international review of willingness-to-pay evidence; development of values using benefit transfers over time and locations; and integration with appraisal methods. Amongst the main findings are: that the willingness-to-pay estimates derived for the UK are broadly comparable with those used in appraisal elsewhere in Europe; that there is a case for a lower threshold at

$45dB(A)_{Leq,18hr}$[1] rather than the more conventional 55dB(A); and that values per dB(A) increase with the noise level above this threshold. There are significant issues over the valuation of rail versus road noise, the neglect of non-residential noise and the valuation of high noise levels in different countries. Conclusions are drawn regarding the feasibility of noise valuation based on benefit transfers in the UK and elsewhere, and future research needs in this field are discussed.

Introduction

In common with many other EU member states (Odgaard *et al*, 2005; Grant-Muller *et al,* 2001) and other industrialized countries (Hayashi and Morisugi, 2000), the UK undertakes cost-benefit analysis of transport projects, subject to finance ministry guidance (HM Treasury, 2003; DfT, 2006). There is an aspiration to include noise benefits (and disbenefits) in this analysis (HM Treasury, 2003: 66; DfT, 2006: 2), however, until 2005 the necessary evidence and methods had not been brought together.

The UK was not alone in omitting noise from its cost-benefit analysis. Odgaard *et al* (2005) found that 12 of the 25 EU member states did not attempt to value noise effects, when their survey was undertaken in 2004. These included both some new EU members such as Latvia and the Slovak Republic, and some long-standing EU members such as Spain, Italy, Belgium and the UK. Many of these countries do regularly assess noise effects as part of their transport appraisal processes, in quantitative or qualitative terms, but have not extended the analysis to monetary valuation for everyday transport projects. Without noise valuation, a cost-benefit analysis of a project with significant noise effects will be incomplete, and will not be an accurate guide to decision-making, as DfT (2006) recognises.

This paper describes the work undertaken in the UK to enable regular valuation of transport-related noise effects. The approach is based on *benefit transfer* from a high quality primary study, in this case the Birmingham hedonic pricing study by Bateman *et al* (2004). Further details of the primary study are given in the opening section. The main steps, subsequently, were to:

i. critically review the Birmingham study, in order to verify that the results were robust and there were no outstanding methodological issues;

ii. compare the Birmingham study against the international evidence, together with (i), to assess its suitability as a basis for benefit transfer;

iii. undertake transfers from a Birmingham basis to a UK basis, and from 1997 (the base year of the hedonic pricing model) to 2002 (the standard base year in UK transport appraisal); and

iv. derive values required by the Department for Transport, including: values by noise level; values by mode; forecast growth in values over time; and a method by which to transfer values to specific localities within the UK.

A final task was to integrate noise valuation with the appraisal process for transport projects. We outline how this was achieved and illustrate its application using a real contemporary example.

Based on this experience, we draw conclusions about the feasibility of introducing noise valuation into appraisal using benefit transfer, in the UK and elsewhere. We compare the UK approach with that in other countries. We also highlight some potentially important limitations of existing noise evidence and set out the issues raised for future research.

Evidence of willingness to pay for peace and quiet

The Birmingham study

The Birmingham study by Bateman *et al* (2004) applied the well-known hedonic price method to measure residents' willingness-to-pay for peace and quiet. Other applications of this method are discussed and compared in the following section. The Birmingham study is distinctive in its use of the 'second stage' of the hedonic price method and in its use of a very large GIS-referenced dataset – these features are explained below.

The hedonic price method starts from the simple observation that a property located in an area of high environmental quality will fetch a higher price than an equivalent property located in an area of low environmental quality. Data from multiple properties is used to derive 'implicit prices' for environmental attributes in the property market (the *first stage* of the method) and then to derive a demand function for peace and quiet (the *second stage*). The second stage removes the influence of supply conditions in the local market and represents – as far as possible – residents' underlying preferences for peace and quiet.

Data for the Birmingham study comprised

- prices of over 10 000 properties in the City of Birmingham sold in 1997 (from Land Registry computerised records) – this is the dependent variable;
- details of the internal and external characteristics of each property (e.g. floor area, age, garden area – these data were prepared from more than one source, including GIS analysis of property footprint and boundaries);
- variables describing the socioeconomic composition of each property's neighbourhood (e.g. wealth, ethnicity – taken from Census data);

- proximity to a variety of amenities and disamenities (e.g. primary schools, local commercial centres, landfill sites – data on accessibility to amenities was not simply straight line distance, but an accessibility measure based on walking or driving distances); and
- details of local environmental conditions (e.g. daytime exposure to noise from road, rail and air traffic measured in $dB(A)_{Leq\ 18hr}$ – derived from a recently-created noise model giving noise levels on each facade for every residential address in Birmingham (DETR, 2000)).

The Birmingham dataset is one of the most comprehensive hedonic property price datasets yet compiled, which contributes to its usefulness in modelling the willingness-to-pay (WTP) for peace and quiet.

In common with previous hedonic pricing (HP) studies of transport noise, the first stage of the Birmingham study used techniques of multiple regression to estimate the hedonic price function

$$P = P(\boldsymbol{z}) \qquad (1)$$

where P, selling price, is a function of $\boldsymbol{z}$, the vector of property characteristics.

The functional form adopted by Bateman *et al* (2004) is in fact semi-parametric

$$\ln P_i = \boldsymbol{z}_i\boldsymbol{\beta} + q(\boldsymbol{x}_i) + \varepsilon_i \qquad (2)$$

where P_i is the selling price of property i,

$\boldsymbol{z}$ is a vector of certain property characteristics that can be combined linearly with parameters $\boldsymbol{\beta}$,

$\boldsymbol{x}$ is a vector of other property characteristics whose influence on price is determined by an unknown function $q(\cdot)$, and

ε_i is a random error term.

The implicit price of noise is then the partial derivative of this function with respect to the noise variable.

The first stage of the Birmingham study produced a set of implicit prices for peace and quiet that were mostly of the correct sign and statistically significant for road and rail noise. Unfortunately, little evidence of a relationship with aircraft noise was found, probably because the techniques used to control for wide-area spatial differences in the property market also subsumed the wide-area differences in aircraft noise.

The models revealed that a 1dB(A) increase in road noise would reduce property prices by between 0.21% and 0.53%, depending on market segment (these market segments are characterised by income, ethnicity, family composition and property size). The rail noise estimates are larger in magnitude, indicating that on average a 1dB(A) increase in rail noise will reduce property prices by 0.67%.

For project appraisal and policy analysis, there are two objections to the use of these implicit prices as measures of the benefits (costs) of projects that reduce (increase) exposure to transport noise. First, the implicit prices in one particular market reflect only the particular balance between supply and demand prevailing in that market – hence their transferability cannot be guaranteed. Second, whilst implicit prices indicate the marginal willingness-to-pay of households for peace and quiet, they give us incomplete information about larger, non-marginal changes. The objections are overcome by the second stage of the hedonic method.

At the second stage, households' choices of noise exposure when faced by different implicit prices are used to identify the demand curve for peace and quiet. This provides both a general measure of welfare change – the area to the left of the demand curve (Bartik, 1988) – and values suitable for transfer to other sites, because they are based on underlying preferences.

