Developing Guidance on the Valuation of Transport-Related Noise for Inclusion in WebTAG

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1. Introduction

Previously, the Department for Transport (DfT) commissioned the University of East Anglia to undertake research into the value of transport noise in Birmingham, combining hedonic pricing methods and an advanced GIS approach to noise mapping. The results were published twelve months ago, to widespread interest in the UK and internationally (Bateman *et al,* 2004).

DfT decided that it wished, in principle, to use the results of that study as the basis for extending monetary valuation in transport appraisal, and commissioned ITS and TSG to assist with the additional tasks:

- checking the robustness of the Birmingham study;
- benchmarking the results against other European work;
- considering issues relating to the transfer of the results across UK locations and through time from the original 1997 Birmingham data; and
- investigating how to integrate the new knowledge with the existing methods for noise measurement and prediction, and with the Department's Transport Analysis Guidance (published online as 'WebTAG' (DfT, 2005)).

The work was undertaken to a tight timescale early in 2005 and this paper, setting out the findings, was presented and discussed at a seminar 'Valuing Transport Related Noise' held at DfT on 17th May 2005. A minimum of essential revisions have been made in this version of the paper, to reflect changes since the Seminar[1].

Section 2 examines the robustness of the Birmingham values and benchmarks them against values obtained in other European studies and those used in appraisal in European countries. Section 3 addresses benefit transfer to other locations within the

[1] in particular: an adjustment to the values to account for the social rented housing sector, which was omitted from the Birmingham model; and the extension of the values from 55dB(A) L_{eq} down to 45dB(A) L_{eq}, on the basis of the willingness-to-pay evidence in Birmingham.

UK and across time, and considers how to integrate noise valuation with current UK noise appraisal methods. Section 4 summarises the key findings.

2. Robustness and benchmarking of the Birmingham results

In this section we explore two main areas:

- firstly, the robustness of the study and the results obtained – in its own terms as a hedonic pricing study; and
- secondly, benchmarking of this study against other methodological approaches and values of noise.

There has been some interaction with the authors of the Birmingham report in order to clarify points of interpretation.

2.1 Robustness

This section contains a critique of the hedonic modelling process and results. It is undertaken with a view to identifying key issues relating to the data or modelling, in order to enable conclusions to be drawn as to whether the Birmingham results are sufficiently robust and valid as measures of the benefits of changes in transport noise in Birmingham. This involves an examination of the scope and modelling methodology as well as narrower issues relating to the final model form.

Capture of values other than noise

The final hedonic price models (reported in Appendix B of Bateman *et al,* 2004) contain a limited range of environmental variables, namely the three noise variables and two view variables. This is common in hedonic models where explanatory variables are often highly correlated with each other. The two view variables are insignificant and for some sub-markets wrong sign which raises questions about their presence in the final models. Arguably the location variables park, industry and landfill could also be taken to represent environmental quality to some degree – though these too are often insignificant and sometimes wrong sign reflecting the confounding effects of access and environment in some cases.

The implication is that other variables related to traffic noise such as:

- Air pollution
- Severance
- Pedestrian risk and safety
- Vibration
- Visual intrusion
- Dust and dirt

…may have been captured in the noise coefficient. This would clearly bias the estimated value of noise upwards. If the data were available it would have been interesting to have used the factor analysis on these variables to construct a “factor” representing the environmental impacts of traffic. Navrud (2004) suggests that Hedonic Pricing is “ideal” where an overall measure of traffic impact is sought and there is no need to isolate separate values for each impact. Bjorner *et al* (2003) tested this theory to a degree by first including both noise and air pollution in their model. This produced a significant noise coefficient but an insignificant air pollution coefficient. They next removed the air pollution variable from the model and found that this made little difference to overall model performance. Similarly, when the noise variable was omitted a significant coefficient on air pollution was obtained. The degree of correlation was such that the two variables could not both be included in the model. The authors conclude that the noise coefficient also contains the influence of other environmental factors and that this has biased their hedonic pricing (HP) estimates of noise costs upwards relative to their contingent valuation (CVM) estimates in a study of transport noise in Copenhagen. However, we do not know the degree to which air pollution influences house purchase decisions as it is less easily observed than noise. The limited evidence available from stated preference studies that have valued both noise and air pollution from transport suggests that air pollution may impose higher costs than noise (Wardman and Bristow, 2004). Given the evidence of Bjorner *et al* and Wardman and Bristow, it is reasonable to conclude that air pollution may have a significant impact on the values derived. In the absence of studies that have obtained values for the whole range of impacts it is difficult to draw conclusions as to which other impacts might be exerting the greatest influence on the value of noise obtained in the Bateman *et al* study. This is clearly an area for further research.

The noise coefficient in the Birmingham study may be capturing the effect of other environmental factors. This might help in the interpretation of certain results. For example on page 147 of the Technical Report, families with young children are reported to have a relatively high willingness to pay for quiet. Could this perhaps be a willingness to pay also for a safer, less polluted environment for the children?

This is an issue to be aware of in applying values as there may be double counting between noise and other environmental impacts in the Appraisal Summary Table. In the absence of further evidence no firm conclusion may be drawn on the extent of any such double counting.

Final form of the first stage model

"With a few exceptions, researchers have abandoned any attempts to recover preferences, and work instead with the hedonic price function" (Haab and McConnell, 2002, p251). The second stage is not normally carried out. Hedonic values in use in appraisal elsewhere are derived from the first stage. Two important reasons for this are the problems of identification of the preference model (Haab and McConnell, 2002) and because the required socio-economic data is not present in hedonic data sets – as is the case here where it has been necessary to make a large number of assumptions:

- Expenditure on property is used to proxy income.
- Personal characteristics of households are constructed from the "factors" based on enumerator area level data and developed earlier in the process. "...ultimately one has to admit that our data is just deficient in this area……we don't know the actual characteristics of property purchasers" (Bateman *et al,* 2004, p135).

- Wrong sign coefficients on noise are set to zero and insignificant coefficients are used in the model. For road noise the implication is that for sub-markets 1 and 2 the value of noise is set to zero; whilst for sub-market 6 an insignificant coefficient is utilized. In the case of rail noise the value for sub-market 7 will be zero whilst for sub-markets 1, 2, 3, 5 and 6 coefficients that are not significant at a 95% level of confidence are utilized. The difficulty in identifying robust coefficients for rail is compounded by the low sample sizes in many of the segments. In effect of the 16 sub-markets for road and rail noise that are modeled only 7 have coefficients that are significant at a 95% level of confidence (Bateman *et al,* 2004, Table 4.14b, p105).
- Simplification of the HP function with the use of factors and a constant term.
- Construction of a discount rate for house purchasers based in part on a matched sample of rented and purchased property of size 22.
- Truncation of the data set to remove properties that appear to be underpriced by omitting the bottom 2.5% of properties from each market segment.

Values derived from first stage hedonic pricing models have been found to be susceptible to the model form used as well as local context (Nelson, 2004; Schipper *et al,* 1998). This is worthy of careful, detailed exploration in the future.

The first stage models in the Birmingham study are constructed on a comprehensive data set and are extremely thorough in the determination of sub-markets, the use of flexible functional forms and the use of spatial smoothing. However, there is room for debate as to whether the final models achieve the optimal balance between parsimony and goodness of fit on the one hand and theoretical consistency on the other. It would have been interesting to know if a model which sought to merge or omit insignificant variables could have produced a more robust estimate of the noise coefficient.

Our view is that it is necessary to acknowledge and keep in mind the limitations of the model, but that in the context in which the results are to be used – a simple national value set – these limitations are not fatal. They do, however, make the issue of benchmarking against other studies important (see below).

Quality of the noise data

The noise estimates for the Birmingham study were obtained from a noise mapping exercise for Birmingham (DEFRA, 2000). This used traffic flow and other information to estimate noise contours at 5dB(A) intervals for road and rail. The data provided to Bateman *et al* (2004) was more detailed and took the form of a noise level for every residential façade in Birmingham. Aircraft noise data was available in the form of 3dB(A) contours radiating from Birmingham International Airport.

Annoyance and value thresholds

The hedonic models reported in Bateman *et al* (2004) used a cut off point of 55dB(A) for daytime noise. This cut-off was achieved by experimentation with various thresholds and gave the best fit to the data, though with some variation between sub-markets. The 55dB(A) cut-off across the board was imposed to give the best overall fit (Day 2005a).

This finding matched existing appraisal practice, where changes in noise levels below a 55dB(A) threshold were given a zero weight in the quantitative analysis (DfT, 2003). Nevertheless, the question was raised as to whether values of noise are indeed zero at levels below 55dB(A). The trend in the Birmingham results is not towards zero at 54dB(A), but towards zero in the region of 42.5dB(A) – see Annex C below, reproduced from Bateman *et al* (2004), Table 5.9. Bateman *et al* (2004) report a value of £31.49 per annum for a 1 dB(A) reduction in road noise from 56 to 55dB(A) (the corresponding figure for rail noise is £83.61): given this, is it correct that willingness-to-pay for a move from 55 to 54dB(A) is zero?

A range of evidence exists, including evidence of cut-offs from studies of noise annoyance, evidence on the relationship between noise values and annoyance, and direct evidence of cut-offs in noise valuation research. Miedema and Oudshoorn (2001) modelled the relationship between noise exposure and annoyance using data from 46 studies across the world (split by mode these included: 20 studies of aircraft noise; 18 of road noise; and 9 of rail noise; and study years range from 1965 to 1993). The studies used are all in the developed world and nine are from the UK. They suggest the following cut-off 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. They may be higher or lower than the 18 hour daytime Leq measure used in the Birmingham study[2] – this will depend on the level of variation between daytime, evening and night time noise.

We would expect that the value placed on noise reflects exposure and annoyance, and there is evidence that this is the case. Bristow and Wardman (2005) find annoyance to be an influential variable in determining values of aircraft noise. The clearest exposition of the relationship between road noise, annoyance and willingness-to-pay is found in Fosgerau and Bjorner (2006), where the relationships between annoyance and noise and between willingness-to-pay and noise are found to follow very similar paths[3].

Valuation evidence was also considered. Bjorner *et al* (2003) found 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. Bjorner *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). Wardman and Bristow (2005), in an SP study of aircraft noise, found that the imposition of any threshold saw a deterioration in the fit of the models. Navrud (2004) finds that the use of a 55dB(A)

[2] We have been advised that the period is 18 hour, although it is not stated in Bateman *et al* (2004).
[3] Also, a comparison of the marginal value function in Birmingham with the annoyance response function used in UK appraisals finds similarities, particularly in terms of the noise level at which the valuation and annoyance response tends towards zero (see Section 3.3, Table 11 and Figure 2 below). Of course, this alone does not prove that the marginal value function actually reaches zero at that level.

cut-off level is the conventional assumption, and that it is supported by evidence from some hedonic pricing studies.

In summary, it is a widespread assumption that 55dB(A) is the appropriate cut-off, 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.

In view of this finding, some further analysis was undertaken on the Birmingham data by Day (2005b):

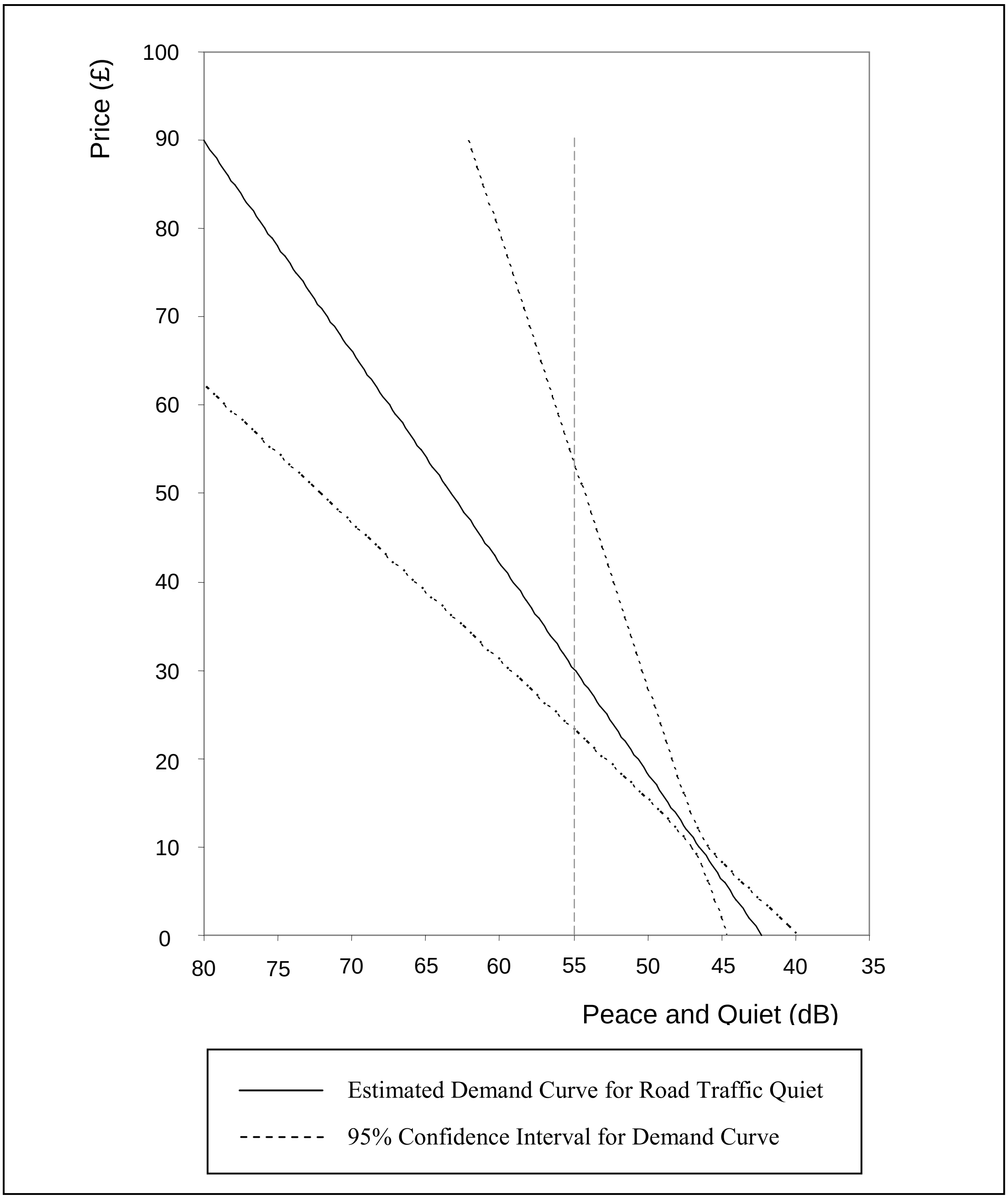
> "To estimate a demand curve for peace and quiet from road noise, we require information on the quantity of peace and quiet chosen by households when faced by different marginal prices. Of course, if the Birmingham market is such that marginal prices below 55dB are always zero, it is impossible to directly identify the path of the demand curve over this range. Accordingly, the original report to the DfT [Bateman *et al,* 2004] illustrated the estimated demand curve only over the range 55dB to 80dB. Likewise, estimates of welfare changes resulting from changes in noise exposure were only provided over the 55dB to 80dB range. What is evident from those estimates is that WTP for marginal changes in the noise environment does not fall to zero at 55dB.
>
> One way of estimating welfare measures for changes in the noise environment below 55dB [is] to project the estimated demand curve below the imposed 55dB threshold" (Day, 2005b).

Figure 1 shows the projected demand curve for peace and quiet in the Birmingham property market in 1997, including the 95% confidence interval on willingness-to-pay (WTP), estimated using Stata's *standard error of the prediction* function.

Day (2005b) reports that:

> "Obviously, the 95% confidence intervals for the estimated demand curve should closely resemble the 95% confidence intervals for welfare estimates of unit changes in road noise provided in Table A7 of the non-technical report and Table 5.9 of the technical report [Bateman *et al*, 2004].
>
> Whilst these latter confidence intervals were estimated from a bootstrap procedure, they are reassuringly close to the parametric confidence intervals presented in Figure 1. For example, the bootstrap procedure [in Bateman *et al*, 2004] indicates that the welfare change associated with a fall from 56dB to 55dB of road traffic noise exposure has a 95% confidence ranging from £24.84 to £52.52. Reading off the money values associated with the parametric 95% confidence intervals at 55dB in Figure 1 gives very similar values".

