# The Valuation of Environmental Externalities:
# A stated preference case study on traffic noise in Lisbon

by

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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# Abstract

This research study was motivated by the need to valuing environmental externalities from road transport. The main objective was to develop a methodology centered on the Stated Preference-choice (SP-choice) method for valuing traffic noise when individuals are in their homes. The aim was to assess the nature and extent of households' heterogeneity of preferences for quiet. For this purpose, two different metrics of the noise variable were used to estimate the marginal values of quiet, ratings based on household's perceptions and the physical noise measures in Leq dB(A).

An innovative computer survey model was developed and administered to more than 400 households in a residential area in Lisbon with high-rise residential buildings in the vicinity of main roads. The experimental design explored respondents' familiarity and experience with perceived noise levels indoors in various apartment situations and at different floors of the block (lot). Lower and upper floors and their exposure to road traffic (fronting the main road or located at the back façade) played a central role in the experimental design. A range of situational, socio-economic, behavioral and attitudinal variables relating to each household were collected. Physical noise measurements were taken at each apartment (indoors and at the exterior façade) and related to respondents' perceptions. Complementary methods such as the revealed preference (RP) data on apartment purchases and the open-ended contingent valuation method (CVM) were also included. The issue of convergent validity of noise value estimates for the same sample of respondents was explored.

Multinomial Logit models including additional effects (MNL-INT) of a wide range of variables were explored, as well as combined MNL-INT with additional variables with random parameters' logit specifications (Mixed Logit, ML). In brief, the study found that models based on respondent's perceptions outperformed those based on physical noise measures. A range of other influential variables were found to interact with householders' preferences such as adjusted household income per person, sign of noise changes (improvements or deterioration in the levels), floor number, base noise level experienced, and others. The ML specifications gave a better fit with the data. The income elasticity of marginal values of quiet was of similar magnitude in the SP-choice and RP methods, but a weak income effect was detected when using the CVM data. Nevertheless, the strategic bias may have affected both the SP-choice and CVM experimental markets. The noise value estimates were in the range of estimates found in other studies.

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# CHAPTER 1:
# INTRODUCTION

## 1.1 SETTING THE CONTEXT: THE NEED FOR VALUING ENVIRONMENTAL EXTERNALITIES FROM TRANSPORT

Interest in the economic "*valuation of the environment*" is not new (see for example, Clawson (1959), Davis (1963), Rosen (1974), Freeman (1979), Mitchell and Carson (1989), OECD (1989), Pearce (1993a), OECD (1994)). The vast literature on environmental economics shows that great attention has been given to natural and environmental resources for the purpose of damage assessment and benefit estimation.

It was after Neil Kinnock's Green Paper to the European Commission (CEC 1995) that a significant shift of focus emerged with regard to transport *externalities*[1] placing special attention on the negative impacts of road transport (mainly accidents, air pollution, noise and congestion effects). These were seen to account for over 90% of the total external costs of the sector, and were believed to be a major cause for an economically inefficient transport sector. Although the problem of transport externalities was earlier debated (ECMT, 1994), the mentioned Green Paper heightened their economic importance in the European context.

The High Level Group on Transport Infrastructure Charging led the European Commission to publish the White Paper on "fair payment for infrastructure use" (CEC 1998). This is built on previous concerns that "all users of transport infrastructures should pay for the costs, including environmental and other external impacts, they impose". To this end, the work conducted by the ECMT Task Force on the Social Cost of Transport (ECMT 1998) gave useful directions towards the internalization of external costs, through a combination of regulations and economic instruments. For this purpose, the various interested countries would need a detailed inventory of the revenues and costs associated to each transport mode.

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[1] In the literature reviewed, transport externalities are also termed alternatively as external effects, external impacts or as external costs.

In Portugal, the Transport Secretary of State/DGTT commissioned in 1998 a study to evaluate the cost coverage of the road transport sector for six categories of vehicles (CESUR/ITEP/LNEC 2000). In this study, the costs of road transport, including those related to noise, air pollution and accident externalities, were compared with revenues at the national level. In the UK, a research study for the DETR focused both on road and rail transport at a national level (Sansom et al. 2001). This study compared fully allocated costs with revenues (cost coverage perspective), as well as marginal costs with revenues (efficiency perspective). Both studies identified some limitations concerning the evaluation of environmental externalities, mainly because environmental data at the more disaggregate level (e.g. individual noise values, population exposure) did not exist, and a range of working assumptions had to be made.

There is a relevant body of research projects at the European level[2], but with the exception of the ExternE project[3], most studies were centered in the "efficient pricing" issue and its implementation in the transport sector. For example, the strategic models developed in TRENEN II STRAN and PETS aimed to compare marginal social costs with existing prices (Nash et al. 2001). Most research projects have largely used state of the art values of the marginal costs of transport externalities.

From my perspective, the marginal social cost pricing related research work brought a new challenge to the interdisciplinary field of transport-environmental economics and econometric modelling: the need to develop appropriate valuation techniques, to assess the negative environmental impacts of road transport that affect individuals' well-being and quality of life.

If one can say that environmental externalities contribute significantly to transport economic inefficiency, other reasons can be brought in to justify the interest on their valuation:

- sustainability issues, and individuals' preferences for environmental quality at the community level;
- project appraisal (e.g. integration of monetary valuations of the environmental impacts into cost-benefit analysis of road transport infrastructures);

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[2] PETS (Pricing European Transport Networks); FISCUS (Cost Evaluation and Financing Schemes for Urban Transport); EUROTOLL (European project for Toll and Pricing Strategies); UNITE (Unification of Marginal Costs and Accounts for Transport Efficiency); TRENEN II STRAN, etc.

[3] ExternE/IER (1997) project on the External Costs of Transport in ExternE- Externalities of Energy, Programme Joule III of the European Commission.

- environmental impact assessment studies of transport infrastructures (include environmental costs of the foreseen impacts) ;
- transport-environmental policy, inform the establishment of environmental standards and choice of economic instruments;
- environmental damage compensation (e.g. to the population exposed to noise impacts), evaluation of the benefits of noise abatement policies, etc..

Recent studies conducted by INFRAS/IWW (1995, 2000) for the UIC found that noise and air pollution (excluding climate change effects) can be estimated to represent respectively 7% and 25% of the total external costs in the 15 EU member states plus Norway and Switzerland (1995 prices). Although transport noise external costs do not have the higher share in terms of GDP, "noise is generally perceived by urban residents as the first and foremost problem associated with road traffic" (OECD 1999).

