The Economic Valuation of Noise in Portugal: Some findings from its former stated preference experiment

E. Arsenio[a] and J. Patrício[b]

[a,b] *Laboratório Nacional de Engenharia Civil, Av Brasil 101, 1700-066 Lisboa, Portugal, earsenio@lnec.pt and jpatricio@lnec.pt*

ABSTRACT: This paper is drawn from the state-of-the-art on existing theories, valuation methods and studies for valuing transport related environmental externalities. It reports the former experiment in Portugal using a disaggregated valuation approach for valuing traffic noise.
As part of a research study at the Institute for Transport Studies, University of Leeds, a computer survey was developed for valuing traffic noise externalities (along with other environmental attributes) focusing in the Lisbon market context. The improved valuation methodology integrated refinements in the Stated Preference (SP) method and two other valuation approaches (Revealed Preference, Contingent Valuation). The issue of convergent validity of noise estimates was sought, as well as the possible transferability of noise values across other contexts. The effects of a wide range of variables related to each surveyed household on the marginal valuations of noise (situational, attitudinal, exposure to traffic noise, perceptions, socio-economic, etc.) were tested. The modelling work used 4944 valid SP observations.
This paper presents the range of noise values estimated from multinomial logit models with additional effects and the mixed logit specifications. Marginal values can be possible inputs within a cost-benefit analysis framework of transportation plans or noise mitigation actions. More research is required on using SP methods to valuing transport related environmental impacts (externalities).

1. INTRODUCTION

The economic dimension of the environmental externalities' problem in Europe [6,7] made a strong point for developing appropriate valuation methods to assess the environmental impacts of road transport. Using a behavioural and microeconomics focus, one can say that traffic related impacts such as noise affect negatively individuals' well-being and quality of life, compromising sustainability objectives.

A range of techniques is available from the environmental economics literature, but their application to value traffic induced externalities is neither direct nor a sole discipline's problem. The synthesis ability of researchers to incorporate contributions of relevant areas such as transport economics and modeling, environmental and mathematical psychology, behavioural economics and acoustics is being a major challenge. Although a preferred valuation approach cannot be yet recommended for major environmental externalities, there has been an increasing interest on exploring the advantage of Stated Preference-choice approach (choice experiments).

As part of a research study, it was developed a novel computer survey centered on the Stated Preference-choice method to value traffic noise externalities in Lisbon [1,2]. The issue of convergent validity of noise estimates was sought, as well as the possible transferability of noise values across other contexts.

2. THEORY AND METHODS FOR VALUING TRANSPORT NOISE EXTERNALITIES

2.1 Background

The valuation of transport related noise refers to a non-marketed public bad. This is an area less well developed in theory and in practice than the valuation of marketed private goods. Following Pearce [9], economic valuation is about "measuring the preferences" of people for an environmental good (or against an environmental bad). Therefore, the problem of valuing traffic noise externalities can be converted into the valuation of individuals' preferences for quiet (or to avoid noise).

One can find in the environmental and transport economics literature several classifications for the existing valuation techniques that can be used to estimate values of environmental goods (bads) for which no real market exists (Figure 1).