Implementing the second stage is theoretically and analytically challenging. Indeed, the Birmingham study is one of only a handful that have attempted to estimate demand relationships using the hedonic pricing method in a theoretically consistent manner (other examples include, Bajic, 1993, Cheshire and Sheppard, 1998, Palmquist and Isangkura, 1999, Boyle et al, 1999 and Zabel and Kiel, 2000). Moreover, as far as the authors are aware, it is the only study to estimate demand relationships for avoidance of transport-related noise using property price data.

In the second stage of the Birmingham study, demand curves for peace and quiet were estimated using multiple regression, controlling for household expenditure and other socioeconomic characteristics. Prices were converted into equivalent annual payments based on the empirical relationship that exists between rents and the purchase prices of houses in the City of Birmingham. Figure 1 shows the resulting demand curve for peace and quiet in relation to road noise (i.e. demand for reduction in road noise) – the data allowed the demand curve for road traffic noise to be estimated with much greater precision than for the other noise sources. Mean values for road noise range from £31.49 per annum for a 1dB(A) reduction from a 56dB(A) baseline to £88.76 per annum for the same change from an 80dB(A) baseline. These are values per household per annum reported in 1997 prices.

[Insert Figure 1 here]

Before taking these willingness-to-pay values forward into the benefit transfer exercise, an independent review was undertaken in order to give a second opinion on the robustness of the methodology and results (Nellthorp *et al,* 2005). The review found no fatal flaws, but did note that:

- there is a risk that other variables related to traffic, such as air pollution, severance, pedestrian safety, vibration and dust and dirt, may have been partly captured in the noise coefficient. This risk arises because these variables were excluded from the final hedonic model. The effect may have been to bias the noise value upwards, although if the value is interpreted as the value of a package of environmental effects this may be more acceptable. Bjørner *et al* (2003) investigated the issue of correlation between noise and air pollution in hedonic pricing models and concluded that the omission of air pollution (due to unacceptable levels of correlation) may bias the noise value upwards. This makes it more important to compare the Birmingham results with those from other hedonic pricing studies and, particularly, studies using other methods (see the next section).
- the number of properties experiencing rail noise was small in many market segments (<50 in half the segments) and consequently the level of confidence in the values of rail noise was generally lower than road.
- although not a criticism of the Birmingham study, its scope is limited to noise experienced at home (residential locations). It does not measure willingness-to-pay for reductions in noise on the street, in open spaces, in workplaces, shops or public buildings. It seems to be an open question, in the current state of knowledge, how important those other settings are in determining the

aggregate effect of transport noise, or the aggregate benefits of reducing it. For appraisal or policy analysis, the aggregate effect is of particular interest.

Finally, the review drew attention to the issue of willingness-to-pay at low background levels of noise. In the first stage of the Birmingham model, price differentials were not distinguishable for noise values below a 55dB(A)Leq threshold. This could be interpreted as indicating that 55dB(A)Leq approximates some background level of urban noise pollution, such that householders are unable to enjoy noise environments that fall much below this threshold. Alternatively, it may simply indicate that the preponderance of properties in relatively quiet locations creates a market in which price differentials are insignificant (or non-existent) below this level of noise pollution.

In Figure 1, the demand curve has been projected down below 55dB(A), revealing that marginal WTP falls to zero at a noise level of 42.3dB(A) with a 95% confidence interval ranging from 39.9dB(A) to 44.7dB(A). At first sight it is somewhat surprising that the confidence interval for the estimated demand curve narrows in the range below 55dB(A). However, there is an intuitive explanation: the bulk of the observations are for households facing relatively low prices and choosing properties below 55dB(A). Our confidence concerning the path of the demand curve is greatest where we have most data and becomes progressively less precise as we move away from the centre of the data (Day, 2005a). In the following section, we return to this issue, focusing on the evidence in the international literature, supportive and otherwise.

International evidence

In this section we compare the results of the Birmingham study with evidence from other valuation studies of transport noise, including those using hedonic pricing (HP), stated preference (SP) and contingent valuation methods (CVM). We also include some relevant evidence linking noise to annoyance.

i) Hedonic pricing studies

The most recent meta-analysis of HP studies by Nelson (2004) concludes that house prices in North America fall by approximately 0.5 to 0.6% in response to an increase in aircraft noise of 1dB(A). Useful reviews may be found in Howarth *et al* (2001), Navrud (2002) and Bateman *et al* (2001) who review 18 studies largely from North America yielding 28 discount rates for road traffic noise with a mean of 0.55%.

Results from recent European hedonic pricing studies are shown in Table 1. The range reported by the Birmingham study (Bateman *et al*, 2004) reflects the different estimates derived for the various market segments. Overall the Bateman *et al* results do appear to be consistent with recent findings in Denmark and the UK, and are just slightly lower than the North American and Swedish figures.

[Insert Table 1 here]

(ii) Stated preference and contingent valuation studies

There are very few studies applying SP techniques to changes in traffic noise and even fewer where the values derived are related to an objective measure of noise. Table 2 builds on the review of European studies reported in Navrud (2004). Most of these studies use either a percentage change in noise levels or an ‘elimination of annoyance from noise’ scenario to present the change in noise, although the Arsenio *et al* (2006) study directly estimates the value of a 1dB(A) change in noise levels. In converting the results to a value per dB(A) Navrud assumes that a 50% change in noise levels is best represented by an 8 dB(A) change whilst the elimination of annoyance is best reflected by a 10 dB(A) change. We also use these assumptions in Table 2. We note that some of the CVM studies yield values that are surprisingly low in view of the evidence as a whole. However, the CVM noise values of Pommerehne (1988) and Soguel (1994) are more in line with those found in the SP studies. Soguel's survey applied iterative CVM, which might be expected to give a higher value than an open ended CVM. Pommerehne offered a move to a neighbouring street where noise levels were halved, which is often a realistic scenario. In adjusting the values for comparability the assumption has been made that values grow in line with GDP and this will have inflated values from early studies such as that by Pommerehne.

[Insert Table 2 here]

For comparison, the Birmingham values range from €50 at 55dB(A) to €144 at 80dB(A) (at 2001 prices), however bear in mind that residential noise levels are rarely as high as 80dB(A). When compared to the studies reported in Table 2, the SP studies, the Soguel and Pommerehne CVM studies and the Birmingham study have produced values which are broadly comparable.

(iii) Values by mode

There are few studies that value rail noise directly and even fewer that value noise for more than one mode (Navrud, 2004). The Eliasson *et al* (2002) study is one of the few and it suggests that values for a measure of rail intrusion are lower than for road intrusion.

Another source of information is the wealth of studies on annoyance from transport noise. Intuitively, willingness to pay for noise reductions might be expected to be related to annoyance caused by the noise, and indeed Fosgerau and Bjørner (2006), find that the relationships between annoyance and noise and between willingness-to-pay and noise follow very similar paths. Most evidence from studies of annoyance suggests that rail noise is less disturbing than road noise. For example, the European Commission position paper on noise and annoyance (EC, 2002) is based upon on the relationships between L_{den} and annoyance synthesized from 46 annoyance studies by Miedema and Oudshoorn (2002) which show lower levels of annoyance from rail than from road at an equivalent noise level (and higher levels for aircraft annoyance than both road and rail). Lower annoyance from a given noise level for rail than for road noise is also found in a recent review of German studies (Moehler and Greven, 2005). A study that finds a contradictory result (Öhrström *et al*, 2005) recognizes it as such: "These findings are in strong conflict with most international and Swedish studies" and speculates that plans for railway construction in the survey area may have influenced responses.