## 1.2 VALUING TRANSPORT EXTERNALITIES: DIFFICULTIES TO OVERCOME

Although the theory, methods and practice of economic valuation are well established, there is not yet an agreement on the best approach to follow for valuing environmental externalities from transport. Some of the difficulties in valuing traffic-induced externalities have already been rehearsed in the literature through various perspectives, and the following critical issues can be pointed out:

- the relation between pollutant doses, individuals' exposure and their potential impacts, e.g. on human health, might not be linear (non-linearities can relate to other influential factors such as individuals' sensitivity to that specific pollutant) but need additional scientific proof;
- environmental impacts can be of various types, and their discrimination is not always possible with the same level of confidence (see for example the World Health Organisation (WHO) guideline values (Berglund et al. 1999) for the adverse effects of noise on health);
- the presence of more that one community pollution source (e.g. road and rail traffic) might exert a cumulative impact which is more difficult to estimate;
- environmental impacts have a temporal dimension which can be markedly of short, medium or long-term;

- the population exposed to the specific pollution source might not be aware of all potential impacts, namely those that affect health.

The relative complexity of the problem demands an interdisciplinary approach able to integrate contributions from various fields. Moreover, the valuation approach to build is to a certain extent dependent on the physical nature of the specific pollutant and its impacts (e.g. if stressor levels are noticeable by the exposed individuals and measurable).

Current scientific knowledge on the quantification of the effects of certain air pollutants at the strategic level (e.g. greenhouse gas emissions and their contribution to global warming) is still associated with a significant level of uncertainty (see for example, European Commission (2001), Colvile et al. 2001). On the other side, most strategic impacts are intrinsically transnational, and might depend on trade-environment policies (Pearson 2000).

At the local level, noise and air pollution are the most significant environmental impacts from road traffic. According to the valuation studies reviewed by the ECMT (1998), estimates of the external costs of road noise range from 0.06 to 2% of the GDP, and from 0.03 to 3% of the GDP for the case of air pollution. The ECMT (1998) noted that these estimates are bound to suffer from "relatively great uncertainty and aggregation". The wide range of values obtained seem to reflect that different valuation methods were used by countries, besides the possible differences in the preferences of the population. Further research efforts need to be made to conclude if a specific valuation approach can be recommended. For the case of valuing noise nuisance, the ECMT (1998) refers that "*stated preference could be regarded as an indicator of what is desirable and avoidance programs as a minimum measure of what is feasible (based on policies actually implemented)*". Recently, Pearce and Özdemiroglu et al. (2002) concluded that if the context of valuation is cost-benefit analysis for example, the welfare theory-consistent approaches that can be used are only choice experiments.

## 1.3 OPPORTUNITIES FOR RESEARCH: A CASE FOR VALUING TRAFFIC NOISE EXTERNALITIES IN THE LISBON CONTEXT

According to the WHO (Berglund et al. 1999), around 40% of the population in the European Union is exposed to road traffic noise levels exceeding 55 dB(A) Leq (daytime), and approximately 20% are exposed to noise levels above 65 dB(A). This situation is an indicator of the magnitude of the noise problem in terms of its potential effects on the exposed population, such as annoyance, interference with individuals' well-being and quality of life.

In Portugal, a survey carried out in 1989 (DGQA 1990) showed that 49% of the population surveyed (sample of 600 individuals living in cities with more than 50000 inhabitants) perceived noise from road traffic as the main disturbance problem. Another study conducted by the Portuguese Ministry of the Environment (DGA 1996) showed that high levels of population exposure to noise from road traffic occurred in Lisbon, where 25% of the population is estimated to be exposed to noise levels between 65 dB(A) and 70 dB(A). As road transport accounts for almost 90% of the passengers and 70% of the goods transported (MEPAT/JAE, 1997), it can be said that the problem of noise generated in this context is an important issue and thus a case for valuing noise exists. Previous valuation studies in Portugal that focused on road transport externalities have identified the need to have reliable country databases and estimates of noise values at the individual level (ISEG/CEETA 1992, CESUR/ITEP/LNEC 2000). The INFRAS/IWW (1995) reported lack of reliability of the noise exposure and traffic data for Portugal.

The INFRAS/IWW (2000) study estimated a total WTP for noise of 416 Million of Euros per year for Portugal (68% of these costs are due to annoyance effects and the other part due to health effects of noise exposure as cardiac infractions). Considering the empirical studies reviewed by INFRAS/IWW (2000), the WTP per dB(A) ranged from 0.09% to 0.12% (share of per capita income).

Overall, the valuation literature dedicated to the environmental impacts of road transport shows a deeper research gap with regards to noise. Indeed, the few valuation studies on traffic noise makes it difficult to compare and validate different value estimates (conducted in different contexts, using different methodologies). Looking at the stressor "noise from road traffic", the following properties can be remarked:

- noise impacts are spatially limited and are mainly perceived in the area within the vicinity of transport activities;
- traffic noise as a dominant source is physically measurable - as a whole *output*, with adequate accuracy;
- for specific levels of the *stimuli,* noise is readily perceived by the exposed population as being a bad;
- noise impacts are predominantly short term, and reactions to noise are readily observable (e.g. installation of double glazing, complaints, etc.);

- noise from road traffic can be considered as bad, depending not only on the levels of the *stimuli* but also on individuals' characteristics (e.g. sensitivity to noise, age, etc.) besides other non-acoustical factors in the specific context.

The inherent subjectivity on the meaning of noise, that can be different for each person exposed to the same measured levels, seems to point out the interest on exploring the advantages of valuation approaches based on data gathered at the individual decision level. This is a case to support the use of stated preference techniques. As individuals code the different stimuli on internal scales that exist in their own minds (Garcia-Mira et al. 1997), an individual's experience with different noise levels in the context and their perceptions can be considered a critical issue in the simulated experimental markets for deriving consistent values of noise.

## 1.4 OBJECTIVES OF THE STUDY

This thesis will be focusing on a specific environmental externality well perceived at the community level – noise from road traffic. The context chosen for valuing traffic noise externalities is the residential one, i.e. when individuals are in their homes.

According to Pearce (1993a), 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 can be converted into the valuation of individuals' preferences for quiet (noise).

The main objectives of the research study can be summarized as:

- to develop a methodology to obtain monetary valuations of the noise externalities in the residential environment, based on stated preference-choice methods;
- to use individual's perceptions of the noise levels in the valuation context set, and to compare discrete choice models' based on perceptions with those based on the real physical measures indoors;
- to derive marginal cost estimates attached to environmental gains (e.g. reduction in the levels of noise) and losses (e.g. increases in the levels of noise), and to consider the wide range of behavioural, attitudinal and contextual variables besides the characteristics of the respondents and their perceptions in assessing individuals' heterogeneity of preferences for quiet (noise) when indoors;

- to address the issue of convergent validity of noise value estimates by using more than one alternative valuation technique.

One of the main requirements for choosing the case study area was that traffic noise would be the dominant environmental pollutant source in the area, and that the influence of other possible noise sources is insignificant. Other critical issues were related to the socio-economic diversity of the population (e.g. households of different income categories) and noise exposure conditions. This context is common in metropolitan areas such as Lisbon, where main roads (e.g. urban expressways) with continuous traffic all day are usually in the vicinity of the residential land use. The noise valuation methodology is applied in a residential area in Lisbon (case study), as it benefited from the collaboration of the LNEC/Department of Transportation and Acoustics.