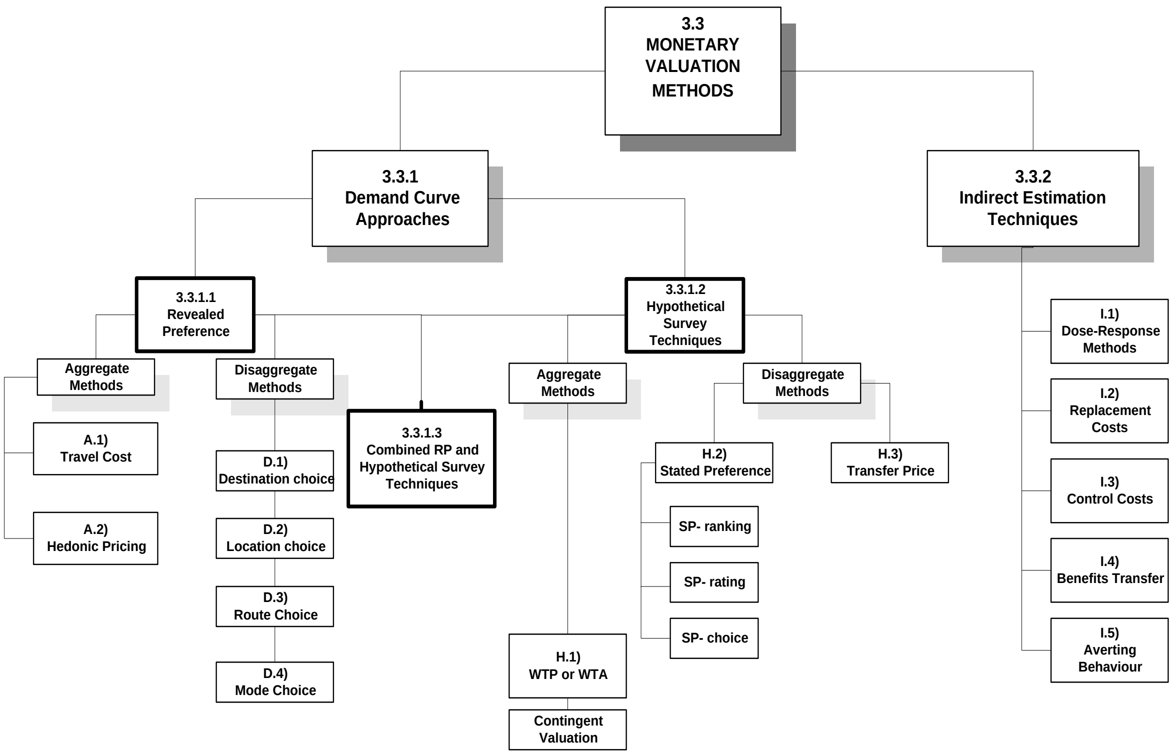


Figure 1 – *Monetary Valuation Methods [2].*

Existing methods were critically reviewed and analyzed following relevant criteria [1]:

- Early developments, applications and acceptability;
- Theoretical principles, assumptions and recent methodological developments;
- Theoretical consistency;
- Major drawbacks and/or advantages if applied to value traffic noise externalities.

This paper reports the research findings for the SP-choice method (Table 1). The family of SP techniques rely on decompositional (disaggregate) methods for modelling individual's behaviour (e.g. for choosing houses or transport modes) when they are faced with a set of mutually exclusive and exhaustive alternatives described as a bundle of specific attributes.

Using a random utility theory framework, individuals who face a set of available alternatives are expected to act rationally and choose the "package of attributes" (or alternative) that conducts to his/her maximum utility. When modelling individuals' behaviour, the researcher is an external observer of the system and does not have the full information of the factors that have influenced peoples' choices. Therefore, it is postulated that for each alternative *i* and individual *k*, the total utility U_{ik} associated to a specific choice (observation of behaviour) is a sum of a deterministic (or systematic) component V_{ik}, and an unobserved error term ε_{ik}:

$$U_{ik} = V_{ik} + \varepsilon_{ik}. \tag{1}$$

It is interesting to note that this formulation allows "apparent irrationalities" in behaviour [6]:

1) Two individuals facing the same choice set and having the same observable attributes may select a different alternative;
2) If one considers the observable attributes, some individuals make not select the best alternative all the time.

From random utility theory, it is expected that the probability of an individual to choose a specific alternative will increase as the deterministic (observable) utility component increases. Several statistical distributions for the error terms are possible to set as well as functional forms for the utility functions, leading to different discrete choice models.

One interesting challenge when valuing a transport related externality is to adequately specify the deterministic component of the utility, and this means to find the best functional forms for the range of influential effects on marginal valuations to be considered. This requires an interdisciplinary (integrated) modelling approach.

