INTERNATIONAL META-ANALYSIS OF STATED PREFERENCE STUDIES OF TRANSPORTATION NOISE NUISANCE

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ABSTRACT

This paper reports the first meta-analysis and most extensive review of stated preference studies of transportation noise nuisance. The meta-analysis is based on a newly compiled data set of 258 values from 49 studies and 23 countries and spanning more than 40 years. Contrast this with the most extensive meta-analysis of the more conventional hedonic pricing approach which includes 53 noise valuations. Moreover, the sample compares favourably with the 444 observations from the very first meta-analysis of the value of travel time savings which is by far the most widely examined parameter in transport planning.

A particularly significant finding of the study is that the intertemporal income elasticity is close to one, somewhat larger than the cross-sectional income elasticity typically obtained from individual studies. This demonstrates the importance of distinguishing the effects of income variations that occur over time, which tend to drive policy, from variations across individuals at one point in time, and such findings are typical of those observed in other markets. Importantly, the values derived are transferable across countries and may be used to benchmark existing evidence and provide values in contexts where none exist.

Other key results are that values for aircraft noise exceed those for other modes, whilst those exposed to higher noise levels and those who are highly annoyed also have higher values in line with expectations. A wide range of design effects were tested but few were significant and these included the consumer surplus measure, the representation of noise and the context.

Keywords: meta-analysis; stated preference; transportation noise; noise valuation; noise nuisance.

INTRODUCTION

Monetary values of the costs of noise nuisance are needed to inform policy development and decision making, ensuring that the benefits of interventions to reduce noise at the emitter or receiver exceed the costs. As there is no market for quiet, the classic approach to valuing noise nuisance has been to seek a market within which noise is implicitly valued. If individuals have a value for quiet then intuitively this would be manifested in, for example, a willingness to pay more for houses in quieter areas. Typically then use is made of the housing market where price is a function of a bundle of characteristics of the house and the neighbourhood including noise. The value of noise obtained is normally expressed in the form of a Noise Depreciation Index (NDI) or Noise Sensitivity Depreciation Index (NSDI) which indicates the percentage change in house prices that results from a 1 decibel (dB) change in noise levels. A detailed exposition of the theory and method of this hedonic pricing (HP) approach may be found in Baranzini et al. (2008).

The quantity of HP studies on aircraft noise is such that a number of meta-analyses have been carried out. The most recent (Wadud 2013) identified 65 NDI values ranging from 0 to 2.3% and included 53 estimates in a meta-analysis concluding that a 1 dB increase in aircraft noise levels leads to a fall in house prices of between 0.45% and 0.64%. This estimate is broadly consistent with meta-analysis by Nelson (2004) and the earlier review by Nelson (1980) though somewhat lower than the estimates of Schipper et al. (1998) of 0.9% to 1.3%[1]. However, few significant influences on values have been detected. Nelson and Wadud found that linear model specifications yielded higher values as did Canadian studies. Wadud also identified a positive effect from income and pre-1965 studies. There are fewer HP studies of road traffic noise and the only attempted meta-analysis was very small scale

[1] Wadud (2013) suggests that after adjusting for different noise indices specifications the results of Schipper et al. (1998) would be closer to those of Nelson 2004. The assumptions made by Schipper et al. (1998) on household wealth have also been criticised (Nelson, 2004). Earlier studies, Button and Nijkamp (1997) and Johnson and Button (1997) were both based on small samples and inconclusive.

based on 16 estimates from 9 studies identifying an NDI of 0.64% (Bertrand 1997, cited in Bateman et al. 2001)[2]. The earliest review by Nelson (1982) identified 9 studies all from North America and 14 values yielding an average of 0.4%. Bateman et al. (2001) reviewed 18 studies of road traffic noise mostly from North America finding a range from 0.08% to 2.22% and an average NSDI of 0.55%. More recent European studies fall within this range and tend to be reasonably consistent with this average (Bristow 2010). Although the HP approach is broadly accepted and underpins many values used in public sector appraisals, the range of values is nonetheless large and, moreover, this variation is largely unexplained.

Stated Preference (SP) methods provide another approach to the valuation of noise nuisance. They are essentially hypothetical questioning techniques, with the two main forms being the Contingent Valuation Method (CVM) and Stated Choice (SC). They offer some advantages over HP techniques. Firstly, control over the experimental conditions ensures the avoidance of correlation between independent variables, sufficient variation in attribute levels, better trade-offs than might exist in the real world, investigation of levels of noise or quiet outside current experience, the avoidance of measurement error in the independent variables and the ability to "design out" confounding variables. Secondly, the analysis is conducted at the level of the decision maker which contributes to more precise parameter estimates not only because samples can cover many decision makers and focus on their actual decisions but also because multiple responses per decision maker can be recovered. Thirdly, such disaggregate analysis allows more detailed insights into how preferences vary according to decision makers' characteristics and circumstances.

Navrud (2002) reviewed valuation studies, focusing on SP methods, and recommended a range of €2 to €32 per dB per household per annum for road noise based on six studies. The EU Working Group on Health and Socio-economic Aspects (2003) utilised his findings

[2] Though Button and Nijkamp (1997) use airport and highway studies in their illustrative analysis and report an airport coefficient, the significance of this coefficient is not given and a simple re-analysis of the data (25 values) reported in their paper suggests the coefficient may be insignificant.

to recommend a value of €25 per household per decibel per year. Navrud recognised a variety of factors, both methodological and socio-economic, that might explain this large range in values, concluding that a meta-analysis would be helpful to test and quantify these effects but at that time there were too few studies available.

We have here identified 62 SP studies of transportation noise and it was possible to extract 258 comparable values from 49[3] of these in order to support the desired meta-analysis. The studies are listed with complete citations in Appendix 1 alongside a table showing key study features. Each study has been assigned a unique number and these are sometimes used in the text to identify studies[4]. To place this research in context, the largest ever review of values from the HP approach, which represents the conventional wisdom in this area, included only 53 observations (Wadud 2013). Indeed, our study compares favourably with the first major meta-analysis of the value of travel time savings, that yielded 444 values from 105 studies (Wardman 1998), bearing in mind that the value of time has dominated transport planning practice since the 1960s.

The SP monetary valuations of noise nuisance assembled exhibit a wide range, as might be expected. This could stem from variations in data type and survey method, the systematic influence of study and country specific factors and, importantly, intertemporal effects. Thus meta-analysis of this variation in valuations across studies and over time can potentially yield important methodological and policy relevant insights and new evidence over and above that which a single study or a conventional literature review can provide.

The main aim of this paper is to provide the first meta-analysis and largest ever review of SP valuations of transportation noise nuisance. It is structured as follows. The next section defines and explains the assembled valuations with reference to relevant variables and,

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[3] Note that multiple valuations are drawn from a study only where they are distinguished by a factor whose influence we are interested in exploring.
[4] The numbers are in italics in brackets to distinguish them from footnotes.

importantly, in the context of evidence in the wider literature. The meta-analysis of SP valuations that follows builds upon and makes use of this discussion. The meta-model is then used to provide illustrative noise valuations for a range of circumstances. Conclusions and recommendations follow this.