The SP noise model explored the fact that buildings have different conditions of exposure to traffic noise (e.g. a quieter façade always exists in comparison to the one that is directly (or more) exposed). The methodological focus was on implementing and validating the model for assessing the heterogeneity of preferences for traffic noise.

This research benefited from an earlier SP experiment conducted by Wardman et al. (1998) that aimed to value air pollution and noise from households and businesses in Edinburgh. In this research the noise variable is expressed by using individual's perceptions and these are related to the equivalent physical noise measures (indoors and outdoors). Discrete choice models based on perceptions are to be compared with those based on physical noise measures. Considering the wide range of variables collected during the main survey related to each household and context, multinomial models with interaction terms and mixed logit model with random parameters are developed to assess the nature and extent of householders' heterogeneity of preferences for quiet (noise). In the thesis the issue of "convergent validity" will be assessed by means of deriving noise values with alternative valuation techniques to the SP- choice such as the CVM and RP- choice methods.

## 1.5 THESIS STRUCTURE

This chapter considered the rationale for valuing environmental externalities from road transport, and the interest in developing the most appropriate valuation method to value noise from road traffic. Chapter 2 provides an integrated review of the theory and methods for valuing environmental externalities. The suitability of existing approaches for valuing environmental externalities, namely traffic noise, is assessed considering the SWOT

(Strengths, Weaknesses, Opportunities, Threats) analysis of the different methods. The most suitable approaches for valuing traffic noise are outlined.

The theoretical background is followed by Chapter 3 which gives the literature review of noise valuation studies that used stated-preference techniques. This provides some useful insights for methodological developments.

As a result of both chapters 2 and 3, the use of Stated Preference techniques for building an innovative noise valuation model is discussed in Chapter 4. The overall survey design is presented as a comprehensive model structure, integrating significant contributions from acoustics engineering, psychophysics and theory of perception, studies on community reactions to traffic noise. The SP design is then presented and the main methodological innovations discussed.

Chapter 5 presents the pilot and the main survey data collection conducted in Lisbon by means of computer aided personal interviews at the home, as well as the noise measurements data collection.

The analysis of the situational, socio-economic, behavioural and attitudinal data related to the sampled householders is conducted in Chapter 6. The analysis here focuses on householders' perceptions and attitudes towards noise when indoors, awareness of the negative impacts of noise and annoyance effects. Models that relate respondents' perceptions with the physical noise measures are also derived.

It follows Chapter 7 where a detailed analysis of the stated preference data is conducted. Alternative models are examined: multinomial specifications with interaction effects of behavioural and socio-economic variables, and mixed logit specifications allowing for taste variation and repeated observations. In the models the noise variable is expressed by using relative perceptions and the equivalent physical noise measures. A comparison of discrete choice models is made.

Chapter 8 presents an alternative modelling approaches for valuing noise derived from the Revealed Preference data on housing choices. Following the methodology in the previous chapter, models based on perceptions and the physical noise measures are estimated.

Chapter 9 presents another alternative approach for valuing noise: the Contingent Valuation method. Non-linear regression models are estimated for each case as before.

The various findings from models in chapters 7, 8, and 9 are then compared in chapter 10, where the issue of convergent validity of noise value estimates is discussed for the same sample of respondents.

Finally, the research is summarized in chapter 11 where the main findings are outlined. Further recommendations for conducting other valuation studies on noise externalities are derived, and needs for future research are identified.

# CHAPTER 2: THEORY AND METHODS FOR VALUING ENVIRONMENTAL EXTERNALITIES FROM ROAD TRANSPORT

## 2.1 INTRODUCTION

This chapter reviews the existing theory and methods that can be used for valuing environmental externalities from road transport. This is considered a fundamental step towards the development of a valuation model of the traffic noise externalities in the residential environment.

The valuation of environmental externalities such as noise from road traffic 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. As suggested by Pearce et al. (1989), the absence of markets in environmental services creates a practical problem of measurement - i.e. one of finding out what peoples' preferences actually are in a context where there are apparent markets - but it does not generate a conceptual problem of measurement.

The remainder of this chapter is organised as follows. Section 2.2 presents the various valuation methods and its usual taxonomy. The main valuation approaches are reviewed in section 2.3. The suitability of the existing approaches for valuing traffic noise externalities is conducted through a SWOT analysis in section 2.4. The main findings are outlined in section 2.5.

## 2.2 TAXONOMY OF THE VALUATION METHODS

Although several techniques can be used to derive estimates of the value of environmental goods (bads) for which no real market exists, there seems not to exist yet a common established taxonomy to represent the universe of the "*non-market valuation techniques*". Table 2.1 represents a synthesis of some classifications found in the transport and environmental economics literature.

**Table 2.1: Taxonomy of the Valuation Methods.**

| |
|---|
| **Bateman and Turner (1992). Evaluation of the Environment.**<br>Demand Curve approaches: revealed preference methods (travel cost, hedonic pricing); Expressed Preference techniques (contingent valuation)<br>Non-Demand Curve approaches: indirect estimation techniques |
| **CEC(1994). Cost-Benefit Analysis and Multi-Criteria Analysis for New Road Construction.**<br>Direct money values<br>Quasi-market observations - Implied Market decisions: revealed preference, hedonic pricing and Travel Cost method; Experimental market techniques: Stated preference, contigent valuation; Surrogate market methods: replacement cost method, shadow prices, surrogate markets.<br>Weights: Points allocation; The ratio method<br>Descriptive Methods |
| **Verhoef (1994). External Effects and Social Costs of Road Transport.**<br>Behavioural linkage techniques: Travel Cost method, Hedonic pricing and Household Production function approach and hypothetical markets (contingent valuation)<br>Non-behavioural techniques: dose-response or damage cost.<br>Shortcut approaches: abatement programs' costs |
| **ECMT (1996). The Valuation of Environmental Externalities.**<br>Revealed Preference techniques: Hedonic Pricing and Travel Cost method.<br>Stated Preference techniques: Contingent Valuation, Conjoint Analysis<br>Avoidance Cost or Replacement Costs<br>Dose-response techiques |
| **ADB (1996). Economic Valuation of Environmental Impacts.**<br>Primary economic valuation methods: revealed preference and stated preference<br>Secondary valuation methods: benefits transfer<br>Alternative monetisation strategies: cost-of-illness measures, etc. |
| **INFRAS/IWW (1995 and 2000). External Effects of Transport.**<br>Welfare Maximisation approach: Resource approach; Utility approach; Prevention approach<br>Risk approach: Diversification approach; Insurance approach; Prevention approach |

In order to analyse further the main valuation techniques used, the following taxonomy is adopted:

1: Implied Market Decisions – 1.1 Travel Cost Method; 1.2 Hedonic Pricing; 1.3 Other Revealed preference methods of market decisions.

2: Experimental Market Techniques – 2.1 Contingent Valuation; 2.2 Stated Preference Techniques.