The SP data has several advantages over the revealed preference (RP) data for the purpose of valuing noise using a controlled choice context:

- Multicollinearity (e.g. between noise and air pollution attributes) can be easily avoided by design;
- Range of attributes' levels is not limited to the availability of data and situations;

- Elicitation of individuals preferences for future (not yet existing) alternatives involving environmental improvements (or deteriorations) is possible;
- Various response formats can be obtained, which also means more convenient values' estimates units.

Table 1 – *The SP-choice method [1]*.

Origins Luce and Suppes (1965)/probabilistic choice theory; Luce (1959)/multinomial logit; Manski (1977)/probabilistic model of choice set generation ;McFadden (1974); Green and Rao (1971);Green and Srinivasin (1978)
Early Applications For earlier studies (70s) see Ortuzar (1980); Travel demand forecasting in 1981; Wardman, Bristow and Hodgson (1997)
Type of Applications (Generic) Forecasting consumer/traveller behaviour;Valuation of non-market attributes (or its relative importance)
Governmental and others acceptability SP/Guides to Practice exist;UK DoT -Value of Time Study
Preferred Suitability Assessing individual's preferences towards various alternatives of investment (e.g. transport improvements that will correspond different levels of provision of environmental quality) in urban areas; Estimation of demand elasticities for the various attributes that characterise each alternative (e.g. decrease in noise levels associated to various transport scenarios).
Assumptions Random Utility Theory
Necessary Data to Collect (Independent variables) Responses (Observations) of individual's preferences for each alternative (set of attributes)/trade-off information.
Dependent Variable Choices.
Estimation Techniques Maximum likelihood; Random Coeff. Logit: Maximum Likelihood using Monte Carlo Integration Nested Logit: Sequential and Simultaneous Estimation
Consistency with Practical Issues Potential biases; Design of SP; IIA property taste variation
Validity Avoid biases and overcome problems; compare estimates with RP data
More recent variants of the SP Combined RP and SP models SP for valuing environmental attributes

2. 2 The SP-choice computer survey

As part of a broader research study [1], it was developed a computer survey model to valuing traffic noise externalities, including other environmental attributes at the micro level comprising simulated apartment choices within the same residential area. Considering that this would be a novel experiment, a wide range of variables (socio-economic, attitudinal, behavioural, householders' perceptions, annoyance effects, etc.) was included in the survey, and aimed to be tested as possible influential variables on the marginal values of quiet. Around 192 variable types were collected, as well as 220 samples of noise levels indoors.

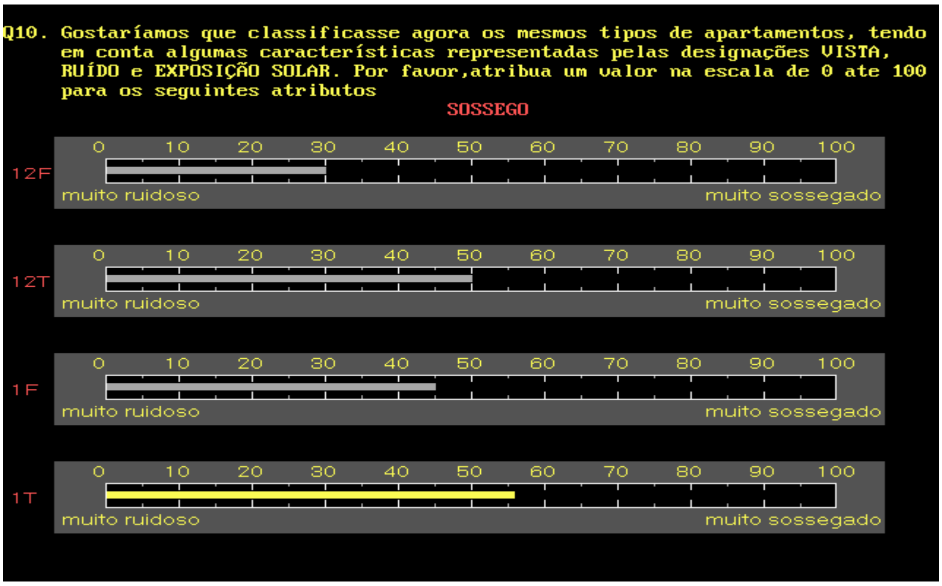
In order to assess the convergent valid of noise values' estimates, two other alternative methods were also considered in the computer survey: a) the revealed preference information on the real apartment choices of the households (choices *ex ante* and *ex post*) and willingness-to-pay questions (Contingent Valuation method) for environmental improvements (or to avoid deteriorations in the levels of stressors).