In view of the wider evidence, the Birmingham results go against expectations. In explaining this, we have already noted the small sample size for rail noise (<50 properties in half the market segments), which is a concern. However, during the critical review process no other specific causal factor emerged. Therefore we highlight this as an area requiring further research, and move on to other issues.

(iv) Thresholds and other non-linearities

The meta-analysis by Miedema and Oudshoorn (2001) of the relationship between transport noise and annoyance suggests the following threshold points: 32dB(A) to move from zero annoyed to having some people who are 'a little annoyed'; 37dB(A) as the threshold where some become 'annoyed' and 42dB(A) as the threshold where some will become 'highly annoyed'. These thresholds apply to Ldn and Lden, measures which – by definition – produce higher levels of dB(A) than a 24 hour Leq measure.

In HP studies, Bjørner *et al* (2003) find that the depreciation rate of property prices with respect to noise increases at higher cut off points, as do Rich and Nielsen (2002) who used a 50dB(A) cut-off. This is also apparent in the results of Lake *et al* (1998) and Bateman *et al* (2000) where the same data set for Glasgow yields a depreciation rate of 0.20% with the threshold set at 54 dB(A) and 1.07% if set at 68 dB(A). Bjørner *et al* (2003) report that 55dB(A) was the best cut-off level in terms of goodness of fit although the model improvement was marginal. The authors caution that the 55 dB(A) cut-off they identified was for a large urban area and that a lower level may be appropriate in a more rural environment. Weinberger (1992), in a CVM study in Germany, found a lower cut-off of around 40dB(A). Bristow and Wardman (forthcoming), in an SP study of aircraft noise, found that the imposition of any threshold saw a deterioration in the fit of the models.

In summary, it is a widespread convention that 55dB(A) is the appropriate cut-off (Navrud, 2004), and some evidence from hedonic pricing studies supports this. However, good evidence from annoyance studies and limited evidence from valuation studies suggest that such a cut-off should be treated with caution. Additional modelling of the Birmingham data set (Day, 2005a) suggests that noise values are positive down to at least a 45 dB(A) threshold.

Evidence on level effects suggests that marginal willingness to pay increases with the level of noise experienced (Pommerehne, 1988; Vainio, 2001; Bjørner, 2004; Arsenio *et al,* 2006; and Bristow and Wardman, forthcoming). There is little evidence to date on the presence of size or sign effects in this context, studies that report on this issue have not identified such effects (Wardman *et al,* 2005). The Birmingham model is consistent with this literature in that it finds a positive level effect. HP cannot, however, be used to identify size or sign effects.

(v) Income and other variables

In environmental valuation as a whole, most of the empirical evidence suggests that the income elasticity of impact values is between zero and one (Pearce, 1980; Kristrom and Riera, 1996**;** Hökby and Söderqvist, 2001). This is consistent with evidence in travel demand analysis, where a significant amount of research indicates a cross-sectional income elasticity of around 0.5 (Gunn, 2001; Wardman, 2001). In the specific context of noise valuation, income elasticities for the willingness to pay for noise reductions have been estimated to be: 0.9 by Pommerehne (1988) in a CVM study of aircraft and traffic noise; 0.7 in an SP study of residential traffic noise in Edinburgh (Wardman and Bristow, 2004); 0.72 to 0.78 in a CVM study of road traffic noise reduction in Copenhagen (Bjørner, 2004); 0.5 by Arsenio *et al* (2006) in a study of traffic noise in Lisbon and values ranging from 0.2 to 0.9 from a study of aircraft noise across three countries and utilising three different types of SP experiment (Bristow and Wardman, 2003).

In summary, there is fairly strong evidence in this context that the cross sectional income elasticity is less than one, most probably in the range 0.5 to 1. There is no evidence available on income elasticity over time. There is no clear evidence on income effects in the Birmingham model as household income is unknown. Nevertheless the market segmentation appears to capture this at least in part. The expenditure variable in the demand equation indicates that at higher levels of expenditure the demand for peace and quiet is higher (Day, 2005b).

Other factors may influence the willingness to pay for noise change. Notably, work by Carlsson *et al* (2004) and Bristow and Wardman (2006) indicates that willingness to pay varies by time of day in the context of aircraft noise, however these types of segmentation cannot readily be identified in an HP study.

(vi) Conclusions

In comparing the Birmingham study with the available body of evidence on transportation noise annoyance and valuation we find that:

- The values are broadly consistent with evidence from HP and SP studies, though less consistent with findings from CVM studies. This is encouraging as we would see the HP and SP evidence as more reliable.
- Evidence suggests that road noise is more annoying than rail and thus should be more highly valued, though the evidence on valuation across modes is sparse. The contradictory finding of the Birmingham study that rail noise is more highly valued than road noise, should prompt further investigation. In the meantime, Birmingham road noise values, based on a much larger sample size, are more attractive as a basis for benefit transfer within the UK.
- Whilst the commonly assumed threshold for noise values is 55 dB(A), evidence from annoyance studies and limited evidence from SP/CVM work suggests that it is lower and this is supported by the remodeling work on the Birmingham data which takes the values down to a threshold of 45 dB(A).

- Wider evidence supports the presence of a positive level effect in noise valuation, also found in the Birmingham study.
- Evidence suggests that the income elasticity is most likely to be between a half and one.
- Evidence suggests that willingness to pay is also related to individuals' perceptions of noise, time of day and other personal and perceptual variables that cannot readily be identified in a HP study.

Steps in benefit transfer

Having established that the Birmingham study results are based on a robust methodology and are consistent, overall, with the international evidence, in this section we set out how the benefit transfers were made from Birmingham to the UK and other specific locations, and from 1997 to later points in time.

Benefit transfer is the term commonly used in economics to describe the use of valuation results obtained in one setting in applied work in another setting (see, for example, Rosenberger and Loomis, 2003, Pearce *et al,* 2002, or Garrod and Willis, 1999). The main alternative to benefit transfer is to conduct original valuation research each time a new project is analysed. However, noise valuation studies of the type undertaken in Birmingham currently cost hundreds of thousands of dollars or euros per study. If, instead, a defensible case can be made for transferring results from specific studies to a more general context – including taking into account factors which affect the marginal value – then it may be possible to make greater use of valuation evidence in project appraisal, without imposing an unbearable burden on decision-making authorities.

In this case, the Department for Transport's requirements were for estimates of willingness-to-pay (WTP) which could be used in standard transport appraisal procedures (DfT, 2006). Specifically, the following were needed in order to make noise valuation operational:

i. WTP for changes in surface transport noise, at 2002 prices and values, £ per dB(A) $_{Leq,18hr}$ per household per annum (national average (mean) values);

ii. forecast growth in values of noise, 2002 to 2061 and beyond;

iii. an indication of how to transfer the values to specific localities within the UK if required; and

iv. integration of noise valuation into the appraisal process for transport projects.