## 2.3 MONETARY VALUATION METHODS

The main valuation methods are critically reviewed considering the following items:

- 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.

### 2.3.1 THE TRAVEL COST METHOD

**a) Early developments, applications and acceptability**

The Travel Cost Method (TCM) is also designated in the literature as the Clawson method or Clawson-Knetsch approach (Clawson 1959). Travel cost models are based on an extension of the theory of consumer demand in which special attention is paid to the value of time (OECD 1989). The TCM usually usues actual observations of travel and recreational decisions to derive estimates of the value people place on recreational sites such as national parks (use value). The statistical relationship between revealed behaviour (e.g. visitation rates to a site) and the total costs (travel, etc.) involved is used as a surrogate demand curve from which consumer's surplus (e.g. per visit per capita-day) can be obtained.

One of the first applications of the TCM (zonal TCM) was in the valuation of recreational sites and this can be found in Wood and Trice (1958), Knetsch (1963) and Clawson and Knetsch (1966). The root of this non-market valuation technique can be found in Hotelling[1] (1931), the resource economist who noted that observed behaviour (e.g. trips made for a

[1] Hanley and Spash (1993) say that it was originated in a letter from Hotelling to the director of the US Park Service in 1947.

recreation site) can be used to obtain a demand curve for an environmental good, and hence a use value of the site/good can be derived.

**b)Theoretical principles, assumptions and recent methodological developments**

The theoretical principles of the TCM are very simple: if an individual has to face consumption costs (e.g. travel costs, travel time, on-site expenditures, entry fees, etc.) to use/enjoy an environmental asset, these can be taken to establish a surrogate market where prices can be derived. This is equivalent to say that individuals consume public goods jointly with private market goods that are related to it, and derive utilities of the public good through consuming the services provided by it. This is the so called 'weak complementarity' assumption (Maler, 1974), and it represents the dual relation between the environmental asset and the related consumption expenditure. This implies that, when consumption expenditure is zero (no trips are made) to a specific site where environmental improvements have been made, the marginal valuation of the relevant environmental assets is also zero. This is subject to various critics, in the view of the "*total economic value*" concept.

Traditional travel cost models explain the demand for number of trips over a specified time horizon (generally a season or year) for either one or several recreational sites or activities (Bockstael, 1995). The theoretical framework for the general TCM can be taken from the household production model of Becker (1965), as presented by Bockstael (1995). The household's decision process can be characterised by the maximisation of utility U derived from a vector of commodities *z (*market goods have price *p)* subject to the income (embodies a cost function C(•) implied by the household technology) and time constraints:

$$max\, U(z) \text{ , subject to}$$

$$\left[K + W(t_w\ )\right]\left(1 - \tau\ \right) - C\left(z, T_z, p\ \right) = 0$$

$$T - t_w - t'_z\, z = 0$$

where $K$ is non-wage income, $t_W$ is the hours worked, $W(t_W)$ is earned income, $\iota$ is the marginal tax rate, $t_Z$ is a vector of per-unit household time costs for producing the vector of commodities, $T$ is the total time available. In this model, trips to the site can be viewed as an essential input in the production of the heterogeneous commodity 'recreational experience'.

The TCM assumes two basic general forms: individual or zonal, the first one is more preferred in situations where some behavioural response sensivity to environmental changes is required. The individual travel cost approach is used to predict the number of visits (dependent variable is usually trips per annum) that will be undertaken by an individual (dummy variables can be added to represent the purpose of the trip, income level, etc.) to a certain site. Travel Cost data is collected for each individual, taking into account the time and costs from a known origin to enter a site. The zonal TCM is used for a segmented valuation of the site taking into account the different zones for trips origins (usually administrative districts), or to predict trips to a site per zone. A demand curve is estimated using multiple regression analysis, and one can explore for example different combinations of entrance fees to the site and expected number of visits.

There exists in the literature other versions of the TCM, such as the Hedonic TCM which has been used to value changes in the attributes of environmental recreational goods (see for example Brown and Mendelsohn, 1984 and Englin and Mendelsohn, 1991), and count models that allow discrete integer values for the dependent variable including non-participants/visitors and participants (see Hellerstein and Mendelsohn, 1992 as cited by Bockstael, 1995). In the Hedonic TCM each individual user has a conditional utility function given that he/she has decided to take a recreational trip. Individuals are assumed to be willing to incur different levels of costs when visiting/using different recreational sites due to their differentiated levels of characteristics (environmental, etc.). This means that given fixed trip costs plus increasing costs associated with increasing expenditures to reach alternative sites (distance and time costs), and all else fixed, the individual will choose a more distant site if it provides higher levels of desired characteristics or attributes. From the regression of travel costs (from one origin to each possible destination sites) on the characteristics at each site, one can estimate a hedonic price function (or value function as called by Brown and Mendelsohn 1984) of those attributes. Therefore, marginal values (partial derivative of the hedonic price function) are estimated for each characteristic, as in the hedonic price method. Also, one can estimate the demand for the specific attribute across all origins and destinations (regressing the average level of characteristics demanded by different groups of individuals at each site on prices of those attributes). Some of the problems found in this approach refer to the fact that negative price values can be obtained for attributes which in fact have positive marginal values, and this problematic result was obtained namely by Bockstael et al.(1987) when estimating the value of water quality improvements. Negative marginal values are related to undesirable attributes, meaning either that the individual would drive further to have less of the good or that he is oversatiated with the desirable attribute/characteristic. Englin and Mendelsohn (1991), for example, have used the hedonic TCM and have verified that several forest attributes have satiation levels below which the attribute is a good and above which the attribute becomes a bad. The TCM assumes the separability of the individual's *utility* function for the environmental good being valued, i.e. the demand for it can be estimated independently of the demand for other alternative goods. Another assumption is that the number of trips to a site will decrease if associated travel costs increase. As referred by Hanley and Spash (1993), travel cost models are estimated not only for particular sites but also for groups of sites (see for example the Willis and Benson (1989) study on UK forests ). The latter approach might be the most appropriate when information about substitute sites of the particular one being valued (e.g. cross elasticities) are available.

**c) Theoretical Consistency**

The principles and theoretical assumptions of the TCM are not always suitable for all environmental valuation problems. Practical issues demand that the analyst verify the consistency of underlying hypotheses and assumptions of the method for the current valuation problem, and moreover if the main limitations found can be overcome. For example, if an individual visits the site being valued as part of a multi-purpose trip, total travel costs refer to the whole trip, so the survey analyst has to establish a weighting scheme, e.g. asking individuals to score in a specific scale the importance of a visit to that site. With a random utility recreational demand model, one can imagine an individual choosing among alternative sites, for example with different environmental characteristics. The additional time and money that he/she is willing-to-pay to use the site yields information for valuing those attributes.