The simulated market involved repeated binary apartment choice situations at the level of the building (same lot) of the respondent. Householders were offered twelve apartment choice (binary choices of apartment alternatives were presented at a time), randomly selected within 16 possible choices. Noise was represented as a subjective attribute able to be attached to each householder context (exposure to traffic noise) and experience (levels perceived at the current and familiar situations).

Four noise levels' situations were selected: a) at the current apartment choice (*status quo*); b) at an apartment located in the same floor and the opposite façade; b) at an apartment located in another extreme floor and the same façade; and c) levels at an apartment located in another extreme floor and the opposite façade. These locations were though to be both realistic and simple in the sense that often households choose to live either in lower or upper floors, fronting the main road or at the back to it. Therefore, respondents could rate and compare in relative terms the attributes perceived in various selected apartment situations (Figure 2, in Portuguese). This is in line with the relative perception's theory [10].

The SP-choice experiment used respondents' perceptions of the indoor noise levels (ratings scales were used), and these were related to the real physical measures collected in situ. Ratings were expected to provide more information than the physical quantities. "Perception is the process of interpreting and making sense of the information which we receive via our senses" [5], and therefore if situations are familiar to respondents their perceptions will reflect their attitudes as well.

The computer aided personal interviews were administered to more than 400 households in Lisbon, which lead to 4944 valid SP observations for discrete choice modelling work.



“Sossego”= Quietness 0 (“Very noisy”); 100 (“Very Quiet”)

Figure 2 – Rating scale for the attribute “Levels of Noise/Quietness as perceived indoors”.

4. ECONOMETRIC MODELS AND MARGINAL VALUES OF QUIET

4.1 Discrete Choice Models

The statistical analysis of the situational, socio-economic, behavioural and attitudinal data related to each household was firstly conducted. This was a useful base for the modelling stage in order to assure consistency with the characteristics of the sample. These results also served as additional criteria for assessing the theoretical plausibility of the models.

The following econometric models were developed using the SP, RP and CVM data:
- Unsegmented binary logit choice models (base models);
- Multinomial logit models with covariates (influential variables);
- Mixed logit models with covariates;
- Non-linear regression WTP models.

This papers focus on models estimated with the SP data (simulated housing market), unsegmented and mixed logit with covariates.

4.2 Marginal Values of Quiet

The mixed logit models have provided the best fit to the data and performed better in explaining individuals' preferences. Table 2 reports one of the final mixed logit models estimated using Gauss [1].

Table 2: Final Mixed Logit model.