In transferring the values from Birmingham in 1997 to other sites in 2002 or any future year, two further issues arose and were addressed:

- the Birmingham results were based solely on property sales, which by definition excluded the social rented housing sector – therefore WTP by citizens in the social rented sector would need to be taken into account;
- given that the Birmingham results for rail noise raise questions in the light of the other international evidence, a way forward was needed.

Below, we describe the main steps in the process, finally reaching the goal of marginal values of noise for use in transport appraisal in the UK.

Transfer between Birmingham and other locations

As in the other European countries which value noise, the UK Department for Transport (DfT) believed it would be of practical value to have a set of WTP values for noise which are representative of average conditions in the UK as a whole. These values should not obscure the major sources of differences in noise valuation found in the evidence, hence differentiation by noise level is desirable in these UK values. However, insofar as differences are due to differences in the incomes of those expressing a WTP, rather than any substantive differences in the annoyance caused, these standard UK values should seek to give a single representative value. This is the same as the approach currently taken to other non-market effects of transport interventions in the UK and in many other European countries – for example, values of casualty reduction are not varied to reflect the ability to pay of those affected by the project.

In addition to these UK standard values, there may from time to time be a requirement for values representing a particular locality, in terms of WTP based on income levels in that locality. In these cases, what is required is not simply benefit transfer from Birmingham to the UK but from Birmingham to other local areas, potentially at NUTS 1, 2 or 3 levels[2].

How are these spatial benefit transfers from Birmingham to the UK and from Birmingham to other localities to be achieved? There are two broad options, and within the first of these some more detailed options, for these transfers across locations:

(i) using the relationship between WTP and household income;

(ii) using the relationship between WTP and property prices.

In (i), we can make use of the evidence on the cross-sectional elasticity of noise values with respect to income, cited above. The evidence could be used to justify the use of elasticities of 0.5 and 1.0, for example, as bounds on any cross-sectional benefit transfers. However, an overriding requirement was for simplicity in the appraisal guidance. Bearing in mind that the effect on the values is small, a judgement was made jointly by DfT and the research team to recommend a cross-sectional elasticity of 1.0 for the time being (an elasticity of 0.5 would reduce the values by 6.6%). This is an issue on which future valuation research will hopefully cast more light, allowing values to be revised and confidence increased, as it has done for values of travel time and safety.

The data on household income at a local level is available in two different forms. One is Total Household Income, a pre-tax and benefits measure, whilst the other is Gross Disposable Household Income, a post-tax and benefits measure. The dispersion of incomes is, as expected, narrower after 'redistribution' than before. Table 3 shows the household income relativity between Birmingham and the UK mean, based on each of these two measures.

[Insert Table 3 here]

Assuming that individuals form their judgements about expenditure – including WTP for peace and quiet – on the basis of their disposable rather than their gross incomes, we prefer the Gross Disposable Household Income basis. Having assumed that the cross-sectional elasticity of noise values with respect to income is 1.0, this implies that a noise value measured in Birmingham in 1997 as £*x* per dB(A) per household per annum, is equivalent to a UK 1997 value of £*x**1.149 per dB(A) per household per annum.

An alternative approach to transferring values between Birmingham and the UK, would be to use the relationship between noise values and house prices. In this case, with a cross-sectional elasticity of 1.0, the factor on the Birmingham values would be 1.283, since UK mean house price in 1997 was £76 100 versus £59 308 in Birmingham. However, house prices are quite volatile even over short periods of time, especially at the regional and local level, meanwhile – as Bateman *et al* (2004: 160) observe – there is no reason to assume that households' preferences for peace and quiet fluctuate in this way. Indeed, if the Birmingham study were re-run in 2005, a different hedonic function is likely to be found, given the new level of house prices in that area. Given the fluctuations in the housing market and the comparatively steady growth in household incomes, and also given the direct link from income to WTP via the household budget constraint, a judgement was made that household income is preferable to property price as a basis for benefit transfers across the UK.

Transfer between 1997 and 2002

Benefit transfers across time have been the subject of recent work by Nellthorp *et al* (2001) and Bickel *et al* (2006) in the context of European cost-benefit analysis research. The approach taken here is essentially the same as in those studies.

In common with the values of travel time savings and accident reductions, a time-series elasticity is assumed for the value of transport-related noise with respect to income (DfT, 2005; DfT *et al*, 2004). Whilst the growth in values of time savings and accident reductions is based on *income per capita*, the growth in the value of noise is related to *income per household*, since the household is the decision-making unit in the Birmingham study and since noise exposure data is conveniently gathered at the level of the household.

The evidence does not furnish us with a time-series elasticity for noise at all, therefore it is necessary to rely on theoretical arguments and comparisons with other cost-benefit items. As Bateman *et al* (2004: 159-160) observe, property price enters the demand equation for peace and quiet in the Birmingham model, so that if this demand equation was taken at face value as an inter-temporal function, WTP for noise changes would have doubled between 1997 and 2004. The authors comment that this is 'unrealistic'.

If instead the 1997 value is inflated using a time-series GDP per household elasticity of 1.0, and using official statistics on GDP per household, we find that the mean Birmingham value for road noise would increase by just £5 at 55dB(A), and by £13 at 70dB(A) by 2002. In appraisal, an elasticity of 1.0 is used for the growth over time in the working time value and for the value of accident savings in the UK, whilst an elasticity of 0.8 is used for non-working time savings. These elasticities, especially for time savings, are based on inference from multiple studies over a long period of time, as well as on theoretical considerations (Mackie *et al*, 2003). For peace and quiet, as an environmental good, it could be argued that with rising incomes and living standards people are likely to want to allocate an increasing share of their income to such goods and to value them more highly. If so, then we might expect the value of noise relative to other expenditure items to be increasing, in other words GDP per household elasticity >1.0. In view of the evidence on the cross-sectional elasticity (≤1.0), however, and on a note of caution whilst noise values are new to appraisal, the decision was made to adopt a time-series elasticity of 1.0 as an interim measure.

The data on which the transfer is based are taken from national statistics (ONS, 2004a). By combining the three components of real GDP, consumer price inflation and growth in the number of households, the factor which is implied to transfer 1997 values to 2002 values is equal to 1.165.

Adjustment for household tenure

The original Birmingham sample included residential property transactions but did not include the social rented sector – that is, households living in council rented or other social rented accommodation (Bateman *et al,* 2004: 16). These include some of the poorest households and have a lower average income than the groups which are included. Data indicates that approximately 28% of Birmingham households were in the omitted tenure categories (ONS, 2005).

The process of revising the WTP estimates to take into account the missing tenure categories made further use of the assumption used elsewhere, that the cross-sectional elasticity of WTP with respect to disposable household income is equal to 1.0. Given that assumption, the key piece of evidence required to estimate a WTP value for the social rented sector, and hence for Birmingham residents overall, is disposable household income by tenure. The best available data suggested that the ratio of social rented sector : private sector incomes was 157.3 : 373.1 (Green *et al*, 1999).

Starting with the interval 45-50dB(A):

$WTP_{private}$ = £12.4

Elasticity of 1.0 and a linear demand function imply that

$$WTP_{social} = \frac{12.4}{373.1} I$$

where I = income,

hence at the mean social rented sector income £151.3, WTP = £5.03.