Figure 1: Road Noise Demand Curve and 95% Confidence Intervals



Source: Day (2005b)

"Projecting the demand curve down below 55dB reveals that marginal WTP falls to zero at a noise level of 42.3dB with a 95% confidence interval ranging from 39.9dB to 44.7dB.

At first sight it is somewhat surprising that the confidence interval for the estimated demand curve narrows in the range below 55dB. As a matter of fact this is quite intuitive. The bulk of observations are for households facing relatively low prices and choosing properties below 55dB. 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.
>
> **Conclusions**
>
> ... the analysis does not support a 50dB cut off point for welfare losses resulting from changes in road noise exposure. Indeed, the research recorded in this document suggests that marginal WTP falls to zero at around 42dB and that we could not reject with 95% confidence that this figure was nearer to 45dB" (Day, 2005b).

Taking into account these results and the wider evidence set out above, the conclusion was reached that there is a case for a 45dB(A)$_{Leq\ 18hr}$ cut-off point when valuing transport-related noise in appraisal. Note that this is reasonably consistent with the standard method of noise assessment for roads (see 'DMRB Volume 11', Highways Agency *et al*, 1994), which recognises that there is an impact on annoyance down to 42dB(A)$_{L10\ 18hr}$ and recommends recording noise changes in bands down to 'below 50dB(A)$_{L10\ 18hr}$' (which is approximately equivalent to 'below 47dB(A)$_{Leq\ 18hr}$'). The 45dB(A) cut-off has been agreed with DfT and the Highways Agency.

Finally, note that the latest National Noise Incidence Study (BRE, 2002) contains evidence on exposure to noise in the UK showing that approximately 54% of the population is exposed to day time noise levels above 55dB(A). Given that this includes noise from all sources, it is likely that a majority of the population (as is the case in the Birmingham sample) are exposed to transport noise levels below 55dB(A). The choice of a 45dB(A) cutoff will therefore significantly increase the number of households included in the quantitative appraisal of transport noise.

Values by Mode

The Birmingham model could not recover significant values for aircraft noise, which is probably due to the low sample size (644). The values derived for road and rail are different in that rail noise is found to have a larger impact on house prices. However, the confidence intervals on the rail values are wide and overlap the road values at all levels of noise. The authors state that at levels of noise above 65dB(A), the hypothesis that road and rail values are the same cannot be rejected, although it *can* be rejected at noise levels between 55 and 65dB(A) with 95% confidence, based on a bootstrapping exercise.

This finding would appear to be at odds with other evidence, and custom and practice, that rail noise is less disturbing – see for example Table 1 in TAG Unit 3.3.2 (reproduced below – Table 11). The EC position paper on noise and annoyance (EC, 2002) relies 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 for 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) states that: "These findings are in strong conflict with most international and Swedish studies" and suggests that plans for railway construction in the survey area may have influenced responses. Whilst annoyance scales and willingness to pay are clearly different scales they are also clearly related, and as annoyance increases the expectation would be for values to increase also – this relationship has been discussed above. There are few studies that value rail noise 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 rail intrusion are lower than for road intrusion.

In summary, there is fairly strong evidence that annoyance from rail noise is less than annoyance from road noise at a specific level of noise. There is also some evidence that the value of noise is related to the annoyance level and what limited evidence there is suggests that rail noise is valued less highly than road traffic noise, yet the Birmingham study suggests the reverse. However, the Birmingham study cannot reject the hypothesis that road noise and rail noise are valued equally in the model at some noise levels, additionally the road noise values are estimated with more precision than the rail noise values. A judgment was therefore made to progress using the values estimated for road noise in the Birmingham model and apply this to both road and rail noise in the absence of further evidence in the UK context. Addressing the issue of the relative values of road, rail and aviation noise will be a key task in future research.

Level, Size and Sign Effects

In the Birmingham model, the value per unit noise change, dB(A), increases with the noise level experienced (see Annex C). This finding is supported by other evidence on level effects which suggests that willingness to pay increases with the level of noise (Pommerehne, 1988; Vainio, 2001; Bjorner, 2004; Wardman and Bristow 2005; and Arsenio *et al,* in press)

Hedonic pricing does not provide any direct evidence on the presence or absence of sign or size effects for marginal changes in noise at a given residential location. This is because it does not directly address the situation in which most residents will find themselves at least in the short term when transport systems change. There is substantial literature on these issues in environmental economics but not in the context of transportation noise. At this stage there is insufficient evidence on sign and size effects to include these aspects in the value function. All that can be said with some confidence is that the value of noise is related positively to the level.

Income effects

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, 2005a).

In environmental valuation as a whole, most of the empirical evidence suggests that the income elasticity of impact values is less than 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 (Bjorner, 2004); 0.5 by Arsenio *et al* (forthcoming) 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 some evidence in this context that the cross sectional income elasticity is less than one. No studies have been found that report an income elasticity above one. There is no evidence available on income elasticity over time. In the absence of any evidence on income elasticity over time and the limited evidence on cross sectional elasticity, a simplifying assumption that the income elasticity is one is reasonable at this time.

2.2 Benchmarking

In this section we consider the broader question of preferred methodology for the valuation of transport noise and seek to benchmark the values found here against those in other studies and in appraisal practice elsewhere in Europe.

Valuation Methods

A wide range of methods have been used to derive environmental values:

1. Revealed Preference: Hedonic Pricing; Travel Cost Method.
2. Hypothetical Questioning: Contingent Valuation Method; Stated Preference (trade-off) approaches.
3. Other approaches: Shadow Pricing/Opportunity Cost; Mitigation Cost; the Dose Response approach/the Impact Pathway approach.

Annex B (derived from Bristow (2004)) gives a brief, general assessment of the appropriateness of the various valuation methods in the context of land based transport externalities, and noise in particular. Here we focus on methods and on empirical studies where the values derived might be expected to reflect the amenity value of transportation noise to households.

Hedonic Pricing

Hedonic pricing has historically been the preferred method for identifying the costs of transport noise, especially in the context of air transport. The advantage of having a base in actual market choices appears to outweigh the difficulties with the technique (Annex B). The most recent meta-analysis of hedonic pricing 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 from a European perspective may be found in: Bateman *et al* (2001); Howarth *et al* (2001); and Navrud (2002). Bateman *et al* (2001) review 18 studies yielding 28 discount rates for road traffic noise with an average of 0.55%. The majority of the studies they reviewed are North American and none were from the UK. Recent hedonic pricing research in

Europe includes the following studies and discount rates with respect to a 1dB(A) change in noise levels:

- Wilhelmsson (2000) found a discount rate to road traffic noise of 0.6% in Stockholm.
- Lake *et al* (2000) found a discount rate of 0.202% for road traffic noise in Glasgow.
- Rich and Nielsen (2002) in a study of Copenhagen found a discount rate of 0.54% for houses and 0.47% for apartments, using a 50dB(A) cut-off.
- Bjorner *et al* (2003) in Copenhagen found a price change of 0.47% assuming a 55dB(A) cut-off.

The Birmingham study (Bateman *et al*, 2004) finds a range for road traffic noise from 0.21% to 0.61% of house price depending on model form and market segment which is more in line with recent European evidence than the Glasgow study.

Hypothetical Questioning Methods

There are very few studies applying Stated Preference (SP) techniques to changes in traffic noise and even fewer where the values derived are related to an objective measure of noise. Table 1 includes both SP and Contingent Valuation Method (CVM) studies which explored willingness to pay for a 50% change in noise levels. To obtain values per dB(A) we first report estimates based on the assumption made by Navrud (2004) of the equivalence between a 50% change in noise and an 8 dB(A) change in noise. Subsequently, and reported in brackets in Table 1, we apply a more conventional assumption that a perceived doubling or halving equates to a 10 dB(A) change in noise levels. The value for the Arsenio *et al* study is directly estimated to an objective noise measure. Interestingly, the CVM noise values of Pommerehne (1988) and Soguel (1994) are more in line with those found in the SP studies. The Soguel study applied iterative CVM and so is expected to give a higher value than an open ended CVM. The survey used by Pommerehne offered a move to a neighbouring street where noise levels were halved, which is a highly realistic scenario. In adjusting the values for comparability the assumption has been made that values grow in line with GDP and this may have inflated values from early studies such as that by Pommerehne.

Table 1: Road Traffic Noise: Willingness to Pay per dB(A) per Household per Year in 2001 €

Author	Method	Location and study year	Value
Pommerehne*, 1988	CVM	Basel, Switzerland, 1988	99 (79)
Soguel*, 1994	CVM	Neuchâtel, Switzerland, 1993	60-71 (48-57)
Saelinsminde, 1999	SP	Oslo and Akershus, Norway, 1993	48-96 (39-77)
Thune-Larsen*, 1995	CVM	Oslo and Ullensaker, Norway, 1994	19 (15)
Wardman and Bristow, 2004	SP	Edinburgh, Scotland, 1996	37-55 (30-44)
Arsenio *et al.,* in press	SP	Lisbon, Portugal, 2001	55

*From Navrud 2004.

Table 2 is adapted from Navrud (2004) and contains values from CVM and SP studies (mostly CVM). The values here are less consistent and some of the CVM studies have values which are unbelievably low.

Table 2: Values for Road Traffic Noise from Studies using Stated Preference or Contingent Valuation.

Author and year of publication	Country	€ per dB(A) per household per year (2001 €)
Pommerehne, 1988	Switzerland	99
Soguel, 1994	Switzerland	65.5
Saelensminde and Hammer, 1994, Saelinsminde, 1999	Norway	72
Wibe, 1995	Sweden	28
Vainio, 1995 and 2001	Finland	7.5
Thune-Larsen, 1995	Norway	19
Navrud, 1997	Norway	2
Navrud, 2000	Norway	27.5
Arsenio *et al*, 2002	Portugal	23.5
Barreiro *et al*, 2000	Spain	2.5
Lambert *et al*, 2001	France	7
Mean		32.1
Median		23.5

Source: Navrud 2004.

The values from the Birmingham Technical Report for the 50th percentile range from €50.27 at 55dB(A) to €144.24 at 80dB(A) (at 2001 prices). When compared to the studies reported in Table 1, the SP studies, the Soguel and Pommerehne CVM studies and the Bateman *et al* study have produced values which are broadly comparable across studies.

Influential Variables

The willingness to pay for reductions in noise varies according to a wide range of variables relating to individuals' perceptions of noise and the related annoyance; their exposure to noise; income; socio-economic and area effects; and the time of day and day of the week. There is a reasonable amount of evidence on income effects and variables relating to household circumstances, less on variation by time of day and day of the week. Work by Carlsson *et al* (2004) and Bristow and Wardman (forthcoming) suggests that willingness to pay does vary by time of day in the context of aircraft noise.

Relating willingness to pay to annoyance levels: WTP for noise reductions is expected to be related to annoyance caused by the noise. We note that a recent paper by Bjorner (2004) contains values for the removal of traffic noise annoyance for respondents reporting different levels of annoyance on a five point scale. The range is wide, from €45 per year for those not annoyed to €361 for those who are extremely annoyed. Preliminary results in analyzing stated preference data by Bristow and Wardman (2005) find that those who were extremely or very annoyed by aircraft noise were willing to pay more to reduce it than those who reported moderate or slight levels of annoyance, who were in turn willing to pay more than those who were not annoyed.

Hedonic pricing models cannot identify the impact of a complete set of policy relevant variables. Nor can they directly identify willingness to pay or accept compensation for changes from the steady state examined. There is a strong case for the use of Stated Preference methods to explore these issues.

Values used in Appraisal in Europe

A review of transport appraisal practice in the EU in 1998 (Bristow and Nellthorp 2000) found that 6 of the 15 countries placed a monetary value on noise. A recent update of this work for the HEATCO project (Odgaard *et al*, 2005) which reviewed practice in the EU 25 (plus Switzerland, but excluding Luxembourg) identified 13 countries which apply a value to noise in appraisal of which 8 are from the original 15 (Austria, Denmark, Finland, France, Netherlands, Sweden and Switzerland) and 5 are new entrants (Czech Republic, Hungary, Lithuania, Poland and Slovenia). Of the remaining countries 9 include noise in quantitative or qualitative ways and 3 either do not include noise or information is not available.

All the countries that place a monetary value on noise include annoyance in the values used and 5 additionally include health effects. For all those countries where information is available at this level of detail (11) annoyance as experienced in the home is included and 6 countries include annoyance experienced elsewhere.

12 of the 13 countries base their values on evidence from hedonic pricing studies (Austria uses both HP and SP/CVM and Germany a CVM study). Further detail on methodology for selected countries may be found in Annex A.

It is clear that:
- There is a growing European consensus on the monetary valuation of noise;
- Where noise is valued, annoyance at home is the priority;

- The vast majority of countries that value noise based their values on hedonic pricing studies;
- Some countries include health effects and impacts at other locations in the value of noise;
- Evidence in Annex A also shows that for a sub-sample of countries where more detail on the underlying valuation process is available: rail noise tends to be treated as less annoying than road noise usually by 5dB(A); a cut-off level beyond which noise is not valued is common and is typically 55dB(A) although Germany and Sweden have lower cutoffs; and
- In most cases the marginal value of noise increases with the noise level.

2.3 Conclusions

This section has reviewed the Birmingham study as a hedonic pricing study, explored the justification for the approach and looked at how the values compare with those found elsewhere. We conclude:

1. The study is a valuable contribution to the literature on the valuation of transport noise.
2. The study is ambitious, particularly in its use of the second stage hedonic model, and the critique above should be read in that context – this study is at least as robust as other recent research.
3. The study produces values which when benchmarked against other values appear wholly reasonable.
4. It provides a starting point for valuing noise in specific circumstances – these are:
    - residential noise
    - in urban areas and potentially in other areas where the noise level is 45dB(A) or above.
5. The values represent amenity value only, although the values may also be capturing a basket of local environmental effects for which noise is a proxy.
6. The benchmarking exercise highlights the following research gaps that, if addressed, could strengthen the basis of and increase the scope of the values available for use in appraisal:
    - exploration of values for health effects of noise based on impact pathway approaches;
    - exploration of values for non-residential contexts, where the most promising method is SP;
    - exploration of the separate values of noise and other local environmental effects;
    - exploration of the differences in values between road noise, rail noise and aircraft noise, using comparable data and methods;

- exploration of values for noise environments below 45dB(A) and in non-urban settings;
- research using SP and RP methods within the same study, where SP methods can be used for segmentation.

3. Benefit transfer and integration with the appraisal process

If the results of the Birmingham study are to be used in transport appraisals throughout the UK, then it is necessary to find a way of transferring Birmingham local study area results to a national context, and to the present day and to future points in time. It is also necessary to consider how the resulting monetary values will be integrated with the measurement, prediction and appraisal of transport noise changes. The purpose of this section is to address these aspects.

3.1 Context

We begin by briefly describing the city of Birmingham in terms of its population and the recent development of its property market. We also describe how the Birmingham local authority area studied by Bateman *et al* (2004) relates to the Birmingham city region as a whole, within the NUTS statistical system. This is partly for the information of those unfamiliar with the Birmingham context, and partly to establish some necessary background for the analysis.

Birmingham is at the centre of the UK's second most populous city region (Table 3).