Variable Description	MEAN (t-stats)	Standard Deviation (t-stats)
Deteriorations in quiet levels (base)	0.0473 (2.54)	-
Improvements in quiet levels (base) ♦	0.0439 (2.49)	0.0206 (8.61)
Interaction of quiet with general flat exposure (dummy var for back) ♦	0.0673 (5.93)	0.0548 (6.47)
Interaction of quiet with number of years living at the site (dummy var NYL ≥ 5) ♦	-0.02346 (-2.19)	0.0214 (2.66)
Interaction of quiet with less familiarity to choice context (lot) ♦	-0.01143 (-0.83)	0.0531 (5.56)
Interaction of quiet with gender ♦	0.02698 (2.977)	0.0472 (4.07)
Interaction of quiet with size of quiet changes relative to the base level of quiet(/1000)♣	-0.00352 (-2.281)	-
Interaction of quiet with dummy for floor number ≥ 4	0.01518 (1.414)	-
Interaction of Housing Service Charge Levels with Current Payment (/10^6)	0.00596 (3.12)	-
Housing Service Charge deflated by Household Income per person ♣♣	-0.03281 (-3.26)	-
Interaction of Housing Service Charge with missing information on income	-0.00022 (-3.28)	-
View ♦♦	-3.527 (-24.9)	0.911 (5.749)
Sun Exposure ♦	0.0391 (7.181)	0.0544 (6.415)

Units used in the estimation: Housing Service Charge in 1999 Escudos (1 Euro=200.482 Escudos); Income per person is in 1999 Thousand Escudos. Quiet, Sun Exposure and View (as perceived): 0 –100 (from worse to best level of the variable, e.g. 0 means "very noisy" and 100 "very quiet"). ♣ Functional form: Quiet*(Quiet-Base Level in the *status quo*)^2

♣♣ Functional form: Housing Service Charge/Income per person $^{0.5}$

♦Normal Distribution. ♦♦ Log-normal distribution. Note that estimation gives the log (coefficient estimate).

Overall, the models developed were able to capture several influential variables on the marginal values of quiet, such as:

- adjusted household income per person;
- apartment floor number (height/distance to noise source);
- number of years living at the apartment;
- gender (context specific);
- size of the environmental change (small effect).
- sign of environmental changes (small effect).

In order to compute an example of marginal valuations, it is considered a male respondent who has lived for less than 5 years in a lower flat (floor number < 4), paying a base housing service charge of 37.4 Euros per month. The selected household chooses an apartment that is quieter than the current one (Table 3). Considering the rating scale used 100 correspondents to the best level of the variable (e.g. very quiet) and 0 to the worst level (e.g. very noisy).

Table 3: Marginal Value of Quiet per unit of perceived improvement.

Euros per household per month				**Marginal Values of Quiet**	
Adjusted Income per person per household*	**Experienced Noise Level in the current apartment**	**Quiet Level**	**Improvement Size**	**Flat exp. Fronting main road**	**Flat exp. quieter façade (back)**
149,6	60	70	10	1,3	3,7
	60	80	20	1,1	3,4
	40	50	10	1,4	3,7
	40	60	20	1,2	3,5
299,3	60	70	10	2,2	5,9
	60	80	20	1,7	5,5
	40	50	10	2,2	6,0
	40	60	20	1,9	5,7

*Unit values: Euros per person of the household per month.

Table 3 shows that the marginal value of quiet is around 3 times higher for an household located at the quieter façade than the same one fronting the main road. It shall be noted that these marginal valuations are point estimates.

Table 4 shows the 95% confidence intervals for the household located at the back façade. The method used was the simulation of multivariate normal variates, i.e. the parameters of the best fit mixed model estimated [1] were computed from a multivariate normal distribution.

Table 4: Confidence Intervals for the Marginal Value of Quiet:
Situation: Household exposed at the quieter façade.

Adjusted Income per person per household*	Marginal Value of Quiet point estimate	Simulation Mean	Lower Limit	Upper Limit	Interval Size
149,6	3,7	2,9	1,9	4,6	2,7
	3,4	2,7	1,7	4,2	2,5
	3,7	3,0	1,9	4,6	2,7
	3,5	2,8	1,8	4,3	2,6
299,3	5,9	4,2	2,6	6,6	4,0
	5,5	3,9	2,3	6,2	3,9
	6,0	4,3	2,6	6,6	4,0
	5,7	4,0	2,4	6,4	4,0

*Unit values: Euros per person of the household per month.