DATA ASSEMBLY AND CHARACTERISTICS

Of the 258 monetary valuations spanning more than 40 years, 30% are from the UK, followed by Norway (11%), Germany (9%), Spain (9%), Sweden (8%), France (7%) and Hungary (6%); no other country exceeds 5%. This indicates the strength of interest in noise nuisance within the European Union. Fourteen studies (29%) yielded a single value with 23 (47% per cent) providing between two and four. Only two studies yielded more than ten values - 19 and 88[5]. Academic journals covered 43% (27%) of the studies (values), conference papers 31% (22%), various reports to Government departments, the EU and University working papers 24% (50%) and one book chapter 2% (1%).

Given that our aim is to explain variations in values across studies, a challenge is to place them on a consistent basis in a metric that is a usable objective measure of noise. The dependent variable is defined as the annual value per household for a change of one decibel. Since few studies report such a value, the following assumptions have been used to convert values expressed in different forms to a decibel value. Firstly, where a proxy means of representation allows a reasonable estimate of the objective change in noise levels to be made then this is used. For example, a change in road traffic flows or aircraft numbers allows the impact on noise levels to be modelled. Secondly, and following Navrud (2002), where a variation represents a halving (removal) of noise levels a change of 8 (10) dB is assumed, and analogously for increases.

[5] This was a large scale study of 6 countries covering multiple modes (Navrud et al., 2006).

Values used in the meta-analysis were uplifted to 2009 using the Consumer Price Index (CPI) for the study country and then converted to $US using official exchange rates for 2009 (World Bank 2010). However, for comparability purposes in the tabulations that follow in this section, the values have been adjusted for income growth, using a GDP per capita elasticity of one[6]. The resulting average value per decibel change per household per annum is $141.59[7], with a range from $0 to $3407.67. The median is $20.45 and the 10th and 90th percentiles $2.18 and $345.60 respectively indicating a highly skewed distribution

We now present tabulations, in the style of a conventional literature review, for what we regard to be the key explanatory factors and in so doing we provide more detail on the characteristics of the assembled sample. We distinguish influential variables that are exogenously determined from design effects. Where appropriate, within study variation is discussed as this provides comparable values in a highly controlled setting devoid of the confounding effects that can be apparent in simple cross-study tabulations.

Influential Variables

Noise source

The weight of evidence indicates that for a given measured level of transportation noise the level of annoyance varies by source; aviation noise is most annoying and rail least annoying (Miedema and Oudshoorn 2001). This underpins the use of a rail "bonus" in appraisal in some countries, although emerging evidence suggests that at very high frequencies (say a train every three minutes) rail noise may be as or more annoying than road noise (Gidlöf-Gunnarsson et al. 2011).

[6] Using an inappropriate inter-temporal income elasticity to adjust across years could result in misleading conclusions. Fortunately, our subsequent meta-analysis indicates that such an income elasticity is fully justified.
[7] At 2009 values $1 = 0.72€ or 0.64 UK £

Limited within study evidence from HP finds road values to exceed rail except at levels over 70dBA (Andersson et al. 2013), rail to exceed road at all levels (Day et al. 2007), air and rail to exceed road[8] (Dekkers and van der Straaten 2009), air values equal to road (Salvi 2007) and road to exceed air though in this specific case this may be due to the low levels of aircraft noise experienced (Pommerehne 1988). Thus the HP evidence is inconsistent. In SP studies, three find values for aircraft nuisance to be clearly higher than for road noise (Duarte and Cladera 2008; Plowden 1970; Thune-Larsen, 1995). A fourth finds the opposite, but again with the caveat about low aircraft noise levels (Pommerehne 1988).One study found road nuisance to be more highly valued than rail (Eliasson et al. 2002) and another provided mixed evidence across five countries (Navrud et al. 2006). This within study evidence from SP is more broadly reflective of the pattern found in the annoyance literature though still not entirely consistent.

Table 1 shows the distribution of values by mode across the entire data set. The air values are significantly higher than those for road and rail. Road and rail are not significantly different, but there is a high level of uncertainty in the rail estimate. Nonetheless, the pattern accords with expectation and convention.

Table 1: Values per dB per household per annum by noise source (2009 US$)

Noise source	Sample	Mean	Standard Error	95% CI (+/- %)	10th and 90th percentiles
Air	69	292.24	33.76	23.10	40.40 786.32
Road	141	105.79	33.40	63.14	1.70 148.39
Rail	44	25.76	18.52	143.79	1.43 13.03[9]
Combined[10]	4	79.10	30.23	75.90	n.a.
Overall	258	141.59	21.41	30.24	2.18 345.60

[8] Albeit with quite different thresholds
[9] The rail values have a very skewed distribution with a few very high values beyond the 90th percentile.
[10] The four values here report noise from all sources (1), road and air (1), and road and blasting (2).

Noise Levels

The majority of HP studies report a single value for noise depreciation. However, a small number (Andersson et al. 2010; Day et al. 2007; Pommerehne 1988; Thanos et al. under review and Wilhelmsson 2000) report an increasing NDI as noise levels increase. Twelve SP studies([4, 5, 7, 16, 19, 21, 29, 30, 33, 34, 37, 42] report values for different base noise categories (though in one case[37] the initial levels are not sufficiently different to draw conclusions). Of the remaining eleven, seven[4, 7, 21, 29, 30, 33, 42] show a consistently increasing value per dB as the base noise level experienced increases. Two studies[16, 19] show higher values for a change in noise levels at higher noise levels but when converted to a per dB value it is lower, in both cases those experiencing higher noise levels were valuing larger changes so there may be a scope effect here. The final two studies[5, 34] both report higher values at lower noise levels. However, these studies were both based on simulation rather than experienced noise and in the latter case the higher noise level was for rail and the lower for road which may have had a confounding effect. The evidence is broadly consistent with respect to higher values at higher noise levels and this is reflected in the data as shown in Table 2.

Table 2: Values per dB per household per annum by current noise level (2009 US$)

Noise level	Sample	Mean	Standard Error	95% CI +/- %	10th and 90th percentiles
Not available	205	90.02	11.47	25.48	1.74 306.05
Under 55 dB	11	31.07	11.74	75.57	1.60 122.47
55 to 64.99 dB	28	423.34	138.89	65.61	12.19 1290.72
Over 65 dB	14	420.01	186.10	88.62	11.06 1964.06

Intertemporal effects

When appraising schemes that impact on noise levels, how their values change over time, particularly with respect to income growth, is critical. The default is to assume that values rise in line with income in the absence of compelling time-series evidence, although there is a significant amount of cross-sectional evidence of how values vary across different income groups.

Evidence from HP studies is limited and mixed. Walters (1975), Palmquist (1992) and Wadud (2013) suggest that income elasticities exceed one and thus that quiet is a luxury good. Other authors (McMillan 1979; Wilhelmsson 2002) identify income elasticities of less than one. In these studies income is proxied by property prices or average incomes for the area or country and only Wilhelmsson (2002) uses the incomes of the actual purchasing households. His estimates of income elasticities of 0.46 for households without children and 0.57 for those with children might then be seen as the most robust estimates of a cross sectional income elasticity for quiet and are very much in line with cross-sectional SP evidence to which we now turn.

As far as SP evidence is concerned, Table 3 reports cross-sectional income elasticities from individual studies. They are consistent with other evidence (Hökby and Söderqvist 2003; Jacobsen and Hanley 2009; Kriström and Riera 1996; Pearce 1980) that income elasticities for environmental goods are positive but less than one.