The same calculation can be made for each noise band, giving the results shown in the 'Birmingham social rented' column of Table 4.

[Insert Table 4 here]

The transfer from Birmingham to the UK as a whole in 1997 is based on GDHI across all households *including* the social rented sector in the UK versus Birmingham. Therefore the final column of Table 4 gives the national average WTP estimates, including tenure adjustment, for use in appraisal.

Note that the outcome of the analysis of household tenure was a downward adjustment of the monetary values by approximately 17.5%, to reflect the WTP of an average household across all tenure types.

Modes of transport

In view of the concerns over the Birmingham rail noise values raised at the review stage, alternatives were considered and discussed. Finally, the decision was made to adopt the Birmingham road values as the basis for benefit transfers for all surface transport, these being based on a large sample size, and the evidence on the relativity of rail values being contradictory. This is an interim position, pending further research. One can envisage situations where the rationale for more differentiated values might be strong – for example, High Speed Rail, heavy freight trains, and perhaps even on-street tram systems in urban areas. It has been agreed that any such adjustment to the values will be carried out on a case-by-case by basis, based on appropriate evidence, which should be properly cited in the appraisal.

Noise values differentiated by noise level

The Birmingham results clearly indicate that the marginal value of changes in transport noise is increasing with the absolute level of noise over the range 45-80dB(A). The *gradient* of the values (i.e. the increase in the marginal value from one dB(A) to the next) is constant across this range. Noise changes below 45dB(A) will be subject to a zero value, based on the evidence available. Above 80dB(A), no further increase in marginal WTP was identified by the Birmingham model, and note that very few properties will typically be in this category.

For reasons of practicality in appraisal, some countries including Sweden, France and Denmark, have opted to simplify the value set, with a 5dB(A) interval banding of values. Below we present the UK WTP values in this way (although values at a finer 1dB(A) resolution were also calculated) per household *or* per person for a 1dB(A) change within specified 5dB(A) intervals. These values (Table 5) are based on the mean road noise values from Birmingham, transferred to a UK basis (factor of 1.149), from 1997 to 2002 prices and values (factor of 1.165) and adjusted to take account of the social rented housing sector (factor of 0.825).

[Insert Table 5 here]

Note that the confidence interval from Figure 1 has not be carried across to Table 5, for two reasons. Firstly, UK DfT practice is to give appraisal values as mean estimates rather than ranges – this simplifies the appraisal process whilst losing some information about the risks attached to monetary values. Secondly, true confidence intervals in Table 5 would include the risk attached to the elasticities used in benefit transfer, which have not been quantified. To give decision-makers a full picture, further research into these risks, and a framework for presenting probabilistic values, would be necessary.

Transfers to localities

In order to transfer these values to specific locations within the UK, giving 'local values', the simplest approach would be to apply the 1.0 cross-sectional elasticity of the value of noise with respect to household income. In order to do this the following formula may be applied, combined with officially published data on GDHI – as seen in the last two columns of Table 3:

> Local value = UK value * $(1+((\text{GDHI}_{local}-100)*E/100))$
>
> where E is the cross-sectional elasticity with respect to GDHI, assumed equal to 1.0.

It is not common practice in UK transport appraisals to use 'local values' in place of national average values for non-marketed effects, however, if a proper distributional analysis is also being presented, then the main cost-benefit analysis may be based on pure WTP (HM Treasury, 2003).

Growth in values over time

Finally, in order to move towards a Present Value of Benefits (PVB) for transport noise in appraisal, it is necessary to consider the growth of values of noise over time. Having established above the assumption of a time-series elasticity equal to 1.0 for the value of noise over time, the following table (Table 6) gives the annual growth factors which are implied. In the longer term, from 2032 onwards, the forecast growth in real GDP is adjusted downward following Treasury advice, in proportion to the reduction in the discount rate from 2032 (i.e. from 3.5% to 3.0%) (HM Treasury, 2003: 25). The final column of Table 6 gives the forecast annual percentage growth in noise values per household.

[Insert Table 6 here]

Comparison of values with those used elsewhere

Having undertaken benefit transfers and derived values for use in the UK, the results were compared with appraisal values used elsewhere. This offers an additional credibility check on the UK values, and helps highlight some international differences of approach.

For the comparison, the UK values in Table 6 were converted to € using the OECD Purchasing Power Parity exchange rate of 1.41515€/£, also adjusting from market prices to factor cost (DfT, 2005) and from households to persons (average household occupancy = 2.36 (ONS, 2005)). Table 7 shows the results for the UK, alongside the values reported by Bickel *et al* (2006) for six other European countries where a direct comparison is feasible.

[Insert Table 7 here]

In Table 7, most values are per dB(A) noise change. However, the Finnish and Swiss values are applied to the change in number of people exposed to noise above 55dB(A) – therefore if the mean noise change was 10 dB(A), the mean value per dB(A) would be 10% of the quoted value.

We infer from Table 7 that:

- overall, the order of magnitude of the UK appraisal values is comparable with the values used in the countries listed, with the exception of Sweden which has much higher values than the others at noise levels >60dB(A);
- most countries recognise the existence of the lower threshold for noise valuation, although there are some differences in its level – Austria shares with the UK the 45dB(A) threshold, Sweden uses 50dB(A), whilst others still use 55dB(A) (except Hungary, which has no explicit threshold);
- in the range 55-65dB(A), the UK's marginal values are distinctly lower than others, however this appears to be caused by a difference of approach in which some countries use a constant marginal value above the threshold (perhaps for

practical reasons) whilst the UK and Sweden allow the marginal value to rise with the noise level, following the evidence.

More generally, drawing on the reviews of appraisal practice by Bristow and Nellthorp (2000) and Odgaard *et al* (2005), it seems clear that:

- There is a growing European consensus on the monetary valuation of noise.
- Where noise is valued, annoyance at home is the main focus, although some countries do also address health effects and/or impacts at other locations, in setting their values of noise.
- The vast majority of countries that value noise base their values on hedonic pricing studies. Germany is the exception, basing its values on a CVM study, whilst Austria uses both HP and SP/CVM, however Table 7 suggests that these differences in methodology have not produced fundamentally different results.

Finally, although not directly comparable and therefore not included in Table 7, the Danish and French appraisals also differentiate by noise level, which provides an interesting comparison with the UK and Swedish values (Table 8). An obvious observation is that the Scandinavian countries seem to share a greater sensitivity to high noise levels, but it would be interesting to investigate the underlying reasons why this is the case, for example, whether this is due to differences within the methodology, or to some real differences in preferences in the countries concerned.

[Insert Table 8 here]

Application to appraisal and illustrative example

There are established methods for measuring, predicting and assessing noise impacts of transport projects in the UK, as in many other countries (DfT, 2003; Highways Agency *et al*, 1994). The purpose of the noise valuation research funded by the Department for Transport – including the Birmingham study and the benefit transfer work – has been to build on these rather than to replace them. Notably, the UK method includes an assessment of annoyance, which will continue alongside valuation, both assessments relying on essentially the same project data.