Time and monetary elements of travel cost can be expected to be highly correlated, so the omission of time can bias the travel cost coefficient upward, thus biasing consumer surplus estimates downward (see example of possible trade-off between money cost and time cost on recreational benefit's estimation in Cesario and Knetsch, 1970 referred by Bockstael (1995)). The time bias was a past difficulty in most studies of recreational benefits using the TCM, as the disutility of overcoming distance was only taken as a function of money costs. So Cesario and Knetsch in the 1970's proposed a corrected cost function, making the visit rate a function of both money and time cost.

More recent developments of the TCM include the Hedonic TCM, sample select models, count models and the random utility discrete choice model, already mentioned. Next, a theoretical reformulation of the TCM using a random utility framework is presented

(Bockstael 1995; McFadden 1974). Assuming that the utility function of an individual who visits site *i* is:

$$V_i\left(E_i, y - p_i - wt_i\ \right)$$

on a given 'choice occasion', conditional on the prior decision of taking the trip[2], being $E_i$ the quality characteristics (vector) at the site, $y$ the related budget for the specific time period and $p_i + wt_i$ the cost of accessing the site.

If there are a set *S* of alternative sites (choices), the individual will choose site *i* if

$$V_i\left(E_i, y - p_i - wt_i\ \right) = \max\ \left(\mathrm{V_s}(E_s, y - p_s - wt_s)\forall_s \in S\right.$$

The utility function is assumed to be a linear function of the explanatory variables with a stochastic term $\theta$ :

$$V_j\left(E_j, y - pj_j - wt_j\ \right) = \theta_{1} E_{j} + \theta_2 \text{ (y-pj-wtj)} + \eta_j$$

If $\eta$ has an independent extreme-value distribution, a conditional logit model can be applied to estimate the probability of an individual choosing site i

$$\mathrm{Prob}(i) = \frac{\exp(\theta\ x_i)}{\sum \exp(\theta\ x_s\ )}$$

As the leisure budget *y* is the same for the set of sites S, it does not enter into the estimation. The independence of irrelevant alternative assumption (the choice of one site over another is independent of the other alternative sites set) implies that the ratio of the probabilities of choosing two alternatives *i* and *k* is a function only of the difference in the explanatory variables:

$$\frac{\mathrm{Prob}(i)}{\mathrm{Prob}(k)} = \exp\ (\theta_1\ (E_i - E_k) + \theta_2\ (p_i + wt_j - p_k - wt_k))$$

In the case of dependence among the alternative sites, the nested logit model is appropriate (McFadden 1978).

**d) Major drawbacks and/or advantages if applied to value traffic noise externalites**

In the USA, early in 1979 the Water Resources Council set forth the TCM (and also the contingent valuation method that is later discussed in this section) as accepted techniques for valuing the benefits of proposed water resources projects. However, 'it is hard to think of useful applications of the travel cost method with respect to the European transport sector, with the possible exception of valuation of certain forms of land take for new transport infrastructure' (ECMT 1996). Several points around the TCM are next discussed:

[2] This approach avoids in this way the need to deal directly with the time allocation problem.

- The TCM assumes that demand structures are identical and that preferences among individuals are the same. However, even if one can control for differences in income, differences in tastes, for example, are more difficult to deal with using an aggregate approach;
- Values are only derived by those who are participants (travellers to the site), so there is a problem of 'truncation bias' when estimating the demand curve for the site (aggregate revealed behaviour often requires re-weighting, as environmental quality improvements will attract new visitors that are at present non-participants/travellers to the site). Smith and Desvousges (1985) and Shaw (1988), for example have already studied further this bias, and others have provided alternative modelling strategies (e.g. Yu-Lan, 1994). The recent development of sample select models (example: tobit model) allow for both participanting and non-participating decisions (non-zero and zero trips) with the same demand function, by including an error term. Different likelihood functions can be associated with different assumptions for the error component of the demand function (Heckman 1979);
- Where one uses the estimated trip demand function based on actual behaviour for example to predict responses to changes in environmental quality, and if only users' data of that site was considered, one can expect possible sample selection bias. A more disaggregate and sensitive approach is therefore preferable in this case;
- The zonal TCM is based on averaging the independent variables (e.g. income, travel costs, etc.) to represent the different travel characteristics of travellers from a particular zone. This can lead to a relatively small variation between groups (e.g. income population levels of different zones) which in reality will correspond to individuals with differentiated behavioural patterns and attribute valuations (e.g. value of leisure time). As noted by McFadden (1974) the process of averaging the independent variables can lead to seriously biased parameter estimates and forecasts. Although we can control the zone analysis unit chosen in the TCM, in practice existing data on the independent variables is often limited to administrative zones (e.g. districts);
- In the TCM valuations are assumed to be independent of the actual demand for the site (number of users) which does not take into account the effects of congestion (these are important in the context of environmental valuation, as they influence environmental quality);
- Values for the attributes such as value of leisure and working time are assumed by the analyst. Therefore in the process of aggregating data, these can influence the results, originating biased valuations in the end.

Table 2.2 makes a sysnthesis of the main items covered for the TCM.

**Table 2.2: Synthesis Table for the Travel Cost Method.**

| | |
|---|---|
| **Origins** | Hotelling (1931)<br>Becker (1965) |
| **Early Applications** | Wood and Trice (1958)<br>Knetsh (1963)<br>Clawson and Knetsh (1966) |
| **Type of Applications (Generic)** | Natural Capital Recreation or Leisure Modelling: forests, natural parks, fishing, hunting, etc.; Valuation of site attributes (Hedonic TCM) |
| **Governmental and others acceptability** | US Water Resources Council in 1979<br>UK Forestry Commission in 1989 |
| **Preferred Suitability** | Use value of an environmental recreational goods to which a large number of visitors are attracted |
| **Assumptions** | Weak Complementarity<br>Separability of the Utility Function |
| **Necessary Data to Collect (Independent variables)** | Socio-Economic Variables (Population): Income, Age, Sex, Education, etc.<br>Purpose of the trip; trip frequency (e.g. trips per annum for each ; O-D matrix; Travel Costs (distance, time, entrance fees, etc.) |
| **Dependent Variable** | Trips per annum (individual TCM)<br>Trips per capita per zone (zonal TCM) |
| **Estimation Technique** | Multiple Regression Analysis/Maximum Likelihood |
| **Consistency with Practical Issues** | Sample Selection Bias, other biases and problems to overcome (multi-purpose trips, holiday-makers, price of substitute goods, etc.) |
| **Validity** | 'Current research does not tell us how close travel cost estimates come to 'true' user value' (Hanley and Spash, 1993).<br>Dependency on the effect of environmental changes on prices in the surrogate market<br>'It is hard to think of useful applications of the TCM with respect to the European transport sector...' (ECMT 1996). |
| **More recent variants of the TCM** | Hedonic Travel Cost Method<br>Count models<br>Random Utility (Discrete Choice) Recreation Demand Model |

### 2.3.2 THE HEDONIC PRICING METHOD

#### a) Early developments, applications and acceptability

The Hedonic pricing technique is based on Lancaster's theory of household consumption (Lancaster, 1966). The Hedonic Pricing (HP) valuation method relies on observations of consumer behaviour on a surrogate market, usually the housing market which is defined as a bundle of valuable attributes (physical characteristics, environmental, etc.) from which implicit prices can be derived. McLeod (1984), for example confirmed the importance of local (dis)amenities in explaining housing prices.