Table 3: UK city regions by population

UK city regions:	Population (2001)
Greater London	7,172,000
West Midlands (Birmingham)	2,554,000
Greater Manchester	2,482,000
Strathclyde (Glasgow)	≈ 2,400,000
West Yorkshire (Leeds)	2,079,000
Merseyside (Liverpool)	1,362,000
South Yorkshire (Sheffield)	1,266,000
Tyne and Wear (Newcastle)	1,076,000
Bristol	≈ 980,000
Lothian (Edinburgh)	779,000

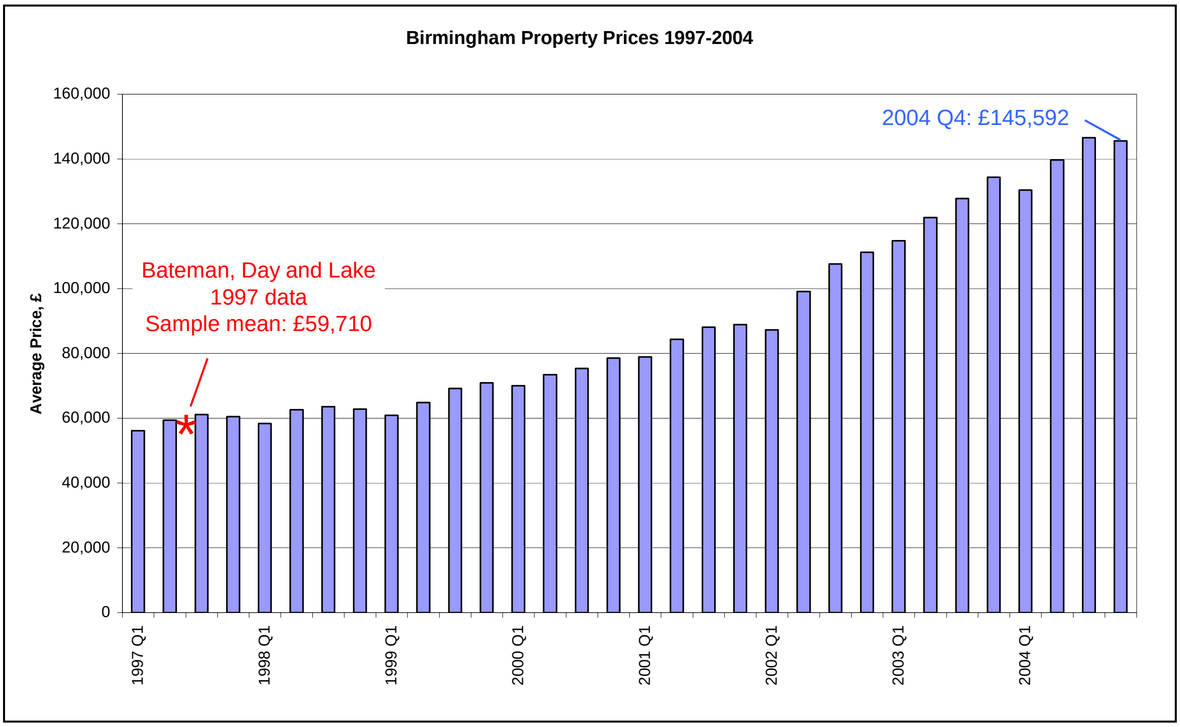
Source: Office of National Statistics (2005), 2001 Census.

'Birmingham' itself is a NUTS3 area, defined by the Birmingham City Council local authority boundary. The population of this Birmingham NUTS3 area, which is the basis of Bateman *et al*'s property market data, was 976,000 at the 2001 census (ONS, 2004). Birmingham lies within a heavily-urbanised NUTS2 sub-region called the 'West Midlands', which comprises Birmingham, Solihull, Coventry, Dudley and Sandwell, Walsall and Wolverhampton. This NUTS2 sub-region is also known as the West Midlands Metropolitan County, and has a population of just over 2.5 million, as shown in Table 3. Finally, there is a larger English region known as the 'West Midlands' (a NUTS1 region) which also includes rural and semi-rural areas of Herefordshire, Worcestershire, Warwickshire, Shropshire and Staffordshire. The population of the NUTS1 region is 5.3 million. The fact that the 'West Midlands'

NUTS1 region and NUTS2 sub-region bear the same name is a potential source of confusion, something to bear in mind when using statistics for this part of the UK.

Since 1997, the UK property market has risen dramatically, Birmingham included. Figure 2 shows that during the calendar year 1997, Bateman *et al*'s sample mean of £59,710[4] was close to the mean Birmingham property price of £59,308[5]. By the final quarter of 2004, the mean property price in Birmingham had risen to almost 2.5 times that level. This raises an issue – not one that we can offer a definitive answer to at this time: what is the time-series elasticity of values of transport noise with respect to property prices? This remains an issue of context, however, rather than a central issue in this exercise, as long as something other than property price is used as the basis for transferring noise values between localities, and between different years.

Figure 2: House prices in Birmingham since 1997



Source: Land Registry data.

3.2 Benefit transfer

To begin, we understand that the Department for Transport's requirements for its advice on appraisal values are the following:

1. Willingness-to-pay (WTP) for changes in surface transport noise, at 2002 prices and values, £ per dB(A) L_{eq} per household per annum[6].
2. Forecast growth in values of noise, 2002 to 2061 and beyond.

[4] Bateman, Day and Lake (2004)
[5] Data from the Land Registry, based on all residential property transactions that year.
[6] The noise metric will be dB(A) $L_{eq\ 18hour}$. The base year of 2002 is consistent with DfT's most recent TAG advice on valuation of travel time savings and vehicle operating cost (TAG Unit 3.5.6, DfT, December 2004a).

3. Variation in WTP by noise level.
4. For specific applications, variation in WTP by household income.

The third item – differentiation of noise values by noise level – is important because the evidence shows that this is a substantial source of variation in WTP. This is true of Bateman *et al*'s findings (2004, Tables 5.9-5.12) and of the European evidence discussed in Section 2. As an aside, this information may also be of use to District Valuers in calculating compensation at the individual property for changes in transport-related noise.

The fourth item would be needed for applications where a 'local value' of noise was required rather than a standard UK value. For comparison, 'local values' of travel time have been used in evaluating the M6(T) toll motorway and the Crossrail underground rail connection in London, where it was judged that the UK value would give seriously misleading results. Local values would also be preferred in cases where a distributional analysis was being undertaken, and hence pure WTP was the required basis for the impact values (DfT, 2004b, Section 1.9).

In transferring the values from Birmingham in 1997 to other sites in the UK in 2005 or any future year, we will require methods for transfer:

- across locations;
- over time;
- across tenure categories – this may require additional evidence or assumptions since the Birmingham results are based solely on owner-occupier property transactions;
- across modes of transport – given that the Birmingham results for road and rail raise questions in the light of the other European evidence (see Section 2.1), a way forward is needed.

In the following sections we address each of these aspects, finally reaching some provisional recommendations on the approach to valuation of noise in transport appraisal in the UK.

Transfer between Birmingham and other locations

As in the other European countries cited in Section 2, DfT believe it would be of practical value to have a set of noise values 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 the valuation of other benefits and disbenefits of transport interventions in the UK, and in many other European countries (see Section 2).

In addition to these UK standard values, there will 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.

How are these spatial benefit transfers from Birmingham to the UK and from Birmingham to other localities to be achieved? The answer is, in general, by using the evidence on noise valuation. There are two broad options, and within the first of these some more detailed options, for these transfers across space:

(i) using household income;

(ii) using 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 (Section 2.1). There we concluded that in view of the evidence, a simplifying assumption that the income elasticity is equal to one is reasonable at this time. The evidence from particular studies, showing cross-sectional elasticities in the range 0.5 to 0.9, 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 in appraisal. However, an overriding requirement for the Department for Transport is simplicity in the appraisal guidance. Bearing in mind that the effect on the values is small[7], a judgement was made in agreement with DfT to recommend a cross-sectional elasticity of 1.0 for the time being. This is an issue on which future valuation research will hopefully shed more light, as it has done for the value of time.

The data on household income at a local level is available in two different forms. One is Total Household Income, defined to include all types of household income including property income, pensions and social security benefits as well as earned income / wages. The other is Gross Disposable Household income, defined as Total Household Income less 'Uses' which include income tax, council tax and rates (local property taxes) and vehicle excise duty, plus social security contributions, property expenditures (mostly mortgages on owner-occupied houses) and insurance premiums paid. Thus Total Household Income is a pre-tax and benefits measure, whilst Gross Disposable Household Income is a post-tax and benefits measure. Table 4 shows the household income relativity between Birmingham and the UK mean, based on each of these two measures. The dispersion of incomes is, as you might expect, narrower after ‘redistribution’ than before.

[7] In the 55-56dB(A) interval, the implied UK value is £34.80 with an elasticity of 1.0 versus £32.50 with an elasticity of 0.5.

Table 4: Household income in Birmingham and the West Midlands, 1997 £ and Index

	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
Great Britain	14,339	101	8,417	88

Source: ONS (2002); ITS analysis.

If the cross-sectional elasticity of noise values with respect to income is 1.0, then that 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**1.205 per dB(A) per household per annum, on the basis of Total Household Income. Alternatively the UK value would be £*x**1.149 per dB(A) per household per annum, on the basis of Gross Disposable Household Income.

It seems reasonable to assume that individuals form their judgements about expenditure – including WTP for peace and quiet – on the basis of their disposable rather than their gross incomes. Hence we prefer the Gross Disposable Household Income basis and the factor of 1.149 for present purposes[8].

A variation on the above approach[9] would be to use the percentiles on the expenditure distribution in the Birmingham model[10] to relate WTP in another location to WTP by a particular income percentile in Birmingham. The main difficulty in practice with this option, is that the shapes of income distributions vary from place to place, as does the mix of private and public housing – the latter being absent from Bateman *et al*'s data. Furthermore, adequate income distribution data[11] is not available at the same spatial level as the mean income data in Table 4. These factors together make it riskier to draw a link between the variation of values derived in Birmingham and the possible variation of the values with income in another local area in the UK. The transfer based on mean income is simpler and in that sense more transparent.

An alternative approach, (ii), to transferring values between Birmingham and the UK using household income, 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

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[8] If the cross-sectional elasticity of noise values with respect to income was in fact 0.5, then that would imply noise values on a UK 1997 basis of £*x**1.075 per dB(A) per household per annum, given variations between Birmingham and the UK in Gross Disposable Household Income.
[9] suggested by Bateman *et al* (2004, p160).
[10] see Annexes D and E.
[11] percentiles on the GDHI distribution.

Birmingham values would be 1.283, since UK mean house price in 1997 was £76,100 versus £59,308 in Birmingham. However, as Figure 2 made clear, house prices are quite volatile even over short periods of time, especially at the regional and local level, meanwhile as Bateman *et al* observe[12] 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, we contend that household income is preferable to property price as a basis for benefit transfers across UK localities.

Transfer between 1997 and 2002

Benefit transfers across time have been the subject of recent work by Nellthorp *et al* (2001) and Hunt (2005) 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, 2004a, 1.2.21; Highways Agency *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 (see Section 2 above), therefore it is necessary to rely on theoretical arguments and comparisons with other cost-benefit items. As Bateman *et al* (2004, p159/60) observe, property price enters the demand equation for peace and quiet in the Birmingham model, such that if this demand equation was taken at face value as an inter-temporal function, the WTP value for noise changes would be £20 per dB(A) per household per annum greater in 2004 than in 1997. The authors comment that this is 'unrealistic'[ally high].

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)[13] 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[14]. 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

[12] p160.
[13] and by £13 at 70dB(A).
[14] See Mackie *et al* (2003).

items to be non-decreasing, in other words GDP per household elasticity ≥1.0. In view of the evidence on the cross-sectional elasticity (≤1.0) and on a note of caution whilst noise values are new to appraisal, we propose to adopt a time-series elasticity of 1.0 as an interim measure.

The data on which the transfer would be based are given in Table 5.

Table 5: UK GDP per household, 1997 and 2002 (components)

Year	UK GDP index at 2001 market prices, 2001=100	UK Consumer Price Index (CPI), 1996=100	Households, Index 1997=100
1997	88.8	101.8	100.0
1998	91.5	103.4	
1999	94.1	104.8	
2000	97.8	105.6	
2001	100	106.9	
2002	101.8	108.3	104.7
2003	104	109.8	
Series code:	YBEZ	CHVJ	

Notes: Series code is for UK National Accounts data; UK CPI is identical to the European HICP index of consumer prices.
Sources: *Economic Trends Annual Supplement, No. 30*, ONS (2004a); TEMPRO data supplied by DfT.

By combining the three components of real GDP, consumer price inflation and growth in the number of households, the implied factor to transfer 1997 values to 2002 values is equal to 1.165.

Adjustment for household tenure

In the Birmingham study, the sample includes residential property transactions but not council rented, other social rented or 'lived rent free' households. The study does include both owner-occupier and buy-to-let properties, since these types could not be distinguished using the data, hence it includes the private rented sector although with certain assumptions about the characteristics of the purchasers and residents (Bateman *et al* discuss this on p135). The study also excludes first-time 'right-to-buys' of council properties – these were excluded on the ground that they would not reflect the full market price[15].

Depending upon the size of the 'lived rent free' group, it seems likely that the tenure types included in the study account for at most 72% of the households in Birmingham, and at most 81% of households in the UK (Table 6). The remainder – in the social rented sector – are likely to include some of the poorest households, and to have on average a lower income than the groups which are included.

[15] See Bateman *et al* (2004), p16.

Table 6: Tenure

Tenure	% of households	
	Birmingham	England and Wales
Owner occupied	60.4	68.9
Rented from Council	19.4	13.2
Rented from Housing Association or Registered Social Landlord	8.4	6
Private rented or lived rent free	11.8	11.9

Source: Office of National Statistics, 2001 Census

Initially, a judgement was made that there was insufficient evidence on which to base an estimate of WTP for peace and quiet in the social rented sector. However, at the Seminar in May 2005 we were encouraged to make 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. Annex G describes the analysis, including the data and assumptions used.

The outcome of the analysis of household tenure was an downward adjustment of the monetary values by approximately 17.5% (see Annex G, Table G5), to reflect the WTP of an average household across all tenure types. It is the adjusted values which are given in this report.

Modes of transport

The evidence indicates that over a substantial part of the noise range, the difference between the rail and road value is not statistically significant – i.e. the hypothesis that they are the same cannot be rejected (Bateman *et al*, 2004, p156). Furthermore, the European evidence indicates that values of rail noise tend to be lower than road noise, whilst the Birmingham results suggest the opposite (Section 2). The Birmingham sample size for road is much larger than for rail (2,723 versus 379), and the sample sizes for rail in some submarkets are low for this type of model (15 observations for submarket 6, 27 observations for submarket 1, between 40 and 55 observations for all but two other submarkets). This gives rise to some concern over the use of the rail results as mode-specific noise values (reproduced in Annex C, right-hand column), or as part of the 'Combined' values (reproduced below in Annex F). An additional concern with the 'Combined' values is that unlike the underlying modal values, these are not strictly increasing with the noise level over the full range of noise levels, which is probably a consequence of the bootstrapping procedure by which they are derived.

In view of these concerns, our recommended way forward is to adopt the Road values (reproduced in Annex C) as the basis for benefit transfers, since these are based on a large sample size and are free from the concerns given above. Whilst some other European countries adopt an adjustment to noise levels so that rail noise is effectively valued lower than road, we would suggest caution in the light of the contrary Birmingham results. As an interim position, pending further evidence, we would suggest adopting the Birmingham road noise values as a general value for surface transport in the UK. We can envisage situations where the rationale for more differentiated values would be strong – e.g. High Speed Rail, heavy freight trains, and perhaps even on-street tram systems in urban areas. However, we suggest that any adjustment to the values be carried out on a case-by-case by basis, based on appropriate evidence, which should be properly cited in the appraisal.

Differences in the level of noise

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). This is shown in Annexes C-E below, reproduced from the Birmingham study report, for the range 55-80dB(A). The extension from 55dB(A) to 45dB(A) is based on additional results supplied by the UEA modelling team who undertook the Birmingham study (see Section 2 above). The *gradient* of the values (i.e. the increase in the marginal value from one dB(A) to the next) is constant across the range.

For reasons of practicality in appraisal, DfT may wish to simplify the value set somewhat, as have other European governments. Some, including Sweden, France and Denmark, have opted for a 5dB(A) interval banding of values. Others have adopted uniform values, which are not recommended here in view of the clear evidence of increasing marginal values with the noise level in Birmingham and other research studies (see Section 2).

Hence the values given in Table 7, which are based on the mean Road values from Birmingham[16], transferred to a UK basis, and from 1997 to 2002 prices and values, could be regarded as 'Standard' values for the UK. These have been derived by taking the Birmingham values for road noise (Annex C), transferring to a UK basis as above (factor of 1.149) and transferring from 1997 to 2002 (factor of 1.165). The values have also been adjusted to take account of the social rented housing sector (Annex G).