Development of a practical method for noise valuation means we have to be specific about input data requirements, process and outputs. Key features of the method are:

- predictions of household noise exposure are needed for two years, typically 2012 and 2027 for current projects;
- data for both the with-project and without-project scenario are required for each year – preferably the data will be cross-tabulated so that the with-project and without-project noise levels are transparent for particular households (or groups of households);
- calculation of the net benefit to households uses the WTP estimates for particular noise changes (Table 5) and the growth of values over time (Table 6), applying these to the noise exposure data;
- discounting is applied at the official social discount rate of 3.5% up to 30 years and 3.0% thereafter.

The application of the method can best be explained using an example. The A3 Hindhead Improvement is a £240million highway project which would remove a bottleneck, the last single-carriageway section between London and the south coast city of Portsmouth on the A3 trunk road. The project includes a tunnel under the

'Devil's Punch Bowl' SSSI (Site of Special Scientific Interest), which is currently divided by the road. This section of the road would be returned to nature.

Noise effects on households would result from changing the alignment of the road and from the new patterns of traffic movement and speed. Table 9 gives an extract from the noise data for this project, at 1dB(A) resolution. The full dataset includes 772 households, and the data for the year 2027 are summarised in Table 10, using 5dB(A) bands. Data of this type are commonly gathered for major highway projects – driven by environmental assessment requirements (Highways Agency *et al*, 1994).

[Insert Table 9 here]

[Insert Table 10 here]

It is evident that there are both gainers and losers from the project in terms of noise – households below the diagonal in Table 10 will benefit from a noise reduction, and vice versa. Whilst the majority of noise changes are small, a handful of households are likely to experience a drop of 20dB(A) or thereabouts, from a starting level in excess of 70dB(A). Given the increasing marginal value of noise as background noise level rises, these stand to gain the most from the project in terms of estimated WTP for noise reduction.

The calculations of net benefit are straightforward, but are aided by use of a spreadsheet, given the number of data points. In order to calculate the benefit from noise reduction in Year *n,* the basic process is the following:

Step 1 Take the Do-Minimum and Do-Something noise exposure for each household.

Step 2 Select and apply the values from Table 5 growthed to Year *n* using the factors in Table 6.

Step 3 Sum the benefits across households.

Thus for Household 1 in Table 9, the benefit in year 2012 is given by

Noise change = 64dB(A) to 59dB(A)

Estimated WTP = (£40.10 + (£53.20*4)) * 1.014888 * 1.017370 * 1.027295 * 1.024814 * 1.019750 * (1.017269^4) * 1.015695

= £304.92

Summed across all 772 households, the net benefit in 2012 is found to be £43,925.

The goal of the analysis is a Present Value of Benefits for transport-related noise, and to reach that point, it is necessary to interpolate and extrapolate from the two years' data (2012 and 2027) to the whole appraisal period, and to apply discounting. The time profile which is assumed for noise exposure is: linear from the opening year (2012) to the future forecast year (2027); thereafter constant at the level of 2027. These assumptions were determined by the Department for Transport, after consulting noise modelling experts who advised that in the long term, there are countervailing forces towards: increases in noise, including from traffic growth; and decreases in noise, including from quieter road/vehicle technology.

After applying the expected growth rate in WTP (Table 6), the time profile of benefits is not quite linear, and rises after 2027 (Figure 2). After discounting, however, it is declining.

[Insert Figure 2 here]

The Present Value of Benefits (Residential Noise) for the project was found to be £1.16 million. For comparison, the qualitative assessment and the quantitative assessment (in terms of annoyance) were as follows:

- Qualitative: "Substantial reduction in noise in parts of Hindhead. Tranquillity would be restored to a large area within Hindhead Common and the Devil's Punch Bowl. Some effects from redistributed traffic on existing roads";
- People annoyed by noise: "Do-Minimum 309 annoyed", "Published scheme 276 annoyed", "Change in population annoyed (Year 15) = –33".

Conclusions

This paper has described the work undertaken to enable regular valuation of transport-related noise effects in the UK, including the primary study in the city of Birmingham, comparisons against European evidence, and benefit transfers to other locations and points in time. If another country wished to develop WTP estimates for use in transport appraisal, then this is one approach they might consider. Valuation studies for every individual project are unlikely to be economic. Transfers from another country may be susceptible to differences of context (Rosenberger and Loomis, 2003). Instead, undertaking a high quality primary study and then transferring results within the country represents a middle way, for which the main pre-requisites are: (i) the primary study itself; (ii) background data to enable the transfers – such as household income data for the study site and the policy sites, and data on any relevant contextual factors such as tenure in this case; and (iii) preparedness of economists to make the kinds of judgements about the unknown elasticities which have been made in this case, in order to establish a working set of WTP values. Refinement of the WTP evidence base can be expected to follow, as and when further WTP studies are conducted. That is the pattern which has emerged over the past three decades with WTP for travel time savings, for example (Mackie *et al,* 2003).

The UK WTP values have been found to be generally consistent with international evidence, and with WTP values used in appraisal elsewhere in Europe. The marginal value of transport-related noise has been found to increase with the starting noise level, as in other studies. The most notable differences are in:

- *the valuation of noise changes on rail versus road*, where there is a widespread practice in Europe of valuing rail noise effects lower than road, whilst the UK primary study found rail noise to be valued more highly (although the differences were not always statistically significant) – the decision was made to equalise the UK appraisal values for road and rail, pending further research;
- *the lower threshold for valuation,* where the evidence from the Birmingham study gives a basis for a non-zero marginal value down to 45dB(A) instead of the more typical 55dB(A).

How robust are these results? Pearce and Özdemiroglu (2002) recommend that +/-30 to 40% is an acceptable amount of error for benefit transfers to be valid. The values taken from the primary study do have explicit 95% confidence intervals, which are: -22% / +71% at 55-60dB(A), or -27% / +87% at 75-80dB(A) (based on Bateman *et al*, 2004, Table 5.9). The peer review of the primary study and the comparisons with European evidence were both undertaken in order to increase confidence in the results, although it is hard to quantify the increase in confidence this gives. The transfers themselves are based on a more limited evidence base of income elasticity evidence and theoretical arguments – again the effect on confidence intervals is unquantified. In an ideal world, one might conduct a meta-analysis of many methodologically similar valuation studies in order to isolate the full set of contextual factors, including confidence intervals on those. Nelson (2004) and Schipper *et al* (1998) have gone some way towards that in the context of hedonic pricing studies of aircraft noise, however that was far beyond the resources available for this benefit transfer exercise, and for other modes and certainly other methodologies the number of comparable studies is probably too small. Therefore, in order to obtain a set of WTP values for use in appraisal, a set of assumptions has been made and the plausibility of the results will be rather dependent on these. These assumptions may be critically examined in the light of evidence which is revealed in future.

This work has served to demonstrate the feasibility of applying noise valuation to real projects, given suitable noise exposure data. The application has drawn attention to two further issues, however. Firstly, noise benefits may be rather small in comparison with project costs (£1.2million versus £240million in the example given, and even if those households which suffered a noise increase were excluded, the net benefit would be only £1.8million). This casts some doubt over whether the inclusion of noise benefits will have a significant impact on project Net Present Values. However, projects aimed specifically at noise reduction would logically be expected to yield higher noise benefits in relation to project cost, for example, the introduction of noise barriers alongside urban expressways. Secondly, the example draws attention to the limited scope of the noise values. They apply to 'residential noise', that is, noise experienced whilst at home, but not to other potentially important locations such as recreational land, public space, shopping streets, workplaces, schools and hospitals.