Table 3: Cross-sectional income elasticities willingness to pay for quiet

Source of Noise	Elasticity	City and Author
Road	0.3	London (Harris 1979)
	0.68	Basle (Pommerehne1988)
	0.4	Helsinki (Vainio 2001)
	0.7	Edinburgh (Wardman and Bristow 2004)
	0.5	Lisbon (Arsenio et al. 2006)
	0.72-0.78	Copenhagen, (Björner 2004)
Air	0.6	Basle (Pommerehne 1988)
	0.4	Lyon and Manchester (Bristow et al. 2009)
	0.2	Athens (Thanos et al. 2011)
Average	0.5	

Whilst the cross-sectional evidence suggests that quiet is not a luxury good, the question as to how values vary over time remains as unanswered now as when Walters (1975, page 10) commented, "Clearly it would be much more satisfactory if the elasticity obtained from cross-section data were also checked against time series data – but no such data are at present available." Findings from what we believe to be the first exact repeat study in the context of aircraft noise were inconclusive (Wardman et al. 2012). We are therefore here in a position to make a significant contribution to the knowledge base regarding intertemporal variations in values.

As very few studies report the average income of the sample, the income variable is defined as the average per capita GDP for the study year and country (2009 US$). The average is $27,806, ranging from $1,156 to $65,324. Tabulations of valuations per year[11] did not reveal the expected relationship between values and income. There could be confounding effects at work which the multi-dimensional nature of a meta-analysis is well positioned to address.

A related question is whether changes in attitudes, technology and the aural environment have resulted in changes in values over time that are independent of income. We have therefore explored whether there is a residual intertemporal effect after isolating the effect of income with a GDP elasticity of one. Table 4 shows that values obtained in the very early studies, all from the UK, are much higher and exhibit very high variation. This may be related to the relatively underdeveloped state of the valuation methodology or the then much higher individual vehicle noise levels. We note that Wadud (2013) found a positive effect from pre-1965 studies in the HP context. There appears to be no clear trend.

[11] In this case not income adjusted.

Table 4: Values per dB per household per annum by decade (2009 US$)

Decade	Sample	Mean	Standard Error	95% CI (+/- %)	10th and 90th percentiles
Before 1980	15	472.90	223.40	94.48	40.84 2133.74
Eighties	10	58.74	22.66	77.15	0.80 225.82
Nineties	56	92.49	19.63	42.45	3.63 194.25
Noughties	177	133.73	23.23	34.74	1.66 396.18

Attitudinal and socio-economic aspects

A number of studies(13, 14, 17, 43) give segmentations according to respondents' reported annoyance levels. The pattern of values reported in Table 5 is reasonably in line with expectations that values will increase with annoyance, but the confidence intervals are large. There was insufficient consistent evidence available to include other attitudinal or socio-economic segmentations.

Table 5: Values, per dB per household per annum by reported annoyance level (2009 US$)

Annoyance level	Sample	Mean	Standard Error	95% CI +/- %	10th and 90th percentiles
Not at all	13	2.64	0.73	55.30	0.08 8.03
Slightly	13	7.10	1.51	42.53	0.63 15.57
Moderately	13	14.28	4.22	59.10	1.43 46.86
Very	14[12]	12.51	3.58	57.23	1.74 40.23
Extremely	13	22.38	7.12	63.68	1.74 75.63

Design Effects

Representation of noise

A key challenge faced in the valuation of environmental attributes in general and noise in particular within a survey context is that of presenting the attribute of interest in a realistic and understandable fashion. Noise cannot be sensibly presented in the dB units in which it is usually measured. Nevertheless, dB has been used alongside verbal and pictorial

[12] All apply this 5 point scale save one value which simply distinguishes between those very annoyed and those not very annoyed.

illustrations (Nunes and Travisi 2007) and in combination with audio playback of levels (Garrod et al. 2002). Researchers have though in the main sought alternative approaches.

Simple approaches include categorical scales, such as 'very noisy', 'noisy', 'quite noisy' and so on (Wardman and Bristow, 2008), proportionate changes (Pommerehne 1988; Soguel 1994; Thune-Larsen 1995; Wardman and Bristow 2004) and indeed purely descriptive (verbal) explanations. The problem is in relating these scales or descriptions to actual levels of noise and in particular at the evaluation stage to be able to know when a change causes an individual to experience one level of the variable instead of another. Table 6 suggests that these approaches yield values that are not significantly different from each other, although with a large spread.

Table 6: Annual Values per dB per household by representation of noise (2009 US$)

Presentation	Sample	Mean	Standard Error	95% CI (+/- %)	10th and 90th percentiles
% change	26	94.07	14.49	30.81	24.36 194.25
Categories	10	58.71	17.60	59.96	12.70 135.57
Verbal	44	162.75	51.03	62.71	5.32 446.10
Proxy	45	340.75	46.03	27.02	25.73 8881.64
Experienced	20	112.55	21.31	37.87	13.71 246.47
Simulation	4	1949.53	574.71	58.96	n.a.
Decibels	12	8.89	5.48	123.2	1.19 50.31
Combined	4	4.63	1.66	71.71	n.a.
Annoyance	93	8.90	1.29	28.99	1.17 20.66

Respondents can experience the environmental impact at different levels under experimental 'laboratory controlled' conditions, but may be affected by the artificial and usually limited exposure (Samel et al. 2004). There are few applications in the context of noise valuation. Plowden and Sinnot (1977) looked at willingness to accept a noisy device into the home, reporting a host of problems. The very few values from pure simulation yield very high values, casting doubt on the reliability of this method.

A proxy measure, such as traffic levels (Langdon 1978) or aircraft movements (Bristow and Wardman 2006; Carlsson et al. 2004; MVA Consultancy 2007) may be used to imply variations in traffic or aircraft noise. With proxy approaches there will always be some uncertainty as to how respondents translate changes in the proxy variable to changes in noise levels. Table 6 indicates that these values may be higher than most other approaches. However, the only study (Wardman and Bristow, 2008) to compare categorical and proxy approaches found that they yielded similar values.

Experienced variation can take a spatial dimension, whereby the respondent is asked to compare different locations with different noise levels (Arsenio et al. 2006; Pommerrehne 1988), or a temporal dimension, where at the same location there is variation in exposure over time (Barreiro et al. 2005; Duarte and Cladera 2008; Thanos et al. 2011). It is especially attractive in that the differences in noise levels presented to respondents are experienced and objectively measurable.

Table 6 indicates that experiments offering changes in annoyance from transportation noise yield much lower values than other commonly used approaches. This is noteworthy as Navrud (2002) recommended the use of changes in annoyance levels as a direct measure of the change in welfare which can be linked to exposure/response functions and thus indirectly to an objective measure of noise. The meta-analysis will allow us to see if the variations in Table 6 are real effects or are explained by other confounding factors.

SP method

While all the values are derived from CVM or SC experiments, both methods have variants. For CVM, this is particularly so with respect to the payment question, ranging from open ended with no prompts to a double bound referendum with a myriad of options in between. There is some evidence that open ended CVM produce lower values than closed ended methods and that closed ended methods produce results closer to those obtained in SC experiments (Cameron et al. 2002; Ryan and Watson, 2009). The latter might be expected as dichotomous choice CVM is essentially the same as SC with two alternatives whilst the former might be because open ended approaches are associated with a greater cognitive burden and thus greater uncertainty in response than closed ended methods (Hanemann 1996) or indeed SC approaches. Moreover, CVM estimates tend to be lower than those obtained in comparable revealed preference exercises (Carson et al. 1996).