Most of the hedonic studies look at the impact on property prices of environmental attributes. However, some wage risk studies can also be found in the literature using the same principles of the HP technique: the wage rate paid for a job (instead of housing price) as a way of expressing labour market forces between supply and demand is the surrogate for safety risks and health. In the UK, Marin and Psacharoupoulos (1982) have tested the theory against empirical evidence on wage rates and death rates in several occupations for the period 1970-72. A latter study by Jones-Lee et al. (1985) which obtained information on the value of the risk of death using a contingent valuation approach, supports the figures obtained previously for the value of life.

One of the earliest HP studies with a special reference to air pollution was published in the late 60s by Ridker and Henning (1967). More recent applications are to be referred to in chapter 3.

#### b) Theoretical principles and assumptions

According to Lancaster (1966), any good possesses a finite number of attributes and it is these attributes (and not the good itself) that are subject to valuation by individuals (consumers). For example, when one individual buys a residential property, she/he is effectively buying a 'residential bundle' composed by physical features (e.g. house type) and surrounding social and environmental attributes associated to that specific property location. Hedonic prices are therefore defined as the implicit prices of attributes that are revealed from observed prices of differentiated products (e.g. different housing locations and different amounts/levels of attributes associated with them).

The theory of hedonic pricing, as formulated by Rosen (1974) is a problem in the economics of spatial equilibrium, so that the marginal bid of an increase in an environmental attribute is equal to its implicit price in the surrogate market. Let **H** be the vector of housing characteristics:

$$H = (hc_1, hc_2, hc_3, \ldots, hc_n)$$

where $hc_j$ is the $j^{th}$ characteristic of the house. If individual households behave identically in the market they will maximize their utility function:

$$U = U(H, \mathbf{G}, \mathbf{A})$$

where G is the vector of market goods available locally and A is a vector of local amenities. The above utility function is constrained by the household monetary income I:

$$I = \boldsymbol{P_g G} + P_h H$$

where $P_g$ is the vector of prices for local market goods, $P_h$ the price of housing (note that housing is a vector of environmental and other attributes). One can solve the last two equations as simultaneous and solve them for H and G, and then obtain an indirect utility function $V$ that relates utility to income, house price, house characteristics, market goods and environmental attributes:

$$V = V(I, P_h, \mathbf{P_g}, \mathbf{A})$$

Assuming that individuals behave freely within the market, a equilibrium point for a constant level of utility, V* will be achieved. Looking at the last equation, one can express it in an equivalent form (at market equilibrium), using now a function on housing prices:

$$P_h{}^* = P_h(V^*, I, \mathbf{A}, \mathbf{P_g})$$

As **A** is a vector of local amenities, here defined as noise levels $a_1$ and air pollution levels $a_2$, one can differentiate the last equation with respect to $a_1$, holding V*, I and $P_g$ constant:

$$\frac{dP_h}{da_1} = -(\partial V^*/\partial a_1)/(\partial V^*/\partial P_h)$$

This equation represents the marginal utility for an improvement in noise levels, and gives the willingness to pay at the equilibrium for that improvement

Following the same process, noise levels' marginal implicit prices can be derived from differentiating the vendor's house price opportunity locus equation (willingness to sell prices): $P_h{}^M = P_h{}^M(I, \mathbf{H}, \mathbf{A}, \mathbf{P_g})$ in order to variable $a_1$. Note that at the market equilibrium (willingness to pay x willingness to sell demand equations), the marginal implicit price for the environmental attribute derived from the housing market (vendor's house price opportunity locus) is equal to the willingness to pay for the marginal improvement[3].

This also relies on the basic assumption that observed variation in housing prices (surrogate market) can be explained in terms of differences in its characteristics. However, if individuals have poor information, e.g. about the variation in environmental characteristics's variation across the housing market, then implicit prices cannot be taken as marginal benefits.

The HP technique involves two fundamental estimation steps: 1) estimation of the hedonic function (variables include physical attributes of the house, indicators of accessibility, indicators of environmental quality, etc.), and to derive the implicit prices for each environmental variable and; 2) estimation of the demand curve for that environmental attribute (e.g. demand curve for quiet). The first stage of the hedonic price approach is to estimate the relationship between property values $P_h^M$ and environmental quality attributes such as site characteristics $\mathbf{S_i}$ neighbourhood characteristics $\mathbf{N_j}$ and environmental characteristics $\mathbf{A_k}$ such as noise levels and air quality:

$$P_h = f[\mathbf{S}_i, \mathbf{N}_j, \mathbf{A}_k] \quad i=1,m \quad j=1,n \quad k=1,l$$

For this purpose the analyst must gather data on house sale prices and all characteristics of the property relevant to the individual's values formation. This estimated relationship is then used, for example, to infer costs of environmental pollution (the hedonic price equation can be estimated through ordinary least squares).

The partial derivative with respect to any characteristic gives its implicit price and this will vary with the level of bad (e.g. noise levels), assuming a non linear function.

Stage two, the estimation of a demand curve for environmental quality is done for example, by regressing implicit prices against air quality and noise levels and relevant socio-economic variables. In this stage, one shall observe the assumptions about the supply side of the market (e.g. residential site air quality), namely if it can be considered fixed (or not).

**c) Theoretical Consistency**

One of the main problems to overcome when using this technique is the fact that the independent variables of interest are often correlated. Air pollution levels can be correlated with noise, for example in most urbanised areas. Morover, this technique implies that the price households are willing to pay for a residence can be fully explained by specific measures of the relevant characteristics (number of rooms, particulate matter concentration

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[3] This theoretical model was adapted from Garrod and Willis (1992a).
**Bold** notation is used for vectors.

levels, etc.), and this requires that the environmental variables selected and their measures reflect an individual's perceptions.

The assumption of perfect equilibrium in the surrogate market (e.g. housing market) is questionable, as in reality there exists imperfect information and sometimes high transaction costs on moving house (this fails to address the equilibrium condition reached by individuals who are able to move freely in the market). The equilibrium assumption also implies that the price paid for a housing property represents the highest bidder and individual's maximum WTP for that 'package of attributes'.

**d) Major Drawbacks and/or advantages if applied for valuing noise**

One of the advantages of the HP method is that the estimation of the marginal prices are relatively straightforward. However, it assumes that there is a continuous variation in the attribute being valued (e.g. levels of noise ) and that all combinations are available in the market, and this can be difficult to verify in some cases. If the combinations of attributes that maximize the household's utility given current prices are not available in the present (but can be availabe in the future), the observed price of each characteristic will be different from marginal WTP.

Like the TCM, the weak complementary assumption is assumed in the HP method, so this technique cannot be used to estimate non-use values. Neverthless, this is not a revelant issue for the present research, and thus does not constitute a criteria to exclude the use of the HP technique for valuing traffic noise externalities.