Any benefit due to 'restoring tranquillity' or simply reducing noise in those locations remains unquantified.

Finally, these conclusions give rise to a number of research needs. Probably the most urgent are: to explore further the relative valuation of rail and road noise in order to address the inconsistencies among the evidence available now; to validate the assumptions made about the income elasticity of WTP for noise across households and over time; and to investigate WTP for non-residential noise reduction, including in public spaces, workplaces and other locations. In addition, there is scope to explore the reasons for the apparently greater sensitivity to high levels of transport noise in some countries, and to gain a better understanding of any packaging effect when noise is correlated with other local environmental attributes.

Notes

1. $dB(A)_{Leq,18hr}$ is a noise measure in units of decibels. Sounds are 'A' weighted for the human ear's response to the mix of frequencies found in transport noise, and presented as an equivalent steady-state noise level over an 18 hour day (0600-0000 hours) so that more constant noises such as heavy road traffic and intermittent noises such passing trains, can be compared. Nijland and van Wee (2005), in this journal, discuss a range of suitable noise measures for transport analysis, and recommend the use of $dB(A)_{Leq}$ measures.

2. NUTS is the 'Nomenclature of Territorial Units for Statistics', the standard spatial hierarchy in European Union countries. NUTS 1 is the first level below the country, e.g. the UK's West Midlands Region (Population 2.6 million) which contains Birmingham. Birmingham City itself is a NUTS 3 area (Population 0.98 million, although many rural NUTS 3 areas have populations below 100,000).

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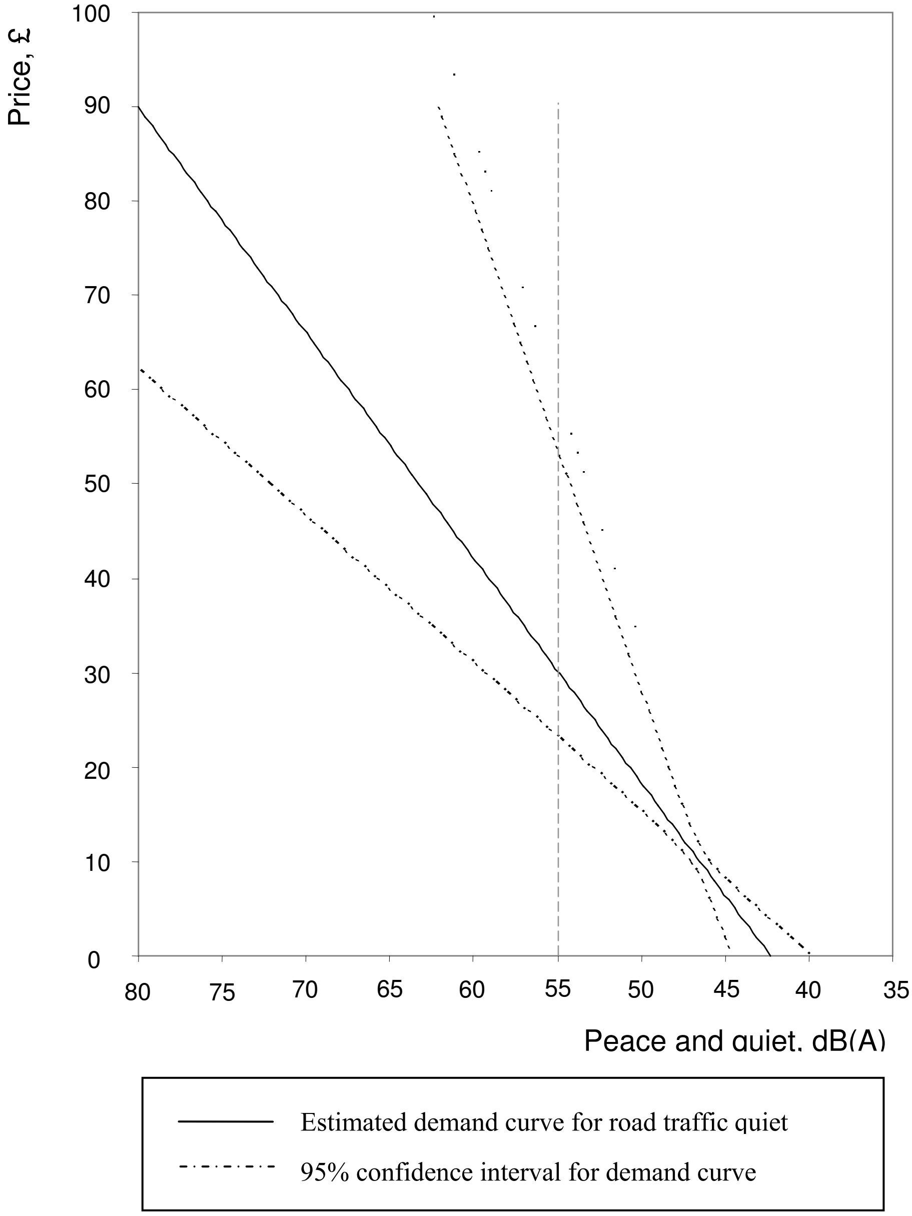
Figure 1. Demand curve for peace and quiet in relation to road noise in Birmingham (and 95% confidence intervals)



Source: Day (2005a)

Table 1. Percentage change in house prices with respect to a 1dB(A) change in road traffic noise levels

Author	**Location**	**Threshold, dB(A)**	**Discount rate, %**
Wilhelmsson (2000)	Stockholm	56 (implicit)	0.6
Lake *et al* (1998 and 2000)	Glasgow	54 68	0.20 1.07
Rich and Nielsen (2002)	Copenhagen: - Houses - Apartments	50	 0.54 0.47
Bjørner *et al* (2003)	Copenhagen	55	0.47
Bateman *et al* (2004)	Birmingham	55	0.21 to 0.53

Table 2. Road traffic noise: willingness to pay per dB(A) per household per annum, 2001 €

Author	Method	Location, study year and scenario	Value
Pommerehne, 1988	CVM	Basel, Switzerland, 1988, % change	99
Soguel, 1994	CVM	Neuchâtel, Switzerland, 1993, % change	60-71
Saelinsminde*, 1999	SP	Oslo and Akershus, Norway, 1993, % change	48-96
Vainio, 1995, 2001	CVM	Helsinki, Finland, 1993, elimination of annoyance	6 – 9
Thune-Larsen, 1995	CVM	Oslo and Ullensaker, Norway, 1994, % change	19
Wibe, 1995	CVM	Sweden (national study) Elimination of annoyance	28
Wardman and Bristow*, 2004	SP	Edinburgh, Scotland, 1996, % change	37-55
Navrud, 1997	CVM	Norway (national study) 1996, elimination of annoyance	2
Navrud, 2000	CVM	Oslo, Norway, 1999, elimination of annoyance	23 – 32
Barreiro *et al,* 2000	CVM	Pamplona, Spain, 1999, elimination of annoyance	2 – 3
Lambert *et al,* 2001	CVM	Rhones-Alpes Region, France, 1999, elimination of annoyance	7
Arsenio *et al,** 2006	SP	Lisbon, Portugal, 2001, change to level in a known location.	55

Source: Values from Navrud (2004) Table 1 except where indicated *.