In the context of road transport noise three studies compare CVM with HP and all three find the HP values to be higher (Bjorner et al. 2003; Pommerehne 1988; Vainio 2001)[13] and one compares SC with HP finding values derived from a willingness to pay experiment to be less than the HP values and those from a willingness to accept experiment to be broadly equivalent (Thanos et al. 2011).

Three studies*(21, 24, 42)* report comparable values for open ended CVM and SC, in two cases the SC values are unambiguously higher and in one*(21)* the CVM values are higher at lower noise levels and the SC values higher at higher noise levels. Table 7 also reveals the CVM values to be much lower in our data set. Confounding factors here could be the presence of strategic bias, where the purpose of the study is transparent and/or the treatment of zero values in CVM. We consider this in the meta-analysis. The within study evidence appears to be broadly consistent with evidence from elsewhere that CVM values tend to be lower than those derived from SC or revealed preference approaches. The different types of CVM are examined in the next section alongside consumer surplus measures.

Table 7: Values, per dB per household per annum by basic method (2009 US)

Method	Sample	Mean	Standard Error	95% CI (+/- %)	10th and 90th percentiles
SC	92	266.07	40.54	30.47	3.87 808.48
CVM	166	72.60	22.94	63.20	1.50 148.19

[13] Pommerehne finds the opposite for aircraft noise, but again this may be related to the low experienced levels of aircraft noise.

Consumer surplus measure

The conventional framing for both SC and CVM questions is willingness to pay (WTP) for a gain, which is the compensating gain (CG) measure of consumer surplus, and willingness to accept (WTA) compensation for a loss, which is the compensating loss (CL) measure of surplus. Although CG and CL form the majority of observations in this sample of studies, there are a number of cases[2, 9, 25, 28, 37, 50] where the question is framed in terms of WTP to avoid a loss, the equivalent loss (EL) measure, or WTA to forgo a gain, which is the equivalent gain (EG). Following Bateman *et al., (*2000) conventional economic theory for a normal good would lead us to expect that CG < CL, CG = EL and EG = CL whilst loss aversion would imply CG < CL (as in the conventional theory but now including an effect for loss aversion that increases the expected difference), CG < EL and EG < CL. De Borger and Fosgerau (2008) find that in the presence of constant loss aversion the reference free underlying value of time will be equal to the geometric means of CL and CG and of EL and EG. We are able to test this relationship in the our meta-analysis and we demonstrate in Table 13 that the relationship indeed holds.

The widely cited review by Horowitz and McConnell (2002) found WTA values to be ten times higher than WTP across 17 studies of public or non-market goods (all framed as CL and CG). For the sub-set of 8 studies that seem furthest from being perceived as private goods the ratio increases to 27.57. In this case higher WTA values would be synonymous with a higher value placed on losses than gains. Limited within study evidence suggests that EG values exceed EL values implying that any effect may be due to framing (Bateman et al. 2000; Wardman and Bristow 2008) where respondents state a higher WTA than WTP possibly for strategic reasons, perhaps viewing money payments as more likely than money gains. We can explore this important question here. The clearest effect, in Table 8, is that willingness to pay for a gain results in by far the lowest values and is significantly lower than all the other formats. CL exceeds CG by a ratio of 19.4:1, EL and EG are far less disparate with a ratio of 1.4:1, though here EL is found to be higher. The evidence seems to suggest loss aversion with respect to CG and CL., However, the EL and EG sample means are not significantly different and the limited within study evidence does not find evidence of loss aversion.

Table 8: Values per dB per household per annum by consumer surplus measure (2009 US$,)

Format	Sample	Mean	Standard Error	95% CI (+/- %)	10th and 90th percentiles
WTPgain (CG)	186	32.94	4.49	27.26	1.65 93.76
WTPloss (EL)	9	308.64	94.44	61.20	n.a.
WTAgain (EG)	9	226.01	27.70	24.51	n.a.
WTAloss (CL)	20	639.45	168.77	52.79	123.36 1265.79
Combined in one model	34	376.54	88.71	47.12	11.06 1128.35

It is difficult to explore confounding effects in a review, but it is important to consider whether the framing or the SP approach was influencing the values most. It appears, as can be seen in Table 9, that the effect of different experimental approaches is dominated by the framing in terms of consumer surplus measure. In all cases, values for a CG are lower than the other forms of consumer surplus. As there were very small numbers in some CVM categories, these have been combined where appropriate (open ended plus and closed ended plus involve combinations of approaches).

Table 9: Values per dB per household per annum by valuation experiment and consumer surplus measure (2009 US$) (number of cases in parentheses)

SP method	WTPgain CG	WTPloss EL	WTAgain EG	WTAloss CL	Both
Stated Choice	71.00 (32)	192.04 (7)	204.26 (6)	525.69 (13)	376.55 (34)
Open ended	55.83 (27)	716.75 (2)	261.38 (1)	252.51 (5)	
Payment card	44.50 (13)				
Closed	16.04 (10)				
Open ended plus	12.98 (91)		140.56 (2)		
Closed plus	32.86 (13)			2346.06 (2)	

META-ANALYSIS

Meta-analysis involves assembling large data sets of variables of interest, here noise valuations, and conducting quantitative analysis to explain how they vary. The review served the purpose of describing the sample of valuations in terms of its key characteristics and the relationships apparent relative to the theoretical background, conventional wisdom, specific study findings and policy recommendations. The meta-analysis in this section builds upon the previous discussion by exploring a broader range of variables and doing so simultaneously, thereby enabling interactions to be examined and confounding effects to be reduced. The dependent variable (defined earlier) in the regression analysis is the value in $US 2009 for a one dB change per household per annum. We aim to explain variations in noise valuations across our assembled evidence according to the variables and levels shown in Table 10.

Table 10: Variables and Levels

Variable (or category for dummy variables)	Levels for dummy variables
Noise source	Air; road; rail; combined.
Noise level	Less than 55dBA; 55 to 64dBA; over 65dBA; not available.
Logarithm of GDP per capita/1000	
Annoyance	Not at all; slightly; moderately; very; extremely; not available.
Representation of noise	% change; categories; verbal; proxy; spatial or temporal experienced change; simulation; decibels; decibel plus other explanation; annoyance.
Payment	Weekly; monthly; annual; per journey; house price.
Context	Home; journey.
Time period noise experienced	Day time; evening; weekend; all time periods or unspecified.
Method	CVM; SC.
CVM iterative	Yes; no.
CVM type	Open ended; prompt; prompt high; prompt low; payment card; iterative bidding; closed then open; referendum double interval; payment card then open; one and a half bound; double bound then open; dichotomous choice; open then payment ladder; not CVM.
CVM data trimmed	No exclusions; 5% or fewer excluded; over 5% excluded;

	upper limit; not available; not relevant SC.
CVM treatment of zeros	All included; protests excluded; all zeros excluded; protests and illogicals excluded; non-players excluded; treated in model; unknown; not relevant SC.
Consumer surplus measure	WTPgain (CG); WTPloss (EL); WTAgain (EG); WTAloss (CL); Combined in one model.
Noise measurement	Real; estimated in study; estimated here for analysis.
Transparency of study purpose	Yes; no.
Publication type	Academic journal; conference paper; academic report; government report; other report; book; phd thesis.
Survey type	In-home capi; in-home interview; other interview; phone; postal; web based; hall test; unknown.
Household or individual response	Household; individual; unknown.
Sample size	
Study effects	Study dummies (see Table A1).
Country effects	Canada; Chile; China; Denmark; Finland; France; Germany: Greece; Hong Kong; Hungary; Ireland; Italy; Japan; New Zealand; Norway; Philippines; Portugal; Spain; Sweden; Switzerland; Thailand; United Kingdom; United States.
Decade of study	Pre 1980; 1980-1989; 1990-1999; 2000 to date.