Table 7: UK-based values for transport-related noise at 2002 prices and values, £

Noise Change in the Interval, dB(A)		£ 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
Low	High		
<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

[16] Bateman *et al* (2004), Table 5.9. Values per person based on the recorded household size of 2.46 for Birmingham at the 2001 Census.

Values at a finer resolution are given in Annex H, Table H1. DfT's new TAG Noise spreadsheet, associated with the revised WebTAG Unit 3.3.2, will make use of these values – being automated there is no disadvantage in having a different value for each 1dB(A) interval. Note also that in the TAG Noise spreadsheet the noise data is grouped into 3dB(A) bands, hence in practice the values are applied to changes between 3dB(A) bands, rather than to all changes as small as 1dB(A). If the data permits, even more accurate results might be obtained by applying the values in Annex H to data at 1dB(A) resolution, however that will not be a requirement given the additional work involved and the apparently small gain in accuracy.

For comparison with the European values given in Section 2, we can convert these results to 2002 € at purchasing power parity using the OECD Purchasing Power Parity exchange rate of 0.706638£/€.

Table 8: UK-based values for transport-related noise at 2002 prices and values, expressed in € at purchasing power parity

Noise Change in the Interval, dB(A)		€ 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
Low	High		
<45		0.0	0.0
45	50	19.4	8.2
50	55	38.0	16.1
55	60	56.7	24.0
60	65	75.3	31.9
65	70	94.0	39.8
70	75	112.6	47.7
75	80	131.3	55.6
>80		138.7	58.8

Noise changes in quieter areas, below 45dB(A), will continue to be reported qualitatively in the appraisal (see below, and Highways Agency *et al,* 1994), but will not be subject to monetary valuation, based on the evidence available.

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. The case for taking this step depends on more general transport appraisal and Treasury Green Book principles, i.e. the choice between standard values and pure WTP values in appraisal.

In order to do this, the following look-up table may be helpful (Table 9), combined with the formula: **Local value = UK value * (1+((GDHI$_{local}$-100)*E/100))** where E is the cross-sectional elasticity with respect to Gross Disposable Household Income[17].

[17] Note that the most relevant GDHI data available is for the period 1997-99. Although the base year for the Bateman *et al* values is 1997 specifically, we assume that GDHI moves sufficiently slowly for the 1997-99 data to be used as a proxy.

Table 9: Gross Disposable Household Income by NUTS 0, 1, 2 and 3 areas of the UK

Country / NUTS 1 / NUTS 2 / NUTS 3	£ per Head (UK=100) 3 year average 1997-1999
United Kingdom	100
England	102
North East	89
Tees Valley and Durham	89
Hartlepool and Stockton-on-Tees	89
South Teesside	86
Darlington	89
Durham CC	90
Northumberland and Tyne and Wear	89
Northumberland	96
Tyneside	90
Sunderland	82
North West	93
Cumbria	94
West Cumbria	85
East Cumbria	101
Cheshire	103
Halton and Warrington	96
Cheshire CC	106
Greater Manchester	92
Greater Manchester South	93
Greater Manchester North	91
Lancashire	91
Blackburn With Darwen	83
Blackpool	89
Lancashire CC	92
Merseyside	92
East Merseyside	79
Liverpool	83
Sefton	110
Wirral	101
Yorkshire and the Humber	93
East Riding and North Lincolnshire	91
Kingston upon Hull, City of	81
East Riding of Yorkshire	99
North and North East Lincolnshire	93
North Yorkshire	107
York	105
North Yorkshire CC	107
South Yorkshire	87
Barnsley, Doncaster and Rotherham	85
Sheffield	91
West Yorkshire	92
Bradford	86
Leeds	97
Calderdale, Kirklees and Wakefield	90
East Midlands	93
Derbyshire and Nottinghamshire	90
Derby	90
East Derbyshire	81
South and West Derbyshire	92
Nottingham	81
North Nottinghamshire	88
South Nottinghamshire	102
Leicestershire, Rutland and Northamptonshire	95
Leicester	81
Leicestershire CC and Rutland	99
Northamptonshire	97
Lincolnshire	97
West Midlands	93
Herefordshire, Worcestershire and Warwickshire	100
Herefordshire, County of	94
Worcestershire	101
Warwickshire	102
Shropshire and Staffordshire	95
Telford and Wrekin	96
Shropshire CC	97
Stoke-on-Trent	83
Staffordshire CC	97
West Midlands	88
Birmingham	87
Solihull	106
Coventry	88
Dudley and Sandwell	86
Walsall and Wolverhampton	89
East	105
East Anglia	97
Peterborough	101
Cambridgeshire CC	103
Norfolk	94
Suffolk	95
Bedfordshire and Hertfordshire	113
Luton	88
Bedfordshire CC	111
Hertfordshire	118
Essex	108
Southend-on-Sea	99
Thurrock	99
Essex CC	110
London	121
Inner London	127
Inner London - West	164
Inner London - East	106
Outer London	117
Outer London - East and North East	112
Outer London - South	120
Outer London - West and North West	119
South East	110
Berkshire, Buckinghamshire and Oxfordshire	115
Berkshire	116
Milton Keynes	98
Buckinghamshire CC	120
Oxfordshire	114
Surrey, East and West Sussex	118
Brighton and Hove	105
East Sussex CC	103
Surrey	131
West Sussex	114
Hampshire and Isle of Wight	101
Portsmouth	87
Southampton	88
Hampshire CC	107
Isle of Wight	89
Kent	101
Medway	99
Kent CC	101

Continued overleaf

Table 9: Gross Disposable Household Income by NUTS 0, 1, 2 and 3 areas of the UK (cont'd)

Country / NUTS 1 / NUTS 2 / NUTS 3	£ per Head (UK=100) 3 year average 1997-1999	Country / NUTS 1 / NUTS 2 / NUTS 3	£ per Head (UK=100) 3 year average 1997-1999
South West	100	**Scotland**	95
Gloucestershire, Wiltshire and North Somerset	103	North Eastern Scotland	102
Bristol, City of	94	Aberdeen City, Aberdeenshire and North East Moray	102
North and North East Somerset, South Gloucestershire	108	Eastern Scotland	99
Gloucestershire	104	Angus and Dundee City	98
Swindon	103	Clackmannanshire and Fife	91
Wiltshire CC	104	East Lothian and Midlothian	96
Dorset and Somerset	102	Scottish Borders	93
Bournemouth and Poole	102	Edinburgh, City of	113
Dorset CC	105	Falkirk	87
Somerset	99	Perth and Kinross and Stirling	108
Cornwall and Isles of Scilly	90	West Lothian	84
Devon	95	South Western Scotland	92
Plymouth	87	East and West Dunbartonshire, Helensburgh and Lomond	96
Torbay	90	Dumfries and Galloway	94
Devon CC	99	East Ayrshire and North Ayrshire Mainland	84
Wales	88	Glasgow City	87
West Wales and the Valleys	87	Inverclyde, East Renfrewshire and Renfrewshire	101
Isle of Anglesey	95	North Lanarkshire	89
Gwynedd	84	South Ayrshire	93
Conwy and Denbighshire	94	South Lanarkshire	98
South West Wales	86	Highlands and Islands	90
Central Valleys	76	Eilean Siar, Orkney and Shetland Islands	88
Gwent Valleys	86	Rest of Highlands and Islands	90
Bridgend and Neath Port Talbot	92	**Northern Ireland**	88
Swansea	90	Belfast	104
East Wales	90	Outer Belfast	95
Monmouthshire and Newport	92	East of Northern Ireland	90
Cardiff and Vale of Glamorgan	90	North of Northern Ireland	72
Flintshire and Wrexham	92	West and South of Northern Ireland	79
Powys	82		

Sources: *Regional Trends*, ONS (2004b); *Regional, sub-regional and local area household income*, ONS (2002)

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 10) gives the annual growth factors which are implied[18]. In the longer term, from 2032 onwards, the forecast growth in real GDP is adjusted downward following Treasury advice[19] and DfT practice. This adjustment is in proportion to the reduction in the discount rate from 2032 (i.e. from 3.5% to 3.0%). The final column of Table 10 gives the annual % growth in noise values at a 1.0 elasticity with respect to GDP per household. These growth factors are comparable to the growth factors in use for the value of travel time savings, but are based on growth in GDP per household, given the units in which noise values are measured.

Table 10: Forecast Growth in the Working and Non-Working Values of Time

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: TAG Unit 3.5.6, DfT (2004a); TEMPRO data supplied by DfT; 'Value growth adjusment factor' based on HM Treasury (2003), p25, footnote 8.

Summary of steps proposed

It may be helpful to end this section with a summary of the main steps proposed in transferring the Birmingham study results (Bateman *et al,* 2004) to UK appraisals now and in the future:

(i) to transfer the results to a UK mean set of values using a cross-sectional income elasticity of 1.0 and the data on Gross Disposable Household Income.

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[18] Note that these growth factors are shown to 4 decimal places to indicate that, given the data in the previous three columns, they can be calculated to more than two decimal places. The number of decimal places used in these factors may affect the PVB result.

[19] see HM Treasury (2003), p25, footnote 8.

(ii) to bring the values to a price base year of 2002, instead of 1997, for consistency with other values in WebTAG, and that this should be done based on an assumed time-series elasticity of 1.0 and using data on GDP per household over the period 1997-2002.

(iii) to make an adjustment to the values to take account of the social rented housing sector, which was not part of the Birmingham hedonic pricing study. This gives rise to the values shown in Table 7, which differentiate between different noise bands following the evidence of the Birmingham study; the marginal value of noise changes is higher at higher levels of noise.

(iv) that for noise effects arising in any year after 2002, the values would be allowed to grow over time, based on an assumed time-series elasticity of 1.0 and using growth factors based on real GDP per household.

(v) that if an appraisal required the use of local values (as has occurred with the M6 Toll and with Crossrail), then local values for other NUTS1,2 and 3 areas can be derived by applying the cross-sectional elasticity of 1.0 and using the Gross Disposable Household Income data for each location (given in Table 9). A simple formula was provided on p25.

3.3 Integration with noise measurement, prediction and appraisal

In this section we will consider how the noise values derived from the Birmingham study can be integrated with the guidance on noise contained in existing documents. **Note that the 'existing documents' referred to here include the June 2003 version of DfT's noise guidance (TAG Unit 3.3.2). Many of the proposals made here will be adopted in the new 2005 version of TAG Unit 3.3.2, which will be available at: www.webtag.org.uk.**

We will follow the appraisal process step-by-step and will aim to address some of the key issues which arise when putting together the willingness-to-pay approach and the existing methods of noise analysis. The headings in this section are, therefore:

- Existing noise analysis guidance;
- Noise measurement and prediction;
- Human exposure to transport noise;
- Annoyance versus marginal values of noise;
- Housing, other buildings, streets and open spaces;
- Interpolation and extrapolation, and the Present Value of Benefits;
- New guidance.

Existing noise analysis guidance

The existing approach to the analysis of noise for UK transport projects, plans and strategies is set out in the Transport Analysis Guidance, TAG Unit 3.3.2 (DfT, 2003). More specialised advice for road schemes is given in the Design Manual for Roads and Bridges, Volume 11 'Environmental Assessment', Section 3, Part 7 (Highways Agency *et al*, 1994). The advice for railways contained in the SRA Appraisal Criteria (SRA, 2003) is less detailed, therefore we will focus on TAG (for road and rail) and DMRB (for roads). The underlying measurement and prediction methods for road and rail noise rely on techniques set out in two documents issued by the former Department of Transport, *Calculation of Road Traffic Noise* (CRTN) and *Calculation of Rail Noise* (CRN) (DoT,1988; DoT, 1995), and on other sources listed in the existing TAG advice document (DfT, 2003).

Note that the existing guidance in TAG focuses on surface transport; noise from aircraft is not explicitly addressed. Air traffic noise is, however, under investigation in an ongoing stated preference study for the Department. The aim of that work is to obtain monetary values for aircraft noise for use in appraisal, and for those values as well as the Birmingham-derived values to appear in TAG.

Noise measurement and prediction

The first step in the process is to measure and predict noise levels in the Do-Something and Do-Minimum situations[20]. The depth and detail of the methods used varies according to the stage in the planning process. For road schemes the "noise and vibration assessment becomes increasingly detailed as a scheme develops"[21]; and for transport 'Plans' the method is more detailed than for 'Strategies':

- for a transport 'Plan' which contains fully-specified projects, and for fully-developed road schemes (DMRB 'Stage 3' appraisal), noise contour maps should be based on a spatially-detailed traffic model representing specific links and nodes in the network;
- for a transport 'Strategy', or for early-stages road schemes which are represented by 'broadly defined routes or corridors' (DMRB 'Stage 1' appraisal), models will be coarser and more approximate methods will be used. For example, TAG recommends calculating average emissions within each model zone using CRTN and CRN, which at the next step are combined with zonal average population densities to approximate noise exposure.

We do not envisage that methods for noise measurement and prediction will need to change substantially as a result of the adoption of noise values. However, there are some caveats that may be worth mentioning:

- The proposal is for noise values to be expressed in £ per $dB(A)L_{eq}$, where $dB(A)L_{eq}$ is the current unit of measurement for rail projects, but not for road. To make the appraisal results more consistent and so clearer for decision-makers, it may be better to map all changes in transport noise using dBL_{Aeq}. The approximate conversion is: $dB(A)L_{eq\ 18hr} = dB(A)L_{10\ 18hr} - 3$.
- Given that the values are available for intervals of 1dB(A) (Annex H) and that these values can easily be combined to give values for larger intervals, there is a great deal of flexibility over the noise bands (in noise exposure data) to which the values can be applied. This may also be an opportunity to rationalise the noise bands used in appraisal – for example to 3dB bands.

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20 See DfT (2003) Paragraphs 1.4.1-1.4.2(i) for Plans and 1.5.1-1.5.2 for Strategies; and DMRB 11.3.7 Chapter 2 'Traffic Noise', Paragraphs 5.1-5.9 and Chapter 8 'Stages in the Assessment of Noise and Vibration Impacts'.

21 DMRB 11.3.7 Paragraph 8.1.

- Finally, noise maps and data should aim to cover the range 45-80 dB(A) wherever possible, to allow the full range of values *by noise level* to be applied.

Human exposure to transport noise

The next step in the process is to calculate noise exposure in the Do-Something and Do-Minimum situations[22]. This is a measure of the number of households affected by different levels of noise. Note that the duration of exposure has already been taken into account, to some extent, through the use of the 18 hour L_{eq} measure to bring different types of noise occurring at different times of day to a common unit of measurement[23]. This also has the effect of flattening any variation during the day since it is an average measure.

At present (DfT, 2003) the appraisal guidance requires that the exposed population within the noise contours should be estimated using the latest available Census data[24]. The proposal here is to work with households as the unit to which values are applied.

The difference in the unit of exposure between DMRB (for roads) and TAG (the multi-modal guidance) has already been acknowledged in TAG (DfT, 2003), Section 2.2. Whereas DMRB counts the number of properties exposed, the existing TAG guidance (DfT, 2003) counts the population exposed. It is perhaps worth reiterating that we propose to use the number of households exposed as the basic unit in future, and worth noting that for conversion between population and households, data on average household size is available for each Local Authority Area in England and Wales and each Council Area in Scotland (both equivalent to NUTS3) in official statistics from the 2001 Census[25]. Household sizes are generally declining in the UK. In 2001 the average household size in England and Wales was 2.36, with a range from 1.58 (City of London) to 2.64 (London Borough of Newham). In Scotland, the average household size is 2.27, with a range of 2.08 (Glasgow City) to 2.54 (East Renfrewshire) by council area.

It is worth noting also that by focusing on households, these data implicitly focus on noise exposure at residences. This is consistent with the approach taken in the Birmingham study (Bateman *et al,* 2004), which also focuses on noise exposure at residences. The wider questions of exposure at non-residential buildings, and on

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[22] See DfT (2003) Paragraph 1.4.2(ii) for Plans and 1.5.3-1.5.4(ii) for Strategies; and DMRB 11.3.7 Chapter 8 'Stages in the Assessment of Noise and Vibration Impacts'.