Another problem to overcome when using an hedonic approach is to deal with the possibility of market segmentation. Michaels and Smith (1990) for example used the hedonic property value model to estimate how households value avoiding proximity to landfills containing hazardous wastes in suburban Boston in the USA, and found that a single price function was not adequate for describing the determinants of the real sales prices due to the existence of different housing sub-markets. In what concerns the valuation of noise, a problem arises when buyers assume averting behaviour in their minds, e.g. they can install double glazing and filters to improve conditions inside the home, and so they might not consider these attributes important in the housing purchase decision. In practice the application of this technique faces also the problem of having the necessary data at the level of disaggregation wanted (e.g. house prices for different housing characteristics on different locations, data on the specific attributes selected, other explanatory variables).

In order to obtain confidence intervals when using this technique, several issues are important to analyse: 1) the degree of equilibrium in the housing market; 2) suitability of the independent variables to explain housing prices; 3) degree of segmentation of the market; 4) test of at least two functional forms in the hedonic price function; 5) reliable data on housing prices and attributes.

Table 2.3 makes a synthesis of the main items covered for the HP method.

**Table 2.3: Synthesis Table for The Hedonic Pricing Method.**

| | |
|---|---|
| **Origins** | Lancaster (1966)<br>Rosen (1974) |
| **Early Applications** | Ridker and Henning (1967)/air pollution |
| **Type of Applications (Generic)** | Use value of environmental goods |
| **Governmental and others acceptability** | OECD (1989: pp.30) |
| **Preferred Suitability** | Estimate costs of air and noise pollution on the residential environment (if effects are clear to respondents, and if the chosen attributes can explain housing prices);<br>Not adequate to estimate non-use values. |
| **Assumptions** | Weak Complementarity<br>Separability of the utility function<br>Equilibrium in the surrogate market |
| **Necessary Data to Collect (Independent variables)** | Socio-economic variables (population): Income, Age, Sex, Education, etc. and attributes selected (e.g. levels of noise; CO concentration levels, etc.). |
| **Dependent Variable** | Housing prices<br>Marginal prices (for estimating marginal bid functions)<br>Wage rates |
| **Estimation Technique** | Multiple Regression Analysis/Maximum Likelihood or Ordinary Least Squares |
| **Consistency with Practical Issues** | Correlation between environmental attributes (multi-collinearity)<br>Measurement errors (associated with independent variables such as noise levels and air quality/pollutant levels measurements)<br>Market Segmentation<br>Perfect equilibrium in the housing market<br>Averting behaviour |
| **Validity** | Observation of assumptions<br>Need complementary information (e.g. on the real housing attributes that had explained choices) |
| **Variants of the HP** | Wage Risk studies |

### 2.3.3 OTHER REVEALED PREFERENCE METHODS ON MARKET DECISIONS

Besides the HP and TCM, there are other valuation methods based on individuals' actual market decisions. Indeed, revealed preference techniques (RP) based on actual choices (e.g. of mode and route) had been extensively used in transport demand analysis (Ortùzar and Willumsen 1998). Using a random utility theory framework, individuals facing a set of available alternatives described by several attributes are expected to act rationally and select the alternative that conducts to his/her maximum utility. Since the modeller in an observer of the system and does not have full information of the factors that influence people's choices, he/she postulates that for each alternative *i* and individual *k*, the total utility $U_{ik}$ associated to a particular choice (observation of behaviour) is a sum of a deterministic (or systematic) component $V_{ik}$ , and an unobservable error term (disturbance) $\varepsilon_{ik}$ :

$$U_{ik} = V_{ik} + \varepsilon_{ik}. \qquad \textbf{(2.1)}$$

$V_{ik}$ is the component of the utility that is observable and $\varepsilon_{ik}$ is the random part. Following Ortuzar and Willumsen (1998) this formulation allows apparent "irrationalities": a) two individuals facing the same choice set ($C_n$) and having the same observable attributes may select a different alternative; b) if one considers the observable attributes, some individuals may not select the best alternative all the time. This also assumes individuals face the same constraints. From theory one can expect that the probability of an individual to choose a specific alternative will increase as the deterministic (observable) utility component increases. For each alternative, the deterministic component is expressed by a set of explanatory variables (e.g. transport costs, noise levels, etc.) that are assumed to be related to individuals' utility functions in the appropriate context. This assumption relies on the fact that those attributes are determinants of the actual behaviour. In reality there might not be sufficient variation in the levels (e.g. noise) in all situations that can explain different behaviours (e.g. housing choices between residential areas located within metropolitan areas). Assuming that the residuals are IID Gumbel distributed, and that the utility functions are linear in the parameters, the multinomial logit model can be expressed as (Ben Akiva and Lerman 1997) :

$$P_{ik} = \frac{\exp(\beta \cdot V_{ik})}{\sum_{j \in C_n} \exp(\beta \cdot V_{jk})} \qquad \textbf{(2.2)}$$

If number of alternatives is equal to 2, this is the binary logit model, and $0 \leq P_{ik} \leq 1$ for all $i \in C_n$ and $\sum_{i \in C_n} P_{ik} = 1$. In equation 2.2, the parameter β (scale) is related to the standard deviation of the Gumbel variate as follows: $\beta = \Pi / \sqrt{6} \cdot \Omega$, where Ω represents the effect of uobserved factors on choices.

## 2.3.4 THE CONTINGENT VALUATION METHOD

**a) Early developments, applications and acceptability**

Early references to the Contingent Valuation method can be found in Davis's (1963a) analysis of the valuation of natural resources (outdoor recreational goods), Brookshire et al.(1980) and Haneman (1994). Some authors refer to a much earlier reference by Ciriany-Wanturp in 1947 who suggested a direct interview method for valuing natural resources (see Mitchell and Carson 1989).

The Contingent Valuation method is a special case of the Stated Preference method, where a direct WTP question is asked in relation to presenting one alternative. The method uses a hypothetical scenario (or contingency), for example a ' specific decrease in noise levels' in a residential area that is proposed by a new traffic scheme.

One of the earliest applications of the CVM (bidding games, where the interviewer suggests increases in the stated value until the maximum respondent's WTP is obtained) for valuing non-use values focusing on aesthetic environmental improvements related to air quality and was developed by Randall, Ives & Eastman (1974) for the case of 'Four Corners' area, USA. Other applications, also using an iterative bidding CV format, have been developed since, for example, by Brooskhire et al. (1982), which examined the value of clean air in the Los Angeles metropolitan area of California.