The form of the reported models is multiplicative, as set out in equation 1, and relates the annualised per dB value of noise (N) to n continuous variables (X_i) and p categorical variables (Z_{jk}) where there are q-1 dummy variables for a categorical variable of q levels.

$$N = \tau \prod_{i=1}^{n} X_i^{\alpha_i} e^{\sum_{j=1}^{p} \sum_{k=1}^{q-1} \beta_{jk} Z_{jk}} \tag{1}$$

The α_i denote elasticities of the noise value with respect to the X variables. The β_{jk} are interpreted relative to the arbitrarily omitted level, with the exponential of β_{jk} denoting the proportionate effect on the valuation from level k of the j'th categorical variable relative to its omitted category. A logarithmic transformation of equation 1 allows parameter estimation by least squares. This multiplicative model performed better than the equivalent additive version.

The results, estimated using Stata (StataCorp 2011), are presented in Table 11 for the sample of 257 observations. We report two models, retaining those coefficient estimates that were significant at the 10% level; combining dummy variables where appropriate and including the base level for ease of interpretation.

An initial fixed effects model was estimated, in which the dummy variable fixed effects relate to specific studies that provide more than one valuation. The purpose of these dummy variables was to discern influences that are study specific and are not captured by other variables in the model or the random error term. An example might be the rigour and care with which the study was undertaken or cultural factors. Note that the eight study specific variables did not dominate the estimation and were only responsible for increasing the goodness of fit from 0.764 to 0.847. This model gave a GDP elasticity of 0.990. We therefore fixed the GDP elasticity to be one and tested the time and country specific effects that would otherwise be too entwined with the GDP elasticity to be tested in the same model since GDP varies over countries and time. The decadal dummies were not significant indicating that once income and other confounding effects are allowed for there is no time trend in the data. Three country effects were found to be significant (at which point one study effect dropped out of the model) but with a minor effect on the goodness of fit which increases to 0.860. Although the insignificant constant is retained, its omission made no material difference to the coefficient estimates. We report this model including study specific and country effects as Model I in Table 11.

We then allowed for random effects based separately upon study and country with the latter providing a better fit to the data. In this latter model, all the country effects became insignificant as did some study effects, suggesting that the findings are transferable between countries. We therefore re-estimated this model omitting these insignificant variables and this is reported as Model II. The remaining significant fixed effects are retained as it is felt that these are in some cases early studies applying highly experimental techniques. The discussion of findings below is based on the outputs of our preferred Model I but, as is apparent in Table 11, there is overall little difference between the parameters of the two models.

The model fit is remarkably good given the widely disparate set of studies and the range of countries and time periods covered and our decision to include all available data rather than exclude outliers. We should also point out in this context that correlations between the coefficient estimates are low, with 99% below 0.4 and only one in excess of 0.5.

Table 11: Meta-Regression

	Model I		**Model II**	
Variable	**Coefficient (t statistic)**	**Effect or elasticity**	**Coefficient (t statistic)**	**Effect or elasticity**
Constant	*0.088 (0.29)*		*0.279 (0.64)*	
Noise Source				
Road, rail, combined	Base		Base	
Air	0.869 (5.85)	+138%	0.841 (5.27)	+132%
Noise Level				
Not available and 55 to 64	Base		Base	
Less than 55 dB	-0.689 (2.75)	-50%	-0.465 (1.73)	-37%
Over 65 dB	0.644 (2.68	+90%	0.567 (2.32)	+76%
Intertemporal				
Log per capita GDP/1000	0.986 (10.93)	0.986	0.921 (6.78)	0.921
Attitudinal Effects				
Annoyed Slightly, Moderately, Very and Not Available	Base		Base	
Not at all annoyed	-1.663 (7.73)	-81%	-1.627 (7.76)	-80%
Extremely annoyed	0.522 (2.43)	+68%	0.559 (2.67)	+75%
Representation of Noise				
% Change, Categorical, Verbal, Proxy, Simulation and Experienced	Base		Base	
Decibel plus description	-1.913 (7.78)	-85%	-2.000 (7.70)	-86%
Annoyance	-1.620 (11.69)	-80%	-1.723 (9.64)	-82%
Valuation Context				
Noise at home	Base		Base	
Noise during journey	1.667 (4.44)	+430%	1.580 (2.94)	+385%

Payment method				
Weekly, monthly, annual, per journey	Base		Base	
House price	1.79 (5.80)	+500%	1.62 (4.87)	+406%
Consumer Surplus Measure				
WTPgain (CG)	Base		Base	
WTPloss (EL)	0.821 (2.88)	+127%	0.894 (2.94)	+145%
WTAgain (EG)	1.143 (3.96)	+214%	1.286 (4.47)	+262%
WTAloss (CL)	1.816 (7.97)	+515%	1.775 (7.82)	+490%
Combined in one model	1.710 (9.97)	+453%	1.752 (9.07)	+477%
Study Specific Fixed Effects				
All other studies	Base		Base	
Study 2	2.080 (5.20)	+700%	1.844 (4.17)	+533%
Study 4	2.975 (5.82)	+1859%	2.834(5.25)	+1602%
Study 5	4.010 (6.94)	+5415%	3.881 (6.56)	+4747%
Study 6	1.420 (2.70)	+314%	n.s.	
Study 17	-2.952 (5.62)	-95%	-3.039 (5.63)	-95%
Study 18	-1.689 (3.22)	-82%	-1.744 (3.00)	-83%
Study 25	1.842 (3.38)	+531%	1.873 (2.93)	+551%
Study 30	-1.746 (4.04)	-83%	-1.61 (1.81)	-80%
Country Specific Fixed Effects				
All other countries	Base		Base	
UK	-0.353 (2.87)	-30%	n.s.	
Germany	-0.765 (4.50)	-53%	n.s.	
Italy	-0.846 (1.87)	-57%	n.s.	
Adjusted R^2 (sample size)	0.860 (257)		0.851 (257)	

Influential Variables

Noise Source

The model reveals very much higher values for aviation noise relative to other modes of transport, in line with the annoyance literature. However, the model does not indicate a rail bonus in contrast to the standard finding in the annoyance literature.

Noise Level

Only a limited number of studies reported the noise level and thus the mid-range is subsumed into the base not available category which will contain a wide range of experienced noise levels. The model shows that where experienced noise levels are below

55dB values are lower and where experienced noise is higher values are likewise higher. This is in line with the evidence reviewed earlier.