[23] although the measure is really being applied to household locations, rather than to the people who live there, so if a Strategy leads to people spending more time in noisier (or quieter) locations away from the home then we might want to consider whether and how to take that into account.

[24] This is the case for detailed and specific Plans (DfT,2003, Paragraph 1.4.2(ii)). For broad-brush Strategies, it is acceptable to use zonal population densities to estimate population exposed (Paragraph 1.5.4(ii)

[25] ONS (2005), National Statistics online Census 2001 pages: http://www.statistics.gov.uk/census2001/ ; and General Register Office for Scotland (2003), *Key Statistics for Council Areas and Health Board Areas Scotland,* Table KS19 'Rooms, amenities, central heating and lowest floor level': http://www.gro-scotland.gov.uk/files/key_stats_chareas.pdf

streets and in open spaces, are taken up by DMRB[26] for roads, and elsewhere in TAG[27]. We will discuss this further below in the section titled *Housing, other buildings, streets and open spaces*.

Annoyance versus marginal values of noise

Having measured and predicted levels of transport noise, and having estimated human exposure to transport noise, the next step is to take the analysis forward to some measure of human impact. This is currently done using the concept of 'annoyance' caused by transport noise, which is recognised by the World Health Organisation and has been defined in surveys by the response 'bothered very much or quite a lot' by transport-related noise[28].

For the individual, annoyance can be been interpreted as a binary variable: one is either annoyed at least 'quite a lot', or one is not annoyed to this degree, by a given level of transport noise. Across the population, the evidence indicates that annoyance responses vary. A body of research, including the Mitchell Committee's research review (DoT, 1991), has led to the adoption of the following annoyance response functions for surface transport noise in the UK (Table 11).

These noise-annoyance relationships are typically applied by multiplying the exposed population by the % annoyed to obtain the number of persons annoyed[29]. The change in the number of persons annoyed, between the Do-Something and Do-Minimum situations, is recorded in the appraisal results[30]. There are some detailed differences of method, however, which are worth mentioning:

- In DMRB (for roads), short-term annoyance effects are considered, as well as the long-term changes from one steady-state to another represented by Table 11. The evidence suggests that in the short term, the change in % of population bothered by an *increase* in traffic noise is a function of the size of the noise increase, and a separate Figure describing this relationship is given for use by analysts[31]. However, these short-term effects are set aside in the general multi-modal appraisal guidance, TAG.
- The TAG advice draws attention to the need for care when there are multiple sources of noise (especially road and rail) and the potential for double counting of annoyance if some of the same properties are affected, but also the possibility that different façades of the same property may be affected[32].

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[26] see for example DMRB 11.3.7 Table 1 (page 8/4), where the noise impacts are shown for Residential properties, Commercial properties, Industrial properties, and Community facilities (including schools, hospitals and open spaces).
[27] See DfT (2003) Section 1.6 and Paragraph 2.2.7; TAG Unit 3.3.7 (DfT, 2004d).
[28] See DfT (2003) Sections 1.1-1.3.
[29] DfT (2003) Paragraph 1.4.2(iii).
[30] DfT (2003) 3.3.2 Paragraphs 1.4.2(iv)-1.4.6.
[31] DMRB 11.3.7 Figure 3.
[32] TAG Unit 3.3.2 Paragraph 1.4.3-4.

Table 11: Annoyance Response Functions for Road and Rail Traffic

Road noise		**Rail noise**	
$L_{Aeq\ 18h}$ dB	% annoyed	$L_{Aeq\ 18h}$ dB	% annoyed
45	4	45	3
46	4	46	4
47	5	47	4
48	5	48	5
49	6	49	6
50	7	50	6
51	7	51	7
52	8	52	8
53	9	53	9
54	10	54	10
55	11	55	11
56	12	56	12
57	13	57	12
58	15	58	13
59	16	59	15
60	18	60	16
61	20	61	17
62	22	62	18
63	24	63	19
64	26	64	21
65	28	65	22
66	31	66	24
67	34	67	25
68	36	68	27
69	39	69	28
70	42	70	30
71	45	71	32
72	48	72	34
73	51	73	36
74	54	74	38
75	57	75	40
76	60	76	42
77	63	77	44
78	65	78	46
79	68	79	48
80	71	80	51

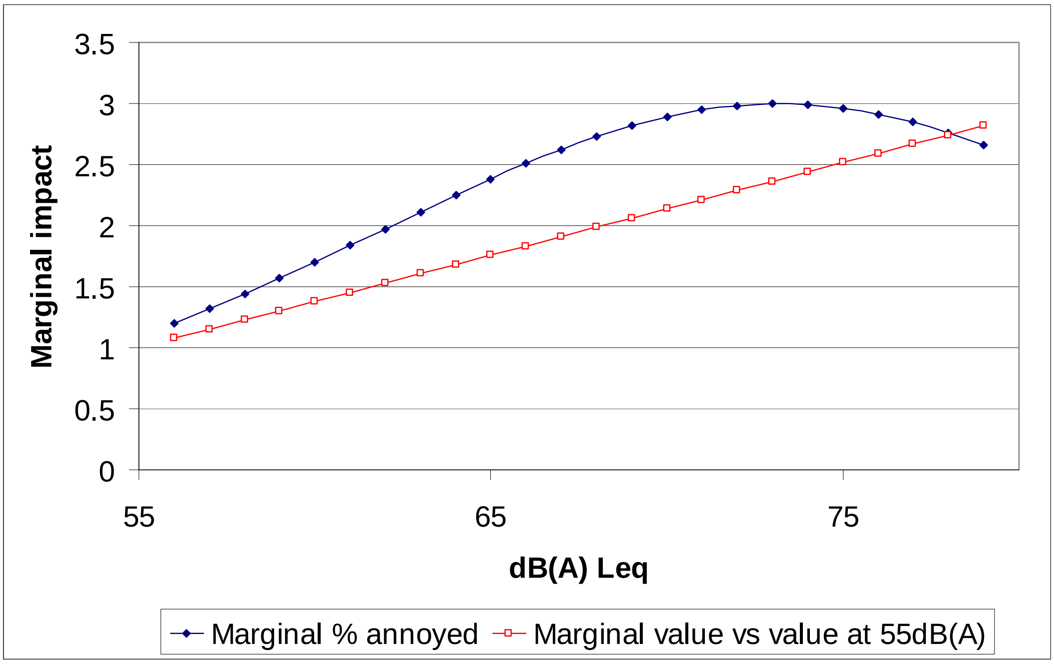
Sources: DfT (2003) Table 1 - Road noise converted to L_{Aeq} using $L_{Aeq\ 18hr} = L_{A10\ 18hr} - 3dB$; Highways Agency *et al* (1994); DfT advice on rail noise annoyance below 55dB.

When we come to apply marginal values of noise derived from the Birmingham study in transport appraisal, it is apparent that *noise exposure measures are needed* as input data – the values are expressed in £ per dB(A) per person (or household) per annum – however *annoyance measures are not required*. Indeed, annoyance and marginal values are, on the face of it, alternative ways of relating noise exposure to human impact.

There are elements of commonality, however. In broad terms, both the annoyance response function set out in TAG (Table 11 above) and the values derived by Bateman *et al* (2004) – if extrapolated back to 45dB(A) – tend toward zero impact around 45dB(A). In addition, both the annoyance response function and the Birmingham values indicate that the marginal impact is then increasing at least up to 73dB(A).

For comparison, in Figure 3 the marginal value function (divided by the value at 55dB(A)) and the marginal % annoyed function have both been plotted against the starting level of noise. The implication seems to be that the shapes of the marginal impact function are somewhat different, as we might expect since the '% annoyed' measure will cease to reflect growing displeasure once a large proportion of the population have already reached the threshold at which they are 'annoyed'. Nevertheless, the similarities observed in Table 11 appear here too.

Figure 3: Marginal Values and Marginal % Annoyed vs Noise Level



Some other European countries have adopted monetary valuation based on the number of persons annoyed, including – we understand – Austria and Norway. Denmark uses a value per seriously annoyed household (equivalent to exposure to a noise level of 75dB(A)) but the value is factored down for households experiencing noise levels between 55 and 74dB(A). The implied marginal value is increasing with noise level. Meanwhile, the majority of countries considered in Section 2.2 have based their methods on a marginal value approach, without going through the step of measuring 'annoyance'.

In view of the evidence on human impact, and the variety of current practice across Europe, we conclude that it would be reasonably consistent for the UK to adopt marginal values based on the Birmingham study for use in cost-benefit analysis of projects, plans and strategies, whilst continuing to use *absolute* measures of 'annoyance' within the appraisal results, where this helps to communicate the findings. For example, in the Appraisal Summary Table which forms part of the UK appraisal results, it would – we suggest – be reasonable to continue to report the % of people annoyed, as part of the 'Quantitative' results, and at the same time report the Present Value of Benefits from noise change in the 'Assessment' column. At present the measure included in the Quantitative part of the table is the 'number of people who are likely to be annoyed in the longer term in the do-minimum scenario and the do-something scenario in the fifteenth year'. We think this continues to be a useful reflection of the underlying noise situation as well as the impact of the intervention.

Housing, other buildings, streets and open spaces

The human costs of noise are not limited to noise experienced at home. This is well put by DMRB: "The World Health Organisation definition of noise nuisance is 'A feeling of displeasure evoked by noise'. The nuisance caused by noise mainly affects people **in their homes** or when they are **in the streets**. However, **areas of open space** that are also used for recreational purposes can also suffer from noise pollution." (DMRB 11.3.7, Paragraph 3.1). This passage could have added noise experienced **at work**, or **at school**, or **in hospital**.

The Birmingham study relates only to noise experienced whilst at home. Noise experienced in other buildings, in the streets and in areas of open space is not addressed. We do not know from this study whether the noise at non-residential locations is valued equally. The amount of time which individuals spend in non-residential locations and the value of peace and quiet during that time are not addressed.

The TAG appraisal guidance for Noise (DfT, 2003) has a similar scope to the Birmingham study – i.e. noise experienced at home – since the assessment of noise exposure seems to be based on resident population[33]. In a separate part of the TAG appraisal (TAG Unit 3.3.7), the assessment of Landscape includes changes in *tranquility* as one of five relevant landscape characteristics. There has recently been work by the Council for the Protection of Rural England and the Countryside Agency to produce 'tranquility maps'[34]. Both the Landscape assessment and the 'tranquility maps' relate to areas with a low background noise level, therefore in principle there seems to be at least some correlation between the areas excluded from the noise values (areas with ambient noise <45dB(A)) and areas included in the Landscape assessment[35]. There may, however, be a case for tightening the definition of tranquil areas so that it specifically relates to all areas below 45dB(A).

This could help to ensure that both urban and rural noise changes are addressed in TAG. Noise values which address noise changes at noisier residential locations can be adopted for the 'Noise' appraisal (DfT, 2003), which already has that focus but lacks monetary valuation. Meanwhile, 'tranquil areas' can continue to be addressed within Landscape[36]. Care will be needed to ensure that suburbs, rural market towns and villages do not fall into a gap between the two. Where these have major transport corridors in the vicinity, the background level of noise may well be greater than

[33] DfT (2003) contains numerous references to 'population' and 'population density' which suggests that resident population will be used in most analyses, although the guidance does not explicitly exclude 'daytime population' – an entirely different basis which would highlight working, education, shopping and recreational uses. TAG also once mentions 'building occupancy databases' as an alternative source of data but does not discuss the practical difference between resident population and 'building occupancy' (DfT,2003, Paragraph 1.4.2(ii)).

[34] Tranquility is defined as "the remoteness and sense of isolation, or lack of it, within the landscape. This can be affected and often determined by the absence or presence of built development and intrusion from traffic" (DfT, 2004d, Paragraph 1.2.10).

[35] There is also a Townscape assessment, which specifically excludes noise.

[36] Section 1.6 of the TAG Noise guidance (DfT, 2003) draws a distinction between 'Quiet areas' and 'occupied buildings'. Quiet areas are to be addressed within Landscape and occupied buildings are to be addressed within Noise. It may be clearer if the distinction was drawn between areas with ambient noise <45dB(A) and ≥45dB(A), or between 'tranquil areas' and 'built-up areas'.

45dB(A); in other cases, even parts of UK cities may be 'tranquil'. Further work may be needed on the definition of 'tranquil areas' to ensure consistency.

Note that noise experienced on street, at work/school/hospital, and in other non-residential buildings is currently not addressed – at least not explicitly – in the TAG method. This is an omission which could be addressed by future research. We note also that most other European countries do not yet attempt to value noise experienced on street, in non-residential buildings or in open spaces, although there are exceptions.

Finally, DMRB (for road schemes) includes a wider-ranging noise assessment, covering all properties and all relevant locations, including sports fields, canals, footpaths, and so on. The results are mapped and reported in terms of the noise level in dB(A) for each location, although the analysis is only carried forward to noise exposure and noise nuisance for residential properties. If ways could be found to value noise experienced on street, in non-residential buildings and in open spaces, DMRB could offer a basis of noise measurement on which to build the analysis.

Interpolation and extrapolation, and the Present Value of Benefits

As with any other component of a cost-benefit analysis in the transport sector, the analysis of noise must address not only a snapshot of future benefits but the whole stream of costs and benefits over the appraisal period – typically the lifetime of the assets created, or an appraisal period of 60 years for most road and rail infrastructure (TAG Unit 3.5.4, DfT, 2004c). Therefore predictions of future noise exposure will be necessary as well as the future values of noise generated using Table 10.

Ideally, forecasts of future noise would be generated for each year in the appraisal period. As with other effects, however, this turns out to be prohibitively expensive and time-consuming in terms of analysis. Noise forecasts will usually rely on future traffic predictions, and those will typically be available for:

- the opening year;
- the last 'forecast year';
- any intermediate 'forecast years' – for example, when a Plan is being appraised which includes two different components coming on line in different years, the second 'opening year' is likely to be modelled.

Using these future traffic levels, noise levels will be predicted using the methods given in CRTN, CRN, DMRB and TAG as discussed above.

It is also possible that the resident population in the affected properties will change over time. The direction of change is hard to predict, since the influences of declining household size and increasing urban density (encouraged by the planning system) will pull in opposite directions. Where there is no firm contrary evidence, a constant exposed population may be assumed. However, where there are grounds to confidently predict changes in the affected residential population – for example, where substantial development land is expected to become available adjacent to transport corridors in areas of high demand – the analysis should consider the implications for exposed population and the assumptions and evidence used should be reported with the appraisal results.

As with other components of the cost-benefit analysis, interpolation and extrapolation will be needed to complete the forecasts for the years between the opening year and the forecast years, and for the years beyond the final forecast year. The approach to this should be consistent with the general advice given in TAG Unit 3.5.4, Section 5.4.

One specific issue that arises is the assumption about traffic growth underlying the noise forecasts. DMRB uses the High traffic growth assumption (Para 8.9), presumably on the precautionary principle, however it would be more consistent with the rest of the CBA if the traffic forecast used to derive the noise level forecasts was in fact the Central or Best Estimate growth forecast. We now understand that this is change is likely to be made in the forthcoming revision to DMRB Volume 11.

Again as with other CBA components, noise (dis)benefits will be subject to a discount rate of 3.5% up to 30 years, falling thereafer (TAG Unit 3.5.4). Hence the Present Value of Benefits for Noise will be the sum of marginal values for the predicted noise change across the exposed population, for each year *t* within the appraisal period, discounted by the relevant discount factor for year *t*.

Guidance

The principal need is for a new section in TAG Unit 3.3.2 on the Valuation of Changes in Transport-Related Noise. This should be applicable to projects, Plans and Strategies, and should cover:

- **stage at which valuation should be attempted** – essentially, under the same conditions as a ‘Stage 3’ DMRB appraisal (that is, for a fully worked-up road scheme) or a ‘Plan’ appraisal (that is, for any fully worked-up package of interventions on any mode) – meanwhile ‘Strategy’ appraisals and early-stages appraisals of specific projects should be continue to be subject to the quantitative approaches set out in TAG Unit 3.3.2 Section 1.5 and DMRB ‘Stage 1 and 2 appraisals’ (DMRB 11.3.7 Chapter 8);
- **method to be adopted** – as outlined in this section;
- **presentation of the results** – using the Appraisal Summary Table, the PVB for Noise (Residential Exposure above 45dB(A)) should be reported in the Assessment column; the PVB for Noise should also be reported in the row headed ‘Noise’ in the Analysis of Monetised Costs and Benefits table (TAG Unit 2.7.1 and 3.5.4); nothing will appear in the Transport Economic Efficiency table or the Public Accounts tables (TAG Unit 2.7.1) which are not concerned with externalities.