5. CONCLUSIONS

The computer survey explored respondent's experience with the levels of the attributes at the current apartment, and his/her familiarity in other situations (not necessarily) experienced in the same building. This conveyed a greater level of realism in the simulated market of apartment choices (SP-choice scenarios). Whereas the use of respondent's perceptions is not new in choice experiments, the link of the "perceived environmental attributes" with apartment situations fronting the main road and at the quieter façade and with lower-upper floors was novel. The use of computer aided personal interviews at the home of the respondents contributed to a high acceptability and made it possible to deal with a more complex design and presentation of the attributes.

As a result of an interdisciplinary approach, the survey integrated a wide range of variables related to the household and the situation in the block and exposure to main road such as socio-economic, behaviour when indoors and towards averting noise, perceptions and attitudes. These served as test variables when evaluating the influential factors of individual's preferences for the environmental attributes.

The modelling work conducted was novel in considering householders' heterogeneity (nature and extent) of preferences on the marginal valuations of traffic noise externalities in the home. Models based on perceptions were statistically superior to those estimated based on physical noise measures. This fact points out the importance of non-acoustical factors in explaining households' preferences for quiet.

The Mixed Logit specifications provided the best fit with the data. This allows the curvature of the indirect utility function to vary across individuals of the same observed heterogeneity (i.e. same observed variables such as income, etc.). The models developed were able to capture several influential variables on the marginal values of quiet such as the adjusted household income per person, apartment floor number (height/distance to noise source), number of years living at the apartment, gender, sign and sign of environmental changes. The implication of this result means that the marginal valuations of environmental attributes in the housing market need to consider the issue of taste variation within the population.

The income elasticity of marginal values of quiet was found to be less than one (0.5). This was a convergent result to the models estimated using revealed preference data.

Although the SP results are promising since value estimates were theoretically plausible, it is recommended that more research can be conducted in other land use (e.g. residential, office/business) contexts for valuing transport related environmental externalities. Valuation studies related with other transport modes (e.g. air and rail) would be important to be conducted, in order to have comparable values' estimates to road traffic.

Reliable values' estimates can be useful inputs to be integrated within a cost-benefit analysis framework (e.g. strategic environmental assessment of a high speed railway corridor). On the other hand, marginal values of traffic noise are required for transport policy purposes and to help setting noise mitigation plans in urban areas.

REFERENCES

[1] Arsenio, E. The Valuation of Environmental Externalities: a stated preference case study on traffic noise in Lisbon. PhD thesis, Institute for Transport Studies, University of Leeds, UK, 2002.

[2] Arsenio, E. Bristow, A. Wardman, M. Silva, F. The Valuation of Noise and Air Pollution: Is there any Best Practice?. In Proceedings of the 19th International Conference of the International Impact Association, University of Strathclyde, Glasgow, 1999.

[3] Arsenio, E. Bristow, A. and Wardman, M. (2000). *An Innovative Stated Preference Computer Survey Model for Valuing Noise Impacts from Road Traffic*. Proceedings of the European Transport Conference (Behavioural Modelling), P441, 67-80.

[5] Cave, S. *Applying Psychology to the Environment*, Hodder & Stoughton, England, 1998.

[6] CEC, Commission of the European Communities. *Towards Fair and Efficient Pricing in Transport*. (Communication by Neil Kinnock to the European Commission), COM(95) 691 Final. Brussels, 1995.

[7] ECMT. *Efficient Transport for Europe: Policies for Internalisation of External Costs*. European Conference of Ministers of Transport, Paris, 1998.

[8] Ortúzar , J. de D. Willumsen, L. G. . *Modelling Transport (2nd edition)*. John Wiley and Sons, Chichester, 1998.

[9] Pearce, D. *Economic Values and the Natural World*, Earthscan, London, 1993.

[10] Shepard, R. *Psychological relations and Psychological scales: on the status of direct psychophysical measurements*. Journal of Mathematical Psychology, 24, pp. 21-57, 1981.