Intertemporal effects

A key finding is that the elasticity of values to income is 0.986, with a narrow confidence interval of ±18% of the central estimate, somewhat higher than the cross sectional evidence where the average elasticity is about 0.5. This finding is very similar to that in studies of the value of time discussed earlier. We note that the most recent meta-analysis of values of travel time (Abrantes and Wardman, 2011) recovered a very similar GDP elasticity of 0.899 but, despite a sample size nearly seven times larger, did not improve on the confidence interval achieved here.

Attitudinal and socio-economic effects

Slightly, moderately and very annoyed were not significantly different from each other or from the not available category. The not available category (by far the majority of the observations) will contain a broad range of annoyance levels and hence it is not surprising that this is not significantly different from the mid-range annoyance categories. Nonetheless, it is encouraging that the meta-model discerns lower and higher values for the not at all and extremely annoyed categories respectively. The effects are large; those who are extremely annoyed have values nearly nine times higher than those not annoyed. This is a larger difference than that between those who experience lower and higher noise levels confirming the importance of perception and sensitivity in determining noise values.

Design Variables

Representation of noise

In looking at representation, percentage change, categorical, verbal description, proxy, simulation and experienced change form the base because they were found to be insignificantly different. One study applying simulation has extremely high values but this is entered here as a fixed study effect as it may be more a function of the nature of this early study than the approach overall. Studies that frame noise as a change in decibels combined with some verbal description or in terms of levels of annoyance yield very much lower values. The annoyance finding is hard to explain but given the range of approaches that yield broadly similar values then annoyance does appear to be an outlier indicating caution in the use of this approach. This is important as this approach is in common use.

Valuation context

The vast majority of studies explored noise experienced in the home. The small number of studies that examined noise during a journey yielded conspicuously higher values which may reflect real differences in values or may be a function of the need to annualise per journey payments.

Payment method

The payment period over which tax, abstract or other payments were made did not have a significant effect, nor did payment for a journey. Payment through house price does have a large and significant effect. This may be because a house has a high value and if asked about one aspect of it values may be high.

SP method

It was possible to identify an effect whereby CVM values were lower than SC though this was only marginally significant and lost significance once fixed effects were allowed for. In light of the earlier discussion, we chose to retain the consumer surplus measure in the model.

Consumer Surplus Measure

Another key finding is that with respect to whether respondents are asked to pay or accept compensation and whether this is for a gain or a loss. For the most common formats, CL

(WTAloss) exceeds CG (WTPgain) by 6.15:1, a much lower difference than that reported in Table 8. This suggests the presence of confounding factors. Although there are only 20 CL values, these are derived from 7 studies[1, 5, 22, 37, 38, 42, 45] using both CVM and SC approaches. We tested for interaction effects between WTP and WTA and whether the experiment was CVM or SC and none were significant, confirming that it is the framing that influences the value independently of whether the experiment is CVM or SC. We note that the model gives a larger value to EG (WTAgain) than to EL (WTPloss) in contrast to Table 8 but in line with the within study findings reviewed. This does not support loss aversion. The EG/EL format provides broadly similar values for gains/losses and WTP/WTA, a ratio of about 1.4:1, perhaps because these types of choices are more prevalent in real life and thus it is easier for respondents to provide realistic answers.

Insignificant Variables

A large number of design variables were insignificant. These included type of survey, household or individual response, noise measured or estimated, time period of exposure and payment period. It is reassuring to note that the necessary assumptions, outlined earlier, made in specifying the dependent variable were tested in the model and did not influence the outcome. Within CVM, data trimming and treatment of zeros do not appear to influence the results. Study transparency was also not significant.

Issues of Study Quality

This analysis has been as inclusive of studies and values as possible. The main criterion for inclusion was that the study reported a dB value or it was possible to estimate one. Undoubtedly, there will be variations in study quality and hence the robustness of the values reported. However, we wished to avoid making subjective judgements on quality which might, for example, have led to the arbitrary exclusion of high or low values. Furthermore, by including studies from the grey literature and conference papers we aimed to mitigate any publication bias[14]. We have, therefore, undertaken a range of tests, in the light of a common criticism of meta-analysis that it does not control for differing quality of the assembled evidence, although we can note that the model fit is very good suggesting the underlying data is robust.

Firstly, as most studies do not report the variance associated with reported values, we used sample size as a proxy for precision and undertook a weighted estimation. This indicated that the error variance was not related to sample size. Moreover, sample size when entered as an independent variable it had little effect on the coefficient estimates. Secondly, it might be expected that studies in peer reviewed journals are of higher quality, but there was no difference in values based on study source, in line with meta-analyses of value of time and time related elasticities (Abrantes and Wardman 2011; Wardman 2012). Thirdly, fixed effects unique to individual studies have been specified and these will to some extent discern study quality, although we should note that only 8 out of 34 study specific dummy variables were significant[15]. Fourthly, the removal of 5% of observations with a standardised residual outside the range ±2 would arguably have accounted for the poorest quality data. Nonetheless, when we did this it had very little effect on the coefficient estimates. Finally, study quality might be expected to have a random effect on values and hence will be incorporated in the error term. Why should poor studies produce systematically lower or higher values?

ILLUSTRATIVE NOISE VALUATIONS IMPLIED BY META-MODEL

We can use the preferred Model I of Table 11 to produce valuations for a range of different situations. The country and study specific effects are not included, partly because many drop

[14] Publication bias occurs where findings that support the conventional wisdom are deemed more acceptable for publication. However, in the case of noise, the conventional wisdom is not as well developed as it is, for example, with respect to the value of travel time savings, which might serve to minimise any incentive to publication bias.

[15] Three of these were very early studies undertaken at a time when the methodology was evolving.

out when random effects are allowed for, partly because they have a very small overall effect and also because we do not regard them to be genuine influences. This procedure is useful in practice where no valuations exist and to determine preferred valuations based on what we deem to be the most suitable input variables. The values implied by the model can also serve as a reference point against which to compare emerging evidence or official values. Table 12 provides such values across the key dimensions of country, represented by GDP, surplus measure, noise level and annoyance levels (and for illustrative purposes representation and context)[16].

Table 12 Forecast values per household per annum per dB (2009 US$) (country GDP per capita in brackets)

	Hungary ($12,867)			UK ($35,164)			Denmark ($55,992)		
	<55dB	55-64dB	>65dB	<55dB	55-64dB	>65dB	<55dB	55-64dB	>65dB
Road WTPgain	6.81	13.56	25.81	18.34	36.53	69.56	29.02	57.79	110.04
Road WTAloss	41.84	83.34	158.68	112.75	224.57	427.60	178.37	355.26	676.45
Road WTPloss	15.47	30.81	58.67	41.69	83.03	158.09	65.95	131.35	250.10
Road WTAgain	21.35	42.52	80.96	57.52	114.57	218.15	91.00	181.25	345.11
Air WTPgain	16.23	32.33	61.55	43.74	87.11	165.87	69.19	137.81	262.40
Air WTAloss	99.77	198.72	378.38	268.86	535.49	1019.62	425.33	847.13	1613.01
Air WTPloss	36.89	73.47	139.90	99.40	197.98	376.98	157.25	313.20	596.37
Air WTAgain	50.90	101.38	193.04	137.16	273.19	520.18	216.99	432.19	822.92
Road WTPloss not at all annoyed	2.93	5.84	11.12	7.90	15.74	29.97	12.50	24.90	47.41
Road WTPloss extremely annoyed	26.07	51.93	98.88	70.26	139.94	266.45	111.15	221.37	421.52
Road WTPloss annoy (representation)	3.06	6.10	11.61	8.25	16.43	31.29	13.05	25.99	49.49
Road WTPloss Decibelplus	2.28	4.55	8.66	6.15	12.26	23.34	9.74	19.39	36.92
Road WTPloss Journey	81.93	163.19	310.72	220.78	439.74	837.30	349.27	695.66	1324.59