Otherwise, the current methods may be retained (subject to the caveats mentioned above) including the Quiet Areas treated as part of Landscape, the assessment of non-residential noise effects in DMRB, and the approaches to noise measurement and prediction as described in DMRB and TAG.

4. Conclusions

The key findings arising from the discussion of robustness, benefit transfer and integration with appraisal methods, are the following:

i. the Birmingham study produces values which when benchmarked against other evidence appear wholly reasonable.

ii. it provides a starting point for valuing noise at residential locations in urban areas and potentially in other locations where the background level of noise is ≥45dB(A).

iii. there is a caveat, that the values may also be partly capturing other local environmental attributes and that this is something that we must acknowledge and accept for now.

iv. in view of the evidence, noise changes below 45dB(A) should be treated in the monetary analysis as having zero value.

v. the values obtained in Birmingham are based on a sample which excluded the social rented housing sector, and an adjustment based on gross disposable household income should be made to take into account these households in assessing the mean value of transport-related noise across the population as a whole.

vi. the noise metric should be dB(A) $L_{eq\ 18hr}$.

vii. the unit of measurement for noise values should be £ per dB(A) per household per annum. Household size data exists, which will allow conversion of noise exposure data between exposed population and number of households exposed, as required.

viii. the relationship between the rail noise value and the road noise value in Bateman *et al* (2004) differs from other European evidence on annoyance, which generally finds that annoyance due to rail noise is slightly lower than for road noise at a given dB(A) level. Given the much smaller sample size for rail – very small in some market segments (<40) – and the presence of insignificant coefficients in the models, the rail values from the Birmingham study should be put on one side, and the road values (with sample size 2,700) should be used as the basis for UK surface transport noise values (road and rail), pending further research.

ix. the values should not be applied to aircraft noise, pending further analysis on UK values of aircraft noise.

x. a time-series elasticity of 1.0 with respect to GDP per household should be used in transferring the Birmingham values forward from 1997 to the base year of 2002.

xi. a cross-sectional elasticity of 1.0 with respect to Gross Disposable Household Income should be used when transferring the Birmingham values to a UK average basis and to specific localities in the UK.

xii. based on these findings, the values shown in Table 7 and Annex H, Table H1 are suitable for use in appraisal.

xiii. growth in values from 2002 forward should adopt a convention similar to that used for working time savings, although based on GDP growth *per household*.

xiv. methods for noise measurement and prediction will not need to change substantially as a result of the adoption of noise values. There is an opportunity to report noise changes using a consistent noise metric (dB(A) $L_{eq\ 18hr}$) across modes, making appraisal results easier to interpret for decision makers.

xv. it would be reasonably consistent for the UK to adopt marginal values based on the Birmingham study for use in cost-benefit analysis, whilst continuing to use *absolute* measures of 'annoyance' within the appraisal results, where this helps to communicate the findings. For example, in the Appraisal Summary Table which forms part of the UK appraisal results, it would – we suggest – be reasonable to continue to report the % of people annoyed, as part of the 'Quantitative' results, and at the same time report the Present Value of Benefits from noise change in the 'Assessment' column. The measure included in the Quantitive part of the table – 'number of people who are likely to be annoyed in the longer term in the do-minimum scenario and the do-something scenario in the fifteenth year' – continues to be a useful reflection of the impact of the intervention as well as the underlying noise situation.

xvi. the current treatment of 'quiet areas' within the Landscape assessment could continue, subject to clarifying the definition of a 'quiet area' and ensuring that suburban areas, market towns and rural villages do not fall into a gap between the monetary analysis of noise and the analysis of impacts on 'quiet areas'. As a starting point, we suggest that the monetary values be applied to all locations experiencing noise in excess of 45dB(A), whether urban, suburban or otherwise – this is likely to include some rural villages.

xvii. there is scope to increase our knowledge of the effect of noise changes other than in residential locations, including: noise experienced on street, at work/school/hospital, and in other non-residential buildings. We note that DMRB (for road schemes) includes a wider-ranging noise assessment, covering all properties and all relevant locations, including sports fields, canals, footpaths, and so on. The results are mapped and reported in terms of the noise level in dB(A) for each location, although the analysis is only carried forward to noise exposure and noise nuisance for residential properties. If ways could be found to value noise experienced on street, in non-residential buildings and in open spaces, DMRB could offer a basis of noise measurement on which to build the analysis.

xviii. the calculation of a Present Value of Benefits for noise will require the use of noise forecasts (for an opening year, forecast year and any intermediate years, as now), and interpolation and extrapolation will be required to complete the forecasts for the full appraisal period, in line with current advice (TAG Unit 3.5.4).

xix. monetary valuation of noise should be attempted at the 'Plan' stage in TAG (i.e. for fully-worked up packages of interventions on any mode) and at Stage 3 in the DMRB assessment for road schemes (i.e. for a fully worked-up road scheme).

xx. this work has also highlighted the scope for further research in the following areas:

- exploration of the differences in values between road noise, rail noise and aircraft noise, using comparable data and methods – and including specific rail cases such as High Speed Rail and urban light rail systems as distinct from conventional ‘heavy rail’;
- valuation of night-time noise;
- research to confirm or revise the time series and cross-sectional elasticity of WTP with respect to household income;
- separate valuation of noise and other local environmental effects;
- values for health effects of noise based on impact pathway approaches;
- exploration of values for non-residential contexts, including schools, hospitals, workplaces, on-street and in recreational areas/open space; and
- research using SP and RP methods within the same study, where SP methods can be used for segmentation.

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Annex A: European Experience

In this annex we provide a little more detail on the basis of values used in appraisal for countries where the information is available. Unless otherwise indicated information is drawn from the HEATCO Country Reports (HEATCO, 2005).

Austria

Values used in Austria are derived from international studies using HP and SP. A single unit value is applied to the annoyance from road traffic only.

Denmark

Navrud (2002) states that the Danish values at that time were derived from two HP studies: Hammer (1974) and Hjort-Andersen (1978). Whilst neither of these studies is available in English, a short summary of the Hammer study is provided by Sundberg and Söderquist (2004). The HP model was based on the sale prices of 118 houses located near the E3 motorway north of Stockholm. No details are given of the model, but the sample size is remarkably small for a HP study. Kristensen, Ohm and Høj (2004) state that the values were under review as a recent HP study for the Danish Environmental Agency produced an average reduction in house prices of 1.2% per decibel of road noise, which in the light of the Bjorner *et al* (2003) results is thought to be too high.

The method is based around a measure of annoyance, SBT, which is related to the level of noise and to the mode, thus 1 SBT can be interpreted as one dwelling exposed to a noise level of 75dB(A), whilst the following annoyance factors can be applied to dwellings at lower noise levels to produce an SBT equivalent. Summing across dwellings produces an aggregate annoyance measure, in SBT:

- annoyance factors for road noise: 55-59 dB=0.12; 60-64 dB=0.24; 65-69 dB=0.49; 70-74 dB=1.00;
- annoyance factors for rail noise: 60-64 dB=0.12; 65-69 dB=0.24; 70-74 dB=0.49.

Clearly there is a 5dB penalty for road noise relative to rail, with a 55dB(A) cut-off point for road and a 60dB(A) cut-off point for rail. At present the values are applied only to noise at dwellings. Hedonic pricing studies provide the value for annoyance. This is then supplemented by an allowance for health costs estimated through lost output and illness costs which is assumed to be 50% of the annoyance costs. The value for the annoyance and indirect social costs of noise equal to 53,090DKK at 2001 prices (€4,249 at 2002 PPP) for an SBT dwelling (as above).

France

Lambert (2000) outlined the original noise values used in France which were based on the assumption that transport noise costs in France were approximately 0.3% of GDP based on an average European value. As Lambert intimated this system has since been replaced by an approach based on hedonic pricing and health effects (Commissariat General du Plan, 2001). The hedonic discount rates are based on review and lean most heavily on the work of Soguel in Neuchâtel. The cut-off point was subject to some discussion based on the premise that "du point de vue économique, la nuisance optimale ne peut pas être la nuisance nulle" (page 81

Commissariat General du Plan). Here the argument was whether to have the cut-off point at 60dB(A) where 20% are annoyed or at 55dB(A). The final recommendation was to include the range 55-60dB(A) but with a lower discount rate, see Table A1 below.

Table A1: Rental Value depreciation as a function of noise exposure levels

Dépréciation des valeurs immobilières en fonction des niveaux d'exposition au bruit

Leq[1] de jour en façade en dB(A)	55 à 60	60 à 65	65 à 70	70 à 75	Au-delà de 75
% dépréciation /décibel	0,4 %	0,8 %	0,9 %	1 %	1,1 %

Source: Commissariat General du Plan (2001).

In practice, the values are applied by calculating the floorspace of all occupied buildings affected by the intervention (in m^2), using nationally published rents to establish rental values, and then using the depreciation % per decibel to value noise changes within each 5dB(A) interval These values are taken to represent the annoyance effects of noise.

These values are used for road. Rail is given a discount of 3 dB(A), (in other words the thresholds are 3dB(A) higher for rail) reflecting lower annoyance levels based on European evidence. This discount is not applied in the case of new TGV lines. The values are recommended in the case of air – with caution – and a 4 to 5 dB(A) penalty on the L_{den} index. Night-time noise is given a +5dB(A) premium value.

The health effects of high noise levels are reflected by a factor of 1.3 applied to the depreciation value when the daytime noise exceeds 70dB(A) during the day (0600-2200) or 65dB(A) during the night.

Noise values grow in proportion with rental values – the published rentals are indexed in line with GDP. In terms of unit of account, the French values are at market prices.

Germany

The method is briefly outlined in (Federal Ministry of Transport, Building and Housing, 2002) which details the shift from an avoidance cost approach to a willingness to pay approach for built-up areas and the retention of an avoidance cost approach for non-built up areas. The document implies that the willingness to pay values are derived from Weinberger *et al,* 1991. Weinberger (1992) reports this study as a large scale CVM study of a sample of 7000 respondents all over the Federal Republic of Germany. The study identified an increasing willingness to pay as noise exposure increased. The cut-off point for wiliness to pay was around 40dB(A).

Two different approaches are used, for locations within or outside built-up areas. In built up areas, WTP to reduce noise is valued down to a target level of *night-time* noise – which is 37dB(A) for road noise and 42dB(A) for rail noise. In this case we see a 5dB(A) penalty to road noise relative to rail noise. A value of €54.71 per person per dB(A) per annum[37] is applied (based on CVM), together with a weight based on threshold exceedence, i.e. $2^{(0.1*\text{difference in Leq})}$ so that a 10dB(A) increase produces a

[37] at 1998 prices. Equivalent at 2002 PPP factor cost is €54.74.

doubling of annoyance. Schemes that generate noise changes of less than 2dB(A) are held to be below the threshold of perception and not valued. The rationale for measuring night time noise is that in general if night-time noise is reduced below target levels then daytime noise generally falls within its target too.

Outside built-up areas, an avoidance cost approach is used instead. Thus, areas within 100m of the transport infrastructure, including open spaces, should be reduced to target levels of noise – an average threshold of 62dB(A) applies (we assume this threshold is a day time level of noise). The cost of the noise barriers required to reduce noise to within the threshold is then used to measure the disbenefit of the intervention; note that the barriers are hypothetical The unit value for noise barriers is in the range €310 to €3680 per metre of barrier at 1998 prices and values (€310.2 to €3682 at 2002 PPP factor cost). Again, however, the 2dB(A) threshold of perception applies, so small changes in noise are not valued in CBA.

Norway

Navrud (2002) indicates that the values used in Norway are based on an SP/CVM study (Saelinsminde and Hammer, 1994; Saelinsminde, 1999) and expressed as a value per highly annoyed person.

Sweden

Navrud (2002) indicates that the Swedish values are based on an HP study by Wilhelmsson. Assuming this is the study reported in Wilhelmsson (2000) the analysis is based on the sale price of 292 houses sold between 1986 and 1995 in Ängby a suburb of Stockholm produced an average noise discount of 0.6%. Sweden uses the marginal values shown in Table A2 for road noise changes, based on an adjusted hedonic pricing method.

Table A2: Swedish Road Noise Values

Level	Value, SEK per person per annum (2001 base)	Value, € per person per annum (2002 PPP at market prices)
51 dB(A)	51	4.93
55 dB(A)	810	78.3
60 dB(A)	1,750	169
65 dB(A)	3,020	292
70 dB(A)	6,780	655
75 dB(A)	16,220	1567

The values are intended simply to represent annoyance, however they do include both indoor and outdoor noise. Indoor noise levels are assumed equal to outdoor noise levels minus 25dB(A). Noise costs are assumed to comprise 60% indoor noise costs and 40% outdoor noise costs. Rail noise is approached differently, using a function in which the number of trains per day and the maximum noise level indoors are arguments.

Switzerland:

The Swiss values are based on an aggregation of evidence from Hedonic Pricing studies in Switzerland and elsewhere as can be seen in the Table below. A discount rate of 0.8% is used which is an approximate average of the three most recent Swiss studies. This value is below the 0.9% used in the pilot accounts constructed for the UNITE project (Suter *et al*, 2002) and somewhat above the average of 57 studies reported in the Table and sourced from Navrud (2002).

Tabelle 4-1: Verminderung des Mietzinses bei Zunahme des Lärms um 1 dB (A)

Autor	Ort und Jahr	Anzahl Beobachtungen	Mietpreisreduktion pro dB
Pommerehne 1987	Stadt Basel 1983-84	200 Mietwohnungen	1.26%
Iten und Maibach 1992	Stadt Zürich 1986	200 Mietwohnungen	0.80%
Soguel 1994	Stadt Neuenburg 1989	390 Mietwohnungen	0.91%
Ecoplan 2001	Kanton Zürich 1995-99	380 Einfamilienhäuser / Eigentumswohnungen	0.66%
Delucchi und Hsu 1998	USA 1990		0.85%
Durchschnitt aus 57 Studien in Nordamerika, Europa und Australien			0.55%
In dieser Studie verwendeter Wert			0.80%

Source: Federal Office for Spatial Development (2004).

Health costs from noise are estimated separately and include medical, output and intangible costs. The values for intangible costs are taken from international studies of willingness to pay for risk reduction (Federal Office for Spatial Development, 2004) yielding a value per year of life lost of 85,473 CHF (at 2000 factor costs).

The values of lost amenity expressed through rent losses is dominant, health costs account for only 12.4% of total noise costs. Road accounts for the bulk of costs, rail accounts for around 13% of total noise costs. Note that a discount of 5dB(A) has been applied recognising the convention that rail noise is less disturbing than road noise.

A cut-off point of 55dB(A) is used based on evidence from studies of annoyance, a degree of consensus in the literature and it's use as a planning value in the Swiss noise prevention ordinance. It is recognised that there is some evidence of willingness to pay at levels below 55dB(A). A sensitivity test revealed that if the cut-off level were to be reset at 50dB(A) the impact in terms of lost rents would be 75% higher. Note that the Swiss assume a constant 0.8% discount throughout the noise range. While recognising that the relationship is likely to be non-linear this assumption is made in the absence of better evidence.

Summary

In summary for those countries where further detail has been accessible we find that:

- the most common cut-off point below which noise is not valued is 55dB(A) for road noise
- the majority of countries have a higher cut-off point for rail noise than road noise as it is deemed to be less annoying.
- Fewer countries include health effects and in some cases this is an assumed value. The Swiss value based on willingness to pay suggests that these costs are around 12.4% of total noise costs.
- The majority of countries have a value that increases with the level of noise.