Table 3. Household income in Birmingham versus the UK, 1997 £ and index

Area	Total Household Income		Gross Disposable Household Income	
	£ per capita	Indexed to UK=100	£ per capita	Indexed to UK=100
UK	14 264	100	9 513	100
England	14 571	102	9 674	102
West Midlands (NUTS1 area)	13 056	92	8 748	93
West Midlands (NUTS2 area)	12 290	86	8 349	88
Birmingham	**11 839**	**83**	**8 276**	**87**
Solihull	15 976	112	10 084	106
Coventry	12 410	87	8 371	88
Dudley and Sandwell	11 982	84	8 181	86
Walsall and Wolverhampton	12 124	85	8 467	89
Herefordshire, Worcestershire, Warwickshire	14 692	103	9 513	100
Shropshire and Staffordshire	13 408	94	9 037	95
Wales	12 029	84	8 389	88
Scotland	13 434	94	8 977	94
Northern Ireland	11 671	82	8 365	88

Source: ONS (2002).

Table 4. Derivation of UK-based values for changes in transport-related noise (adjusted to include the social rented sector)

		All values per dB(A) per household per annum				
Noise change in the interval, dB(A)		**Birmingham**			**UK**	
		Private sector	Social rented	Mean		
Low	High	1997 £	1997 £	1997 £	1997 £	2002 £
45	50	12.40	5.03	10.2	11.76	13.7
50	55	24.33	9.87	20.1	23.07	26.9
55	60	36.26	14.71	29.9	34.38	40.1
60	65	48.19	19.55	39.7	45.69	53.2
65	70	60.12	24.38	49.6	57.00	66.4
70	75	72.05	29.22	59.4	68.31	79.6
75	80	83.98	34.06	69.3	79.62	92.8

Table 5. UK-based values for transport-related noise at 2002 prices and values, £

Noise Change in the Interval, dB(A) Low	High	£ per household per annum for a 1 dB(A) change within the stated interval	£ per person per annum for a 1 dB(A) change within the stated interval
<45		0.0	0.0
45	50	13.7	5.8
50	55	26.9	11.4
55	60	40.1	17.0
60	65	53.2	22.6
65	70	66.4	28.1
70	75	79.6	33.7
75	80	92.8	39.3
>80		98.0	41.5

Table 6. Forecast growth in the values of noise change

Range of years	Real GDP growth, % per annum	Household growth, % per annum	Value growth 'adjustment factor'	Growth in values of noise change, % per annum
2002-2003	2.25	0.75	1.0000	1.4888
2003-2004	2.50	0.75	1.0000	1.7370
2004-2005	3.50	0.75	1.0000	2.7295
2005-2006	3.25	0.75	1.0000	2.4814
2006-2007	2.75	0.76	1.0000	1.9750
2007-2011	2.50	0.76	1.0000	1.7269
2011-2021	2.25	0.67	1.0000	1.5695
2021-2031	1.75	0.33	1.0000	1.4153
2031-2032	2.00	0.17	1.0000	1.8269
2032-2036	2.00	0.17	0.8571	1.5417
2036-2051	2.00	0.00	0.8571	1.7143
2051-2061	1.75	0.00	0.8571	1.5000
2061 onwards	2.00	0.00	0.8571	1.7143

Sources: DfT (2005); TEMPRO data supplied by DfT; HM Treasury (2003: 25).

Table 7. Noise values used in appraisal in seven European countries, € 2002 per person per annum at factor cost

Country	Differentiation	45-50dB(A)	50-55dB(A)	55-60dB(A)	60-65dB(A)	65-70dB(A)	70-75dB(A)	75-80dB(A)
Values in €/dB(A)								
Austria	road noise only	36.4	36.4	36.4	36.4	36.4	36.4	36.4
Germany	noise exposure in built-up areas	0	0	52.0	52.0	52.0	52.0	52.0
Hungary *	annoyance from road noise	68.2	68.2	68.2	68.2	68.2	68.2	68.2
Sweden	road noise only	0	3.7	58.8	127	219	492	1 177
UK	road and rail noise	6.8	13.3	19.9	26.4	32.9	39.5	46.0
Values in € per person exposed to noise above 55dB(A)								
Finland	noise exposure in built-up areas	0	0	695	695	695	695	695
Switzerland	annoyance in dwellings	0	0	362	362	362	362	362

Source: Bickel *et al* (2006), Table 6.4; UK data added.

Notes: * Hungary has no lower threshold.

Table 8. Ratio of noise value at 70-75dB(A) to noise value at 55-60dB(A)

Country	**Values**		**Ratio**
	at 55-60dB(A)	at 70-75dB(A)	
Denmark	'Annoyance factor' 0.12	'Annoyance factor' 1.00	8.3
France	0.4% of property value per dB(A)	1.0% of property value per dB(A)	2.5
Sweden	58.8 € per dB(A)	492 € per dB(A)	8.4
UK	19.9 € per dB(A)	39.5 € per dB(A)	2.0

Sources: Bickel *et al* (2006); Nellthorp *et al* (2005).

Note: all values based on HP studies.

Table 9. Extract of noise data, 1dB(A) resolution, 2012 (opening year) and 2027

Household	Do-Minimum noise level, dB(A)$_{Leq\ 18hr}$		Do-Something noise level, dB(A)$_{Leq\ 18hr}$	
	2012	2027	2012	2027
1	64	64	59	60
2	61	61	57	58
3	61	61	57	58
4	62	62	58	59
5	61	61	58	59
6	61	61	58	59
7	62	62	59	60
8	61	61	58	59
9	64	64	61	62
10	67	67	63	64
11	69	69	66	67
.	.	.	.	.
.	.	.	.	.
74	51	51	53	54
75	53	53	54	55
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
772	54	55	51	52

Table 10. Cross-tabulated noise data using 5dB(A) bands, 2012 and 2027

2012

Do-Minimum noise level, dB(A)$_{Leq\ 18hr}$ \ Do-Something noise level, dB(A)$_{Leq\ 18hr}$	<45	45-49.9	50-54.9	55-59.9	60-64.9	65-69.9	70-74.9	75-80
<45	14							
45-49.9	8	76	12					
50-54.9	13	25	137	4	6			
55-59.9			40	115	22			
60-64.9				47	123	39		
65-69.9					14	25		
70-74.9		16			2	12	11	
75-80				8		2	1	

2027

Do-Minimum noise level, dB(A)$_{Leq\ 18hr}$ \ Do-Something noise level, dB(A)$_{Leq\ 18hr}$	<45	45-49.9	50-54.9	55-59.9	60-64.9	65-69.9	70-74.9	75-80
<45	14							
45-49.9	8	59	31		1			
50-54.9	13	12	145	6	5			
55-59.9			33	77	54			
60-64.9				43	128	11		
65-69.9					12	69		
70-74.9		1	15			13	14	
75-80				8				

Figure 2. Example noise benefit profile including value growth