The values vary across the three countries selected to reflect income differentials. Road and air values are given for the four different surplus measures. The values derived using EL (WTPLoss) and EG (WTAgain) fall between the CL (WTAloss) and CG (WTPgain) values

[16] Any variable not explicitly included in the table is at the base level.

and are reasonably close together. Since EL and EG are probably closer to real life decision making and their values lie in the middle range we favour these for value estimation. The remaining values in Table 12 are estimated for road and EL and show the additional effect of annoyance level over and above that of noise level. Values for those not annoyed are only 11% of the values of those who are extremely annoyed.

The Table also shows the very low values obtained when the change in noise levels evaluated is described in terms of dB with verbal description or as annoyance. As previously noted, annoyance is a common form of presentation and yields values that are disturbingly low compared to other approaches. Values derived in the context of a journey are very high.

We can compare the estimated values for the UK with the recommended values in the UK Government's Transport Analysis Guidance (WebTAG) (Department for Transport 2012) which were derived from an HP study of Birmingham. We take their values in UK£ for 2010 for 50, 60 and 70dB to be broadly equivalent to the noise groups used here and convert our estimates to 2010 UK£. We also test the expected relationship considered earlier that the geometric mean of EL and EG and that of CL and CG should be equivalent (De Borger and Fosgerau, 2008). Table 13 shows that the geometric means are within 10% of each other, demonstrating an encouraging degree of correspondence between theory and practice. These geometric means provide the most appropriate SP derived estimated values to compare with the HP derived WebTAG values. The model values are somewhat higher than the WebTAG values but are broadly similar in terms of relativities between noise levels.

Table 13: Comparison of WebTAG and model estimate values at UK £ 2010

Noise level	WebTAG	Geometric Mean CL and CG	Geometric Mean EL and EG
<55dB	24.67	30.94	33.32
55 to 64dB	58.82	61.62	66.06
>65dB	93.09	117.34	126.35

CONCLUSIONS

This paper reports the most extensive review and the first meta-analysis of SP studies of transportation noise nuisance. The meta-analysis is based on a newly compiled data set of 258 values from 49 studies and 23 countries across a 40 year time period. The meta-model has a very good fit given the disparate nature of the data and our decision not to exclude values that might subjectively appear to be outliers. The model recovers significant and plausible effects from a number of key influential variables.

Very notably, this study addresses the longstanding issue first raised by Walters (1975) concerning how environmental valuations vary over time. It provides for the first time an estimate of the intertemporal income elasticity for noise from transportation sources of 0.986, with a narrow confidence interval of ± 18% of the central estimate. This elasticity is higher than the estimates from cross-sectional studies in our review which yield an average cross-sectional income elasticity of 0.5. This pattern of intertemporal and cross-sectional results is highly consistent with evidence relating to the value of travel time savings. We would recommend that valuations of transportation noise nuisance used in appraisal are increased in line with real incomes as they are in the UK. Earlier studies appear to yield higher values independently of any income effect suggesting that values are not increasing over time for reasons other than income.

Values for aviation noise are higher than for other modes and this is in line with the annoyance literature. However, we find no support for a rail “bonus”. The model also recovered the expected variation in values for those who were more or less annoyed and those exposed to higher or lower noise levels.

A wide range of survey and experimental design features were tested but few were significant. Amongst the insignificant variables were those relating to the specification of the dependent variable where a range of essential assumptions had to be made. This is most reassuring. A small number of design effects including the representation of noise as decibels plus description and the use of house prices as a payment vehicle were significant. However, these are not in common usage and this evidence would support their avoidance in future studies. Context was significant in that noise during a journey was valued differently from that experienced at home; this is worthy of future investigation as there is very little evidence on noise values in contexts other than the home.

An important finding, although completely unsurprising, is that the conventional framing of the willingness to pay question in terms of a gain produces values that are demonstrably lower than other approaches. The meta-analysis reveals a large difference between willingness to pay for a gain and willingness to accept a loss (though somewhat lower than that found in the review once other factors are allowed for). Interestingly, the less common approaches of willingness to pay to avoid a loss and willingness to accept to forgo a gain produce values that lie between the other two and are reasonably close together. It is encouraging that the geometric means of the modelled values are consistent with the relationship put forward by De Borger and Fosgerau (2008). As the latter two approaches may also be viewed as closer to real life decision making but are rarely used in SP experiments there is clearly a case for further studies to utilise these forms of framing.

The meta-analysis also reveals some important insights into the use of different representations of noise. A wide range of approaches are found to be insignificantly different. However, the use of decibels with description and annoyance yield very much lower values than other approaches. This is important as annoyance has been recommended as a measure for use in SP studies as it is argued to directly reflect welfare loss. We would contend that the use of annoyance is not appropriate.

Not only does our meta-analysis provide, as we have seen, important insights into how values vary some of which do not emerge from standard literature review, another of the attractions of the method is the ability to provide forecast values where none exist and serves as a useful benchmark against which to assess emerging evidence in the area. We would argue that the values are transferable across countries. We have provided illustrative values and a very encouraging finding is that our estimates for the UK are close to those in UK official guidance derived from an HP study. We would argue that since this model provides usable values across countries, income levels, noise levels and annoyance levels, it provides a significantly firmer basis for deriving values for use in policy and analysis than Navrud was able to provide in 2002.

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APPENDIX 1: Study Details

We here provide a list of the studies used in our analysis and also a summary table of the key features of their noise valuations.

In some cases more than one reference was used to obtain data for a single study, where this is the case all references used are cited below. The study code is given in brackets next to each study. The codes range from 1 to 52 as three studies were excluded after coding as part of the checking process leaving 49 used in our analysis.

The summary Table A1 contains for each study the study code, author and year of publication; country and study year, source of study; sample size; noise source; method; number of values and the range of values (mean, standard deviation, minimum and maximum).