Annex B: Valuation Methods in the Context of Transport Noise

A wide range of methods have been used to derive environmental values:

1. Revealed Preference: Hedonic Pricing; Travel Cost Method
2. Hypothetical Questioning: Contingent Valuation Method and Stated Preference (trade-off) Approaches
3. Other approaches: Shadow Pricing/Opportunity Cost; Mitigation Cost and Dose Response or the Impact Pathway Approach.

This Annex gives a brief, general assessment of the appropriateness of the various valuation methods in the context of land based transport externalities, and noise in particular[38]. The discussion of methodology based on Bristow (2004).

Revealed Preference Methods

Revealed preference methods which have or could be used to value noise are explored here. The travel cost approach is excluded as irrelevant in the context of residential noise, although it might have some potential in the assessment of tranquil areas. The key methods reviewed here are hedonic pricing, opportunity cost and the impact pathway.

Hedonic Pricing

Hedonic pricing has been widely used to value noise and to a lesser extent air pollution from transport and other sources from the impact on willingness to pay in the surrogate housing market. Direct comparison of studies applying hedonic pricing is difficult due to differences in functional form, quality and scope of data, definitions of variables such as accessibility, level of discrimination of the measure of the impact being valued[39], omitted variables and others (Smith and Huang, 1995; Schipper *et al*, 1998; Nelson, 2004). The hedonic pricing method has been questioned on several counts including; imperfect knowledge of the attributes of each location and other market imperfections, correlation of explanatory variables, and the difficulty of measuring intangible influences and individuals' perceptions of them.

The method is suited only to impacts where the effects are fully perceived and understood by individuals making decisions in the market of interest. This condition applies more strongly to noise effects than to other externalities associated with transport. Even in the case of noise although the resulting disamenity is well perceived it may not have been so at the time of moving house, also it is unlikely that individuals would have considered (or even be aware of) the potential impacts on health. A large number of hedonic pricing studies exist, which form a body of evidence on noise. However, even where, like noise the impact is well perceived there may be imperfections in the housing market that do not allow those who would like to express a preference for quiet to do so. Transaction and moving costs will make the current house more attractive than it would otherwise be (Palmquist, 1992). There is an additional element a loss of "personalized advantages" (Walters, 1975) or

[38] For a more detailed description, see, for example, Haab and McConnell (2002) or Garrod and Willis (1999).
[39] For example the noise contour or pollution definition.

a preference for staying put. In effect then there are two main elements of disamenity from noise or other environmental impacts:

- Disemenity to property holders which may be measured using hedonic pricing methods. Although the data may not be sufficiently detailed to include the impacts of averting behaviour. Possible health effects which may be poorly perceived and understood are unlikely to be reflected in values derived from an hedonic pricing study.
- "friction" effects in terms of additional moving costs. This means that the total disamenity is not reflected in the value derived from an hedonic pricing study.

Hedonic pricing studies will only obtain the perceived values of residential property owners in an area. Disbenefits to property owners that are omitted include transaction costs of moving and any unperceived effects such as those on health. The method does not capture impacts on other property types, impacts on pedestrians and visitors or non-use values where relevant. Values could therefore be viewed as placing a minimum value on transport noise.

Avoidance or Opportunity Costs

"Values the benefits of environmental protection in terms of what is being foregone to achieve it" Garrod and Willis, 1999

Alternative cost approaches seek to value implied expenditure or costs incurred. One method is to examine the costs of averting behaviour (Nero and Black, 2000), whether incurred by the individual (eg, double glazing, behavioural change) or other bodies (eg, noise barriers, noise regulations). Mitigating expenditure rarely eliminates the nuisance and will not necessarily reflect the value of the nuisance to the individual. Indeed recent research (Brutel-Vuilmet *et al,* 2004) suggests that for certain aircraft flight tracks noise may be higher inside properties with double glazing than those with single glazing. Such expenditures can indicate the minimum value society at present places on the different aspects, impacts and contexts of noise nuisance.

Impact Pathway Approach

The Impact Pathway Approach was developed in the ExternE project (Bickel *et al*, 1997) in the context of air pollution. The approach builds a pattern of impacts from the bottom up in a site specific way. The first step is to estimate emissions from transport. The second step involves atmospheric modelling to estimate the marginal increase in pollutant concentrations. The third step applies exposure-response functions to estimate the final impacts in terms of: years of life lost; asthma attacks; hospital admissions; crop yield loss; damage to buildings etc. The final step is to value these impacts. The values are derived outside the process. There is a growing consensus at a European level on the value of a statistical life lost (Nellthorp *et al,* 2001) however values of an acute death brought forward exhibit a large range making their application problematic (Department of Health, 1999). As the average loss of lifetime from air pollution effects is approximately 9 months, while for an average traffic fatality it is around 30 years (Expert Advisors to the High Level Group on Infrastructure Charging, 1999), the use of the same value of statistical life lost does not seem appropriate. The ExternE project used years of life lost. The issue then becomes one of how this should be valued, dividing the value of a statistical life by the average life expectancy, allowing for discounting was suggested by the Expert Advisors to the High Level Group on Infrastructure Charging (1999) subject to caveats on the value of one year of life versus many and a need to examine the relationship between the value of a year of life and the value of life. This approach was adopted in UNITE (Bickel *et al,* 2003) where it was also applied to the health effects of noise nuisance.

This method has been discussed in some detail as it is particularly useful where impacts are not well perceived or understood making the application of stated preference techniques or other revealed preference techniques difficult. This is the case in the context of the health effects of noise. At present the Department does not feel that the evidence on the health effects of noise is convincing. In the event that improved evidence becomes available in the future, this is clearly a promising technique by which to obtain values.

Hypothetical Questioning Methods

The Contingent Valuation Method (CVM) usually takes one of two forms, depending on the response scale used. Open-ended CVM asks directly for a maximum willingness to pay whilst what is termed referendum or iterative bidding CVM asks the respondent whether they would be willing to pay a series of different amounts. The main shortcoming of the open-ended method is that the respondent finds it more difficult to state the maximum amount that would be paid. However, the iterative bidding procedure requires more questions and there is convincing evidence that starting point bias is a problem whereby the valuation obtained depends on the initial price in the iterative bidding process (Mitchell and Carson, 1989). Recent moves towards the use of dichotomous choice CVM perhaps more it close to stated preference trade-off techniques.

CVM was the first of the hypothetical questioning techniques used to value environmental factors and since the 1970's it has been extensively applied to a wide range of environmental attributes (Mitchell and Carson, 1989; Bateman and Willis, 1999). In the context of transport externalities, examples include studies of: noise (Pommerehne, 1988; Soguel, 1994; Navrud, 2000; Barreiro *et al,* 2000; Bjorner 2004); air pollution (Carlsson and Johansson-Stenman, 2000; Bateman *et al,* 2002a); the health impacts of air pollution (Navrud, 2001) and nuisance and intrusion from traffic (Walker, 1997; Bateman *et al,* 2000).

Stated Preference (SP) experiments offer the decision maker hypothetical scenarios and the preferences expressed indicate the relative importance of the attributes that characterise the scenarios. The most common form of evaluation is choice, although ranking exercises are sometimes employed, and typically just two alternatives are compared with between nine and twelve comparisons involved and usually between four and six attributes characterising each alternative.

SP has its background in mathematical psychology in the 1960's and has been extensively used in a wide range of contexts (Wittink and Cattin, 1989; Louviere *et al,* 2000) but it is only recently that it has begun to be used for the valuation of environmental attributes (Bateman *et al,* 2002b). In the context of valuing the environmental impacts of transport, SP studies have been conducted of road traffic noise (Arsenio *et al,* 2002; Garrod *et al*, 2002; Galilea and Ortúzar, 2003), air traffic noise (Thune-Larsen, 1995; Bristow and Wardman, 2004b) a range of impacts including traffic noise (Daniels and Hensher, 2000), the intrusion effects of transport (Eliasson *et al,* 2002), air quality (Nelson, 1998; Ortúzar and Rodríguez, 2002) and both noise and air quality (Sælinsminde, 1999; Hunt, 2001; Wardman and Bristow, 2004).

There has been increasing interest in the use of SP methods to value environmental externalities from traffic. In part this stems from a relatively recent appreciation of the contribution that this technique can make in the area of environmental valuation, but a further stimulus has been worsening environmental problems and a corresponding increased concern to evaluate the welfare implications. The discussion below is largely drawn from Wardman and Bristow (2004).

Hypothetical questioning techniques are susceptible to a range of biases, many of which could apply to any questionnaire survey, for example, interviewer bias, self-selection and non-response although CVM is perhaps more prone to non-response bias than other types of questionnaire as it can induce protest responses. Other potential sources of bias affect the valuation and include: information; strategic; payment vehicle and in the case of CVM starting point bias. Good design can minimise most effects. In this context information is particularly important and will be discussed later.

Discussion of the merits of CVM and SP often view them as widely different approaches to valuation. It is fair to say that their spheres of application have been quite distinct and that their differences have tended to be exaggerated. CVM can be seen as a special case of SP where there are only two attributes, one of which is typically money and the other is a single change in environmental conditions (Boxall *et al,* 1996). In most cases, the main differences between SP and CVM can be summarised as follows:

- SP examines several attributes simultaneously whilst CVM tends to look at attributes in isolation. SP therefore has an important advantage since the purpose of the study will be less obvious and a lesser incentive to strategic bias can be expected (Bohm, 1971; Wardman and Whelan, 2001). Zero willingness to pay 'protest' responses are common in CVM whilst values based on willingness to accept compensation tend to be far higher than willingness to pay values (Mitchell and Carson, 1989; Horowitz and McConnell, 2002). Bateman *et al* (2000) report values for changes in traffic levels that are 7 times higher for losses and suggest that this may be partly due to the fact that "traffic problems are a source of strong emotions". In addition, SP can examine interaction effects and package effects and is also more useful when the scenario under consideration is multi-dimensional

- SP examines different levels of attributes, whereas CVM generally does not, and hence the SP approach supports detailed and controlled analysis of the functional relationship between the valuation of an attribute and its level as well as sign and size effects. "The stated preference approaches for multiple attributes provide more information than dichotomous choice CV because they involve respondents in more choices. By inducing more choices per respondent, one gets more information about preferences, and better precision on preference parameter estimates. Further, when one of the scenarios (or alternatives) is the status quo, the calculation of WTP relative to the status quo is easily done." Page 272 Haab and McConnell (2002).

- SP tends to ask for the order of preference whilst CVM tends to ask for the strength of preference. Although CVM is less tedious where it involves a single question, and the information content of the single response is in principle high, SP responses can be expected to be more reliable for two key reasons. Firstly, it is simpler to indicate the order than the strength of preference. Secondly, individuals routinely make choices but are rarely required to establish the strength of preference in real life decision making.

- SP is a behavioural model from which values are implied, whereas CVM is a direct valuation model. Whilst SP is more suited to forecasting applications, CVM can avoid the problems involved in the development of choice models. For example, CVM obtains values for each individual, thereby avoiding problems of preference and functional form heterogeneity in SP models which typically pool data across individuals, and assumptions about how individuals make decisions are not needed. In general, CVM data is easier to analyse.

- CVM is relatively straightforward to design. In contrast, there is no unique SP experimental design, even in a tightly defined choice context, and the SP design procedure is somewhat more complicated and surrounded by greater uncertainty.

Although SP does not dominate CVM from a theoretical perspective, it is, on balance, preferable. The risk of strategic bias is clearly present in CV questions where the object of the exercise is clear. In SP experiments it is possible to mask the purpose of the exercise through the use of a number of attributes in an experiment. Evidence from SP applications in transport suggests that where the objective of the exercise is obvious, especially where the issue is contentious, strategic bias is likely to occur (Bristow and Wardman, 2004a). Thus in order for SP to retain an advantage over CVM the purpose of the experiment should be masked.

Note: that the EC position at present appears to be to support the use of values derived from stated preference studies.

Annex C: Welfare estimates for changes in noise exposure at means of covariate data (with 95% confidence interval)

Noise Change		Welfare Change per Annum (1997 prices)			
High	**Low**	**Road**		**Rail**	
56	55	31.49 (24.84 to 52.52)		83.61 (43.21 to 461.80)	
57	56	33.88 (26.51 to 57.26)		85.85 (44.43 to 473.39)	
58	57	36.26 (28.18 to 61.97)		88.09 (45.65 to 484.98)	
59	58	38.65 (29.81 to 66.64)		90.33 (46.87 to 496.58)	
60	59	41.04 (31.48 to 71.31)	181.32 (140.90 to 309.87)	92.57 (48.08 to 508.17)	440.45 (228.24 to 2,424.92)
61	60	43.42 (33.14 to 75.97)		94.82 (49.30 to 519.77)	
62	61	45.81 (34.81 to 80.64)		97.06 (50.52 to 531.36)	
63	62	48.19 (36.48 to 85.31)		99.3 (51.73 to 542.96)	
64	63	50.58 (38.15 to 89.97)		101.54 (52.95 to 554.55)	
65	64	52.97 (39.82 to 94.77)	240.97 (182.41 to 426.53)	103.78 (54.17 to 566.14)	496.49 (258.67 to 2,714.78)
66	65	55.35 (41.49 to 99.57)		106.02 (55.39 to 580.05)	
67	66	57.74 (43.16 to 104.37)		108.26 (56.60 to 594.85)	
68	67	60.12 (44.82 to 109.17)		110.51 (57.82 to 609.65)	
69	68	62.51 (46.50 to 113.97)		112.75 (59.04 to 624.45)	
70	69	64.9 (48.16 to 118.77)	300.62 (224.12 to 545.85)	114.99 (60.26 to 639.25)	552.53 (289.10 to 3,048.25)
71	70	67.28 (49.83 to 123.57)		117.23 (61.47 to 654.04)	
72	71	69.67 (51.50 to 128.37)		119.47 (62.69 to 668.84)	
73	72	72.05 (53.17 to 133.18)		121.71 (63.91 to 683.64)	
74	73	74.44 (54.84 to 137.98)		123.96 (65.12 to 698.44)	
75	74	76.83 (56.50 to 142.78)	360.27 (265.84 to 665.88)	126.2 (66.34 to 713.24)	608.57 (319.53 to 3,418.20)

76	75	79.21 (58.17 to 147.58)		128.44 (67.47 to 728.03)	
77	76	81.6 (59.84 to 152.38)		130.68 (68.52 to 742.83)	
78	77	83.98 (61.51 to 157.18)	419.92	132.92 (69.57 to 757.63)	664.61
79	78	86.37 (63.18 to 161.98)		135.16 (70.62 to 772.43)	
80	79	88.76 (64.85 to 166.78)	(307.55 to 785.90)	137.41 (71.67 to 787.23)	(347.83 to 3,788.16)

Reproduced from Bateman *et al* (2004), Table 5.9

Annex D: Welfare estimates for changes in Road noise exposure at different percentiles of the Expenditure Distribution

Noise Change (dB)	Welfare Values for Changes in Road Noise at Percentiles of Expenditure Distribution (£ per annum in 1997 prices)						
	5th	10th	25th	50th	75th	90th	95th
56 to 55	18.72	21.84	26.11	30.64	36.05	42.54	47.50
57 to 56	21.11	24.23	28.49	33.03	38.43	44.92	49.89
58 to 57	23.50	26.61	30.88	35.41	40.82	47.31	52.27
59 to 58	25.88	29.00	33.27	37.80	43.20	49.70	54.66
60 to 59	28.27	31.39	35.65	40.19	45.59	52.08	57.05
61 to 60	30.66	33.77	38.04	42.57	47.98	54.47	59.43
62 to 61	33.04	36.16	40.42	44.96	50.36	56.85	61.82
63 to 62	35.43	38.54	42.81	47.34	52.75	59.24	64.20
64 to 63	37.81	40.93	45.20	49.73	55.13	61.63	66.59
65 to 64	40.20	43.32	47.58	52.12	57.52	64.01	68.98
66 to 65	42.59	45.70	49.97	54.50	59.91	66.40	71.36
67 to 66	44.97	48.09	52.35	56.89	62.29	68.78	73.75
68 to 67	47.36	50.47	54.74	59.27	64.68	71.17	76.14
69 to 68	49.74	52.86	57.13	61.66	67.06	73.56	78.52
70 to 69	52.13	55.25	59.51	64.05	69.45	75.94	80.91
71 to 70	54.52	57.63	61.90	66.43	71.84	78.33	83.29
72 to 71	56.90	60.02	64.28	68.82	74.22	80.71	85.68
73 to 72	59.29	62.40	66.67	71.20	76.61	83.10	88.07
74 to 73	61.67	64.79	69.06	73.59	78.99	85.49	90.45
75 to 74	64.06	67.18	71.44	75.98	81.38	87.87	92.84
76 to 75	66.45	69.56	73.83	78.36	83.77	90.26	95.22
77 to 76	68.83	71.95	76.21	80.75	86.15	92.64	97.61
78 to 77	71.22	74.33	78.60	83.13	88.54	95.03	100.00
79 to 78	73.60	76.72	80.99	85.52	90.92	97.42	102.38
80 to 79	75.99	79.11	83.37	87.91	93.31	99.80	104.77