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Appendix Table A1: Key Study Characteristics

Study number[1]	Study	Country and study year	Source	Sample size	Noise source	Method	Number of values	Value per dBA 2009 US$ (not income adjusted) Mean (standard deviation) [Min/Max]
1	Plowden, 1970	UK, 1968	Report	530	Road Air	CVM	1 2	84.92 121.96 (19.48) [102.47-141.44]
2	Ollerhead, 1973	UK, 1972	Report	601	Air	CVM	6	86.95 (49.40) [28.72-161.13]
4	Langdon, 1978	UK, 1972	Journal	2933	Road	CVM	3	70.25 (29.98) [41.48-101.31]
5	Rosman, 1978	UK, 1976	Report	5(a) 24 5(b) 20	Road Road	CVM CVM	1 1	1681.17 633.68
6	Pommerrehne, 1988	Switzerland, 1984	Book chapter	221 221	Air Road	CVM CVM	1 1	68.06 159.09
7	Weinberger, 1992	Germany, 1989	Journal	7000	Road	CVM	8	22.45 (20.10) [0.00-58.64]
8	Soguel, 1994	Switzerland, 1992	Report	200	Road	CVM	1	115.52
9	Feitelson, 1996	USA, 1990	Journal	9(a) 426 9(b) 274	Air Air	CVM CVM	1 1	555.71 336.06
10	Navrud, 2000	Norway, 1999	Conference	10(a) 402 10(b) 184	Road Road & Air	CVM CVM	1 1	21.30 21.30
11	Faburel and Luchini, 2000	France, 1999	Conference	510	Air	CVM	1	14.02
12	Vainio, 2001	Finland, 1993	Conference	418	Road	CVM	2	12.15 (3.34) [9.79-14.51]
13	Lambert et al, 2001	France, 2000	Conference	331	Road	CVM	6	13.36 (4.90) [7.72-21.35]
14	Bjorner, 2004 and Bjorner et al 2003	Denmark, 2002	Journal	857 sub-samples 83-430 by annoyance	Road	CVM	6	28.52 (18.55) [7.06-57.15]
15	Pronello and Diana, 2003	Italy, 2001	Conference	168	Rail	CVM	1	3.80
16	Barreiro et al, 2005	Spain, 1999	Journal	460, sub samples 59-146 by	Road	CVM	3	12.56 (2.18) [10.51-14.85]

				noise level				
17	Martin et al, 2006	Spain, 2004	Journal	296	Road	CVM	2	1.35 (0.29) [1.15-1.56]
18	Duarte and Cladera, 2008	Spain, 2007	Conference	18(a) 309 18(b) 295	Air Road	CVM	1 1	15.49 5.87
19	Kondo et al, 2003	Japan, 1999	Conference	323	Road	CVM	6	14.98 (2.78) [11.92-19.26]
20	Sælinsminde, 1999	Norway, 1993	Journal	1680	Road	SC	1	124.18
21	Thune-Larsen, 1995	Norway, 1994	Report	473 sub-samples by noise level (size unknown)	Air Air Road	SC CVM CVM	4 4 1	73.29 (45.97) [28.93-146.60] 64.67 (30.37 [33.14-113.16] 24.84
22	Willis and Garrod, 1999	UK, 1997	Journal	85	Road and blasting	SC	2	93.40 (53.40([55.64-131.16]
23	Scarpa et al, 2001	UK, 1999	Report	23(a) 413 23(b) 407	Road Road	SC SC	4 4	3.71 (0.64) [2.77-4.54] 2.35 (0.48) [1.95-3.16]
24	Wardman and Bristow, 2004	UK, 1996	Journal	398	Road Road	SC CVM	7 2	74.46 (31.02) [42.41-127.24] 28.49 (7.57) [20.92-36.05]
25	Arsenio et al, 2006	Portugal, 1999	Journal	412	Road	SC	2	126.06 (28.77) [105.72 – 146.41]
26	Galilea and Ortuzar, 2005	Chile, 2002	Journal	150	Road	SC	1	45.90
27	Tudela and Garcia, 2004	Chile, 2003	Conference	151	Road	SC	3	3.57 (2.57) [1.33-6.35]
28	Bristow and Wardman, 2006	28(a) UK, 2002 28(b) France, 2002	Conference	195 208	Air Air	SC SC	8 11	336.74 (213.98) [99.98-839.00] 333.35 (220.62) [109.47-702.92]
29	Caulfield and O'Mahony, 2007	Ireland, 2006	Conference	190	Road	SC	4	89.89 (56.07) [48.79-172.75]
30	Li et al, 2009	Hong Kong, 2007	Journal	667	Road	SC	4	8.95 (3.46) [5.29-13.55]
32	Paramog et al,	Philippines,	Journal	80	Road	SC	2	8.74 (8.49) [2.74-14.75]

	2006	2005						
33	Kim et al, 2003	UK, 2002	Journal	96	Road	SC	2	1410.33 (145.10) [1307.74-1512.94]
34	Eliasson et al, 2002	Sweden, 2000	Conference	100	Road Rail	SC SC	1 1	1977.04 706.80
35	Dave et al, 2009	Portugal, 2008	Conference	106	Road	SC	4	125.98 (12.07) [110.87-140.42]
36	Hunt, 2001	Canada, 1996	Journal	1277	Road	SC	1	227.05
37	Thanos et al, 2011	Greece, 2005	Journal	689	Air	SC	4	75.03 (62.32) [20.78-130.31]
38	Carlsson et al 2004	Sweden, 2003	Journal	717	Air	SC	9	281.11 (215.27) [29.53-720.99]
39	Nunes and Travisi, 2007	Italy, 2005	Journal	482	Rail	SC	2	4.14 (3.96) [1.34-6.94]
40	Walton et al, 2004	New Zealand, 2001	Journal	402	Road	SC	1	44.15
42	MVA, 2007	UK,	Report	42(a) 1737 42(b) 60	Air Air	CVM SC	2 6	84.07 (37.27) [46.80-121.34] 800.90 (308.77) [205.31-1095.15]
43	Navrud et al, 2006	43(a) UK, 2005 43(b) Norway, 2005 43(c) Hungary, 2005 43(d) Germany, 2005 43(e) Spain, 2005 43(f) Sweden, 2005	Report	12 to 469, sub-samples by annoyance 6 to 416 as above 44-523 as above 43-471 as above 37-359 as above 31-471 as above	Road Rail Road Rail Road Rail Road Rail Road Rail Road	CVM CVM CVM CVM CVM CVM CVM CVM CVM CVM CVM	8 8 8 8 8 8 8 8 8 8 8	6.73 (5.52) [0.89-20.34] 3.02 (2.94) [0.61-10.50] 26.12 (14.30) [2.12-54.09] 18.80 (24.61) [2.52-82.92] 1.47 (0.92) [0.29-3.11] 3.75 (0.54) [3.18-4.99] 1.83 (1.18) [0.12-4.10] 6.13 (4.01) [0.06-10.86] 6.97 (2.80) [2.44-11.49] 5.21 (1.43) [2.73-7.79] 15.90 (10.35) [3.17-38.67]

44	Zhao et al, 2010	China, 2009	Conference	102	Road	CVM	1	6.86
45	Caplen et al, 2000	UK, 1998	Journal	116	Air	CVM	4	134.32 (105.22) [41.01-285.23]
46	Baughn and Savill, 1994	UK, 1993	Report	13	Road	CVM	1	14.21
47	Navrud, 1997	Norway, 1996	Report	1000	Road	CVM	1	2.44
48	Wibe, 1997	Sweden, 1995	Report	2322	Road and other	CVM	1	36.88
49	Sharp, 1973	UK, 1972	Report	30	Road	CVM	1	3.67
50	Wardman et al, 2012	UK, 2012	Conference	565	Air	SC	3	150.71 (166.01) [27.87-339.58]
51	Lera-Lopez, 2012	Spain, 2009	Journal	900	Road	CVM	1	1.14
52	Charlermpong and Klaikleung, 2012	Thailand, 2010	Conference	189	Air	SC	1	74.32

[1]Studies originally numbered 3, 31 and 41 were excluded from the data set as the method and /or noise source was not comparable.