Reproduced from Bateman *et al* (2004), Table 5.11

Annex E: Welfare estimates for changes in Rail noise exposure at different percentiles of the Expenditure Distribution

Noise Change (dB)	Welfare Values for Changes in Rail Noise at Percentiles of Expenditure Distribution (£ per annum in 1997 prices)						
	5th	10th	25th	50th	75th	90th	95th
56 to 55	51.78	59.55	70.19	81.49	94.96	111.15	123.52
57 to 56	54.02	61.79	72.43	83.73	97.20	113.39	125.77
58 to 57	56.26	64.03	74.67	85.97	99.44	115.63	128.01
59 to 58	58.50	66.28	76.91	88.21	101.69	117.87	130.25
60 to 59	60.75	68.52	79.15	90.46	103.93	120.11	132.49
61 to 60	62.99	70.76	81.39	92.70	106.17	122.35	134.73
62 to 61	65.23	73.00	83.63	94.94	108.41	124.60	136.97
63 to 62	67.47	75.24	85.88	97.18	110.65	126.84	139.22
64 to 63	69.71	77.48	88.12	99.42	112.89	129.08	141.46
65 to 64	71.95	79.72	90.36	101.66	115.13	131.32	143.70
66 to 65	74.20	81.97	92.60	103.91	117.38	133.56	145.94
67 to 66	76.44	84.21	94.84	106.15	119.62	135.80	148.18
68 to 67	78.68	86.45	97.08	108.39	121.86	138.05	150.42
69 to 68	80.92	88.69	99.33	110.63	124.10	140.29	152.67
70 to 69	83.16	90.93	101.57	112.87	126.34	142.53	154.91
71 to 70	85.40	93.17	103.81	115.11	128.58	144.77	157.15
72 to 71	87.65	95.42	106.05	117.36	130.83	147.01	159.39
73 to 72	89.89	97.66	108.29	119.60	133.07	149.25	161.63
74 to 73	92.13	99.90	110.53	121.84	135.31	151.50	163.87
75 to 74	94.37	102.14	112.78	124.08	137.55	153.74	166.12
76 to 75	96.61	104.38	115.02	126.32	139.79	155.98	168.36
77 to 76	98.85	106.62	117.26	128.56	142.03	158.22	170.60
78 to 77	101.09	108.87	119.50	130.81	144.28	160.46	172.84
79 to 78	103.34	111.11	121.74	133.05	146.52	162.70	175.08
80 to 79	105.58	113.35	123.98	135.29	148.76	164.94	177.32

Reproduced from Bateman *et al* (2004), Table 5.12

Annex F: Best estimates of combined road and rail welfare values

Noise Change		Prob. Road & Rail Welfare Values are identical	Best Estimate of "Combined" Road & Rail Value		
High	Low		"Combined" Welfare Value	Prob. Road >= "Combined"	Prob. Rail <= "Combined"
56	55	0.026	62.67	0.010	0.134
57	56	0.028	61.40	0.018	0.105
58	57	0.030	59.94	0.034	0.076
59	58	0.032	65.34	0.032	0.111
60	59	0.034	68.96	0.034	0.131
61	60	0.036	73.49	0.034	0.155
62	61	0.038	78.04	0.034	0.183
63	62	0.044	82.54	0.034	0.215
64	63	0.047	86.96	0.034	0.242
65	64	0.050	85.76	0.045	0.207
66	65	0.056	80.11	0.075	0.140
67	66	0.064	80.41	0.091	0.128
68	67	0.071	74.13	0.195	0.069
69	68	0.074	76.92	0.201	0.077
70	69	0.079	80.28	0.195	0.088
71	70	0.084	82.93	0.201	0.096
72	71	0.090	86.42	0.195	0.111
73	72	0.096	88.70	0.202	0.117
74	73	0.098	92.46	0.196	0.132
75	74	0.102	93.92	0.210	0.130
76	75	0.106	98.60	0.196	0.150
77	76	0.113	95.06	0.278	0.112
78	77	0.122	98.92	0.260	0.131
79	78	0.131	100.51	0.282	0.130
80	79	0.140	102.17	0.296	0.130

Reproduced from Bateman *et al* (2004), Table 5.10

Developing Guidance on the Valuation of Transport-Related Noise
for Inclusion in WebTAG:

Note on the Influence of Tenure

John Nellthorp, 6 June 2005

In the Paper prepared for the DfT Seminar on 17th May 2005, the section relating to tenure read as follows:

> “***Differences in tenure***
>
> Census data indicate that there are differences in tenure between the study sample, Birmingham as a whole, and the whole of England and Wales (Table 6).
>
> Table 6: Tenure

	% of households	
Tenure	**Birmingham**	**England and Wales**
Owner occupied	60.4	68.9
Rented from Council	19.4	13.2
Rented from Housing Association or Registered Social Landlord	8.4	6
Private rented or lived rent free	11.8	11.9

> Source: Office of National Statistics (2005), 2001 Census
>
> In the study, the sample includes residential property transactions but not council rented, social rented or ‘lived rent free’ households. The study does include both owner-occupier and buy-to-let properties, since these types could not be distinguished using the data, hence it includes the private rented sector although with certain assumptions about the characteristics of the purchasers and residents (Bateman *et al* discuss this on p135). The study also excludes first-time ‘right-to-buys’ of council properties – these were excluded on the ground that they would not reflect the full market price[40].
>
> Depending upon the size of the ‘lived rent free’ group, it seems likely that the tenure types included in the study account for at most 72% of the households in Birmingham, and at most 81% of households in the UK. The remainder are likely to include some of the poorest households, and to have on average a lower income than the groups which are included.
>
> Despite this, we have found little evidence that would allow robust adjustments to the results. Therefore we suggest making an assumption, although it is a heroic one, that the Bateman *et al* results *are* representative of the whole Birmingham population in 1997, unless and until a better rationale can be found”.

It was agreed at the Seminar that it would be worthwhile to explore this issue further (Vause, 2005):

[40] See Bateman, Day and Lake (2004), p16.

> "Issue: The housing tenure issue was raised. If we take on the assumption that WTP mainly varies with income and we know the relative income of people in the rented sector as compared to those in the owner occupied sector we could adjust the value to be transferred to take this into account. (presumably this means our current value will be too high as it is based on the 80% or so of the population who are on average richer than those remaining in the rented sector)
>
> This point was taken on board. [ITS] agreed to look into data availability on the relative income of owner occupied and renting households. If sufficiently local and robust data is available it was agreed it would be the right thing to do to adjust the value when transferring to a national average value to be used across all residentially properties".

In investigating this issue, we have briefly examined:

- the rationale for revisiting the social rented sector;
- evidence on household incomes by tenure;
- evidence on direct tax and National Insurance contributions by income - this would be necessary to infer disposable household incomes from the gross household income data by tenure (as it is disposable household income to which we agreed the WTP for peace and quiet is likely to be sensitive);
- evidence on the proportion of households in different tenure types in different locations – in particular Birmingham versus England as a whole.

Below, we present the findings and consider the implications for the appraisal values of transport-related noise.

Rationale for revisiting the social rented sector

A key omission from the work to date is to consider the effect of *including the social rented sector* – i.e. households renting from their local authority or from other Registered Social Landlords including Housing Associations. These households were omitted from the Birmingham study (Bateman *et al*, 2004) because they do not appear in property sales data. As above, we initially felt there was insufficient basis to estimate their WTP for peace and quiet. However, at the Seminar we were encouraged to make 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.

Household incomes by tenure

The most suitable data that we have been able to obtain is in fact the Gross Income of households, by tenure, in England for the fiscal year 1997/8. Gross Household Income differs from the Gross Disposable Household Income (GDHI) used in the calculations so far chiefly in that:

- Gross Income includes income from employment, investments **and state benefits**;
- to obtain Disposable Income it is necessary to deduct direct taxes, i.e.:
    - income tax
    - Council tax
    - National Insurance Contributions
    - net of any discounts or rebates on the above which are granted to the household.

Therefore an additional stage will be required – see the following section.

Table G1 gives the mean Gross Incomes of households in each of the main tenure categories for the year 1997-8, taken from ONS data.

Table G1: Gross Household Income by Tenure

Gross weekly income of household by tenure
England 1997/8

Tenure	Mean income, £/week	Share of households
Owned outright	335	26.1%
Buying w mortgage	582	42.8%
All owners	*493*	*68.8%*
Council rented	169	16.5%
Other RSL	176	4.9%
All social rented	*170*	*21.3%*
All private rented	*344*	*9.8%*
TOTAL	*408*	*100.0%*

Source: Green *et al* (1999), Tables 1A and A1.11

Direct tax and National Insurance Contributions by income

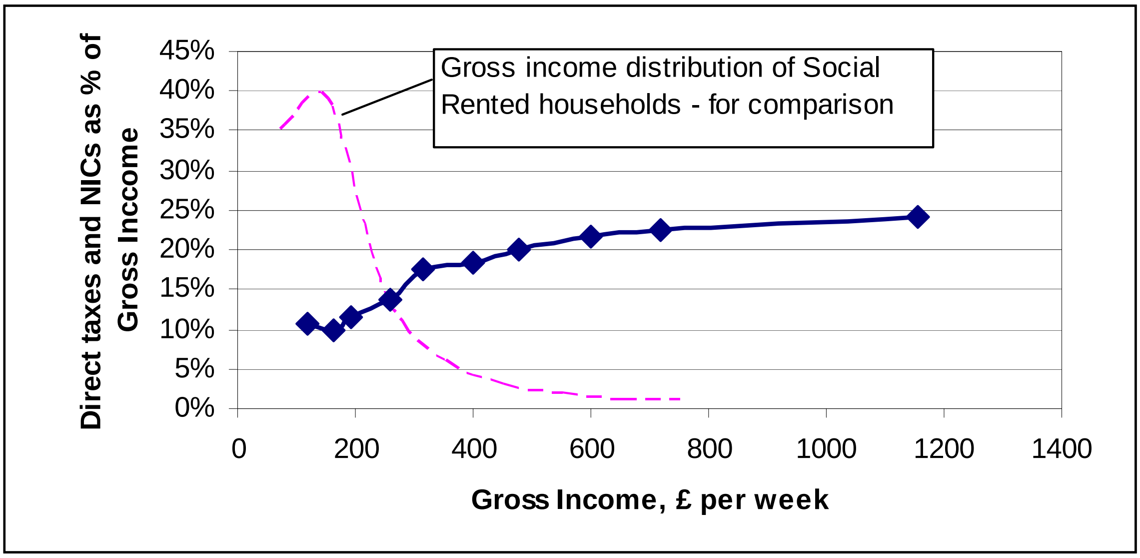
The effect of direct taxes and National Insurance Contributions is proportionately greater at higher Gross Income levels (Table G2 and Figure G1), with an exception in the bottom income decile.

Table G2: Direct Tax and National Insurance Contributions by Income Decile

	Bottom	2nd	3rd	4th	5th	6th	7th	8th	9th	Top	All
Direct taxes and employees NICs as % of Gross Income	11%	10%	11%	14%	18%	18%	20%	22%	22%	24%	20%
Weekly gross income	117	164	192	261	317	400	479	599	718	1155	442

Source: Green *et al* (1999), Table 2A
Note: Deciles are based on Equivalised Disposable Income.

Figure G1: Direct Tax and National Insurance Contributions by Income



Gross Disposable Household Income

By deducting direct taxes from Gross Income, we obtain an estimate of Gross Disposable Household Income by tenure (Table G3).

Table G3: Gross Disposable Household Income by Tenure

Mean household income, £/week England 1997/8		
Tenure	Gross income net of direct tax and NICs Mean, £/week	Share of households
Council rented	150.4	16%
Other RSL	156.6	5%
All social rented	*151.3*	*21%*
Owned outright	274.7	26%
Buying w mortgage	454.0	43%
All owners	*386.0*	*69%*
All private rented	*282.1*	*10%*
All private	*373.1*	*79%*

Sources: ITS analysis.

Tenure types in the UK

The proportion of households in the *social rented* sector varies across the UK. In England, 21% were in that sector in 1997/8 as shown in the tables above. In Wales in 1997, 27% were in that sector. In Scotland, there is tradition of high levels of social renting, and 36.1% were in that sector in 1994.

The data we have for Birmingham relates to the 2001 Census, when the figure was 27.8% of households in *social rented* accommodation.

Approximation of WTP for peace and quiet among social rented households in Birmingham, 1997

Assuming a cross-sectional elasticity of P_x with respect to income of 1.0, and given that at Income = £373.1 , P_x = £12.4:

elasticity of 1.0 and a linear demand function implies that

$$P = \frac{12.4}{373.1} I$$

hence at Income = £151.3, P* = 5.029.

We can make the same calculation for each level of WTP in the private rented sector, giving the results shown in Table G4. This assumes that in 1997, the share of social renting among total households in Birmingham can be found by a linear interpolation between the 1991 and 2001 Censuses, during which period social renting in Birmingham fell from 32% to 27.8% (Birmingham City Council, 2005), however, strictly it is uncertain how much of the change occurred after 1997[41].

Table G4: UK-based values for changes in transport-related noise at 2002 prices and values, £ per annum (adjusted for social rented sector)

Values for a 1dB(A) change within each 5dB(A) interval

dB(A)Leq Lo	dB(A)Leq Hi	Birmingham Private sector 1997 £ per household per dB(A)	Birmingham Social Rented 1997 £ per household per dB(A)	Birmingham Mean 1997 £ per household per dB(A)	UK 1997 £ per household per dB(A)	**UK 2002 £ per household per dB(A)**
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**

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 there it is not necessary to make any further changes to obtain the UK values.

[41] The change was made up of a drop by about 8% in council renting and a smaller rise in RSL renting.

Implications for the UK 2002 Values

Finally, Table G5 compares the values presented on 17 May with the adjusted values, based on the evidence on household income by tenure set out in this Note. Across the board, there is a 17.5% reduction in the values per decibel.

Table G5: Comparison of Unadjusted and Adjusted Values

dB(A)Leq Lo	dB(A)Leq Hi	2002 £ per household per annum per dB (unadjusted for tenure)	**2002 £ per household per annum per dB (adjusted for tenure)**
45	50	16.6	**13.7**
50	55	32.6	**26.9**
55	60	48.6	**40.1**
60	65	64.5	**53.2**
65	70	80.5	**66.4**
70	75	96.5	**79.6**
75	80	112.5	**92.8**

Table H1: Willingness-to-pay based values for changes in transport-related noise in the UK

Noise change in the interval $dB(A)_{Leq}$ Lo	Hi	2002 £ per household per annum per dB(A)
<45		0.0
45	46	8.4
46	47	11.1
47	48	13.7
48	49	16.3
49	50	19.0
50	51	21.6
51	52	24.2
52	53	26.9
53	54	29.5
54	55	32.1
55	56	34.8
56	57	37.4
57	58	40.0
58	59	42.7
59	60	45.3
60	61	48.0
61	62	50.6
62	63	53.2
63	64	55.9
64	65	58.5
65	66	61.1
66	67	63.8
67	68	66.4
68	69	69.0
69	70	71.7
70	71	74.3
71	72	76.9
72	73	79.6
73	74	82.2
74	75	84.9
75	76	87.5
76	77	90.1
77	78	92.8
78	79	95.4
79	80	98.0
>80		98.0

Note: Noise reductions will be valued with a positive sign;
noise increases will be valued with a negative sign.