In the USA, early in 1979 the Water Resources Council set forth the Contingent Valuation method, together with the TCM, as accepted techniques for valuing the benefits of proposed water resources projects. In 1989, the well known Exxon Valdez oil spill off Alaska raised the question of the estimation of non-use values in damage compensation. This led the NOAA (National Oceanic and Atmospheric Administration) in 1992, under the Oil Pollution Act (1990) to publish guidelines for the application of CV methods, the only acceptable and known method at that time to deal with the estimation of non-use values. These guidelines contain recommendations in order to avoid potential biases associated with the application of this survey technique. In the USA, the World Bank also uses the CVM for assessing various investments proposed for funding by underdeveloped countries (e.g. Valuation of Tropical Forests of Madagascar, 1995). However, following the proceedings of a conference on CV sponsored by the US Department of Energy in 1994, there seems still to exist a lot of debate on the overall acceptability of the CV method as a preferred valuation technique (see also Carson, 1996).

In the UK, the CVM has never been explicitly recommended by any governmental department, although the Department of the Environment, Transport and the Regions had funded research associated with the applicability of other disaggregate approaches within the stated preference arena, not necessarily CV (see for example, Conference Proceedings on 'Determining Monetary Values of Environmental Impacts' (University of Westminster 1997). Recently, the UK Department for Transport, Local Government and the Regions commised a study on using stated preference techniques, including the contingent valuation method (Pearce and Özdeminroglu al. 2002).

**b) Theoretical principles and assumptions**

The Contingent Valuation approach is a demand curve approach which can in theory estimate the true Hicksian welfare measures for changes in the provision of an environmental good (see demonstration in Bateman and Turner 1992 ). This relies on the method to elicit direct questions of how much income consumers are willingness-to-pay (WTP) to ensure that a welfare gain occurs e.g. due to environmental quality improvements, or how much income they are willing to accept to have a welfare loss. The theoretical principles can be found in Hicks (1943) as already referred through the concepts of *compensating* and *equivalent variation* (hereafter referred to as CV and EV), money measures of a change in utility (consumer surplus measures related to the WTP and WTA-willingness-to-accept). These can express welfare gains (benefits) or welfare losses (costs).

In a CV scenario, the reference level is the one before the change has taken place (reference state), so one may ask what is the individual's WTP for that change such as the utility level is the same as before the economic change (e.g. price changes of environmental goods or decrease in levels of the bad). The amount that an individual would be WTP for that change is finite and limited by income (Layard and Walters, 1978). On the other hand, if one asks the amount an individual would be willing to accept as compensation for the change (e.g. associated to an increase in the levels of a bad such as noise that will correspond to a welfare loss), this amount could be infinite.

Considering that individuals derive utility $U$ from an environmental good A such as environmental quality and market goods G:

$$U = U[A, \mathbf{G}]$$

the correspondent *indirect utility function* (see glossary) is:

$$V^* = V[\mathbf{P}_g, A, I]$$

where $I$ is the household budget.

The CV valuation approach asks respondents to state the income adjustment - *WTP* or *WTA* for a change in the environmental quality from $A_0$ to $A_1$. This is equivalent to say that the CV survey (max WTP statements) will identify points on the inverse compensated demand function WTP = $P(A,U^0)$ so that :

$$V[A_o, I] = V[A_1 I - WTP]$$

In the referendum approach where a change in environmental quality is identified together with a proposed WTP* amount, the respondent indicates yes (acceptance) or no (rejection) of the inequality:

$$V[A_1, I - WTP^*] >< V[A_0 I]$$

and if the survey WTP* is a lower or upper bound of the 'true' WTP.

Recent developments in theory (e.g. Knetsch (1990) and Haneman (1991), Adamowicz et al. (1993)) show that WTP and WTA can differ significantly because of the substitution effects and also because indifference curves may be 'kinked'. Other effects can explain this difference such as income effects (Hicks consumer theory) and psychological phenomenon such as loss aversion.

In practice, the CV approach integrates several steps, and some issues can be associated to each one :

1) Scenario building, which involves the setting up of an hypothetical market (verify contents validity, i.e. make sure that the contingent market makes sense so that it can be easily understood by respondents);
2) Bid Vehicle definition, i.e. how WTP for a specific change will be administered (face-to-face interview, mail, telephone or combination of these, computer-based);
3) CV question format, which involves the choice of type of CV surveys to be administered to a specific population in order to get bids (WTP or WTA). This can involve formats that generate continuous data, or discrete data. The former ones include *open-ended*

*elicitation questions* (ask maximum WTP without suggesting any value), and the offer of *payment cards* (range of typical/chosen values is presented in a card and respondents choose the appropriate one). The most used discrete CVM is the simple *dichotomous choice* format (ask if WTP is greater or less than a printed value), but others include the *iterative bidding method* (higher values are continuously suggested to individuals until they state their maximum WTP), and the *simple referendum*[4], where respondents have to answer yes or no to a specific payment suggested;

4) Mean WTP/WTA estimation, i.e. calculate an average bid for the population surveyed (overcome problems such as protest bids, e.g. modelling them as zero bids, and exclude outliers when mean value is used, and 'don't know' responses). In a closed-ended CV format, for example, a logit equation that relates the probability of a positive answer to each suggested amount can be estimated; Wang (1997) provided a utility-theoretical interpretation (random valuation model) for the treatment of 'don't know' (DK) responses in the CV surveys, so that one can avoid the loss of choice information with DK answers.
5) Bid Curves Estimation, i.e. bid curves can be estimated for example using WTP values as the dependent variable, and regressed on several independent variables (income levels, age, levels of degradation in air quality, etc.) using Ordinary Least Squares (OLS) or Maximum Likelihood.
6) Aggregation Process, i.e. the process whereby the bids are converted to a population total value figure (use total bid or mean bid and verify if total economic value figures when decomposed into use and non-use values are coherent, and see if the sample is representative of the population).

### c) Theoretical Consistency

In the application of the CVM, several biases can be associated to each step and to a specific choice format, and so invalidating estimates:

- In cases where an initial bid is suggested to respondents, this might lead to the formation of a different range of final bids in respondent's minds (*starting point bias*). For example, Rowe et al. (1980) in a CV-bidding game for valuing visibility, found that an increase in \$1 in the starting bid resulted in a \$0.6 increase in the final bid. It is also interesting to note, as referred by Brookshire et al. (1982) that if the starting bid is significantly different from the respondent's actual WTP, the respondent may become

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[4] Referendum CV questions are also called closed-ended, dichotomous choice, or take-it-or-leave-it CV questions (see also Cameron and Huppert, 1991).

bored with the bidding game and truncate the process before she/he can state actual WTP.

- In the case of proposed improvements in environmental quality, e.g. in residential areas, respondents may think that stated bids will be collected in the future, so they understate their WTP *(strategic bias).* Policy changes that involve environmental goods that are non-excludable in consumption, will inevitably face the free-rider problem.
- If respondents are not familiar with the good being valued or they do not have enough information on those changes (e.g. health effects of air pollution due to air quality changes), they might state WTP with a large random error term (*hypothetical bias*).
- Other potential biases can be found in the literature, and include *mental account bias* (if an individual bids an amount based on a weighted allocation of a calculated environmental budget that takes into account time and money constraints), *choice of bid vehicle bias or instrument bias* (e.g. in the case of an entry fee in a commercial area where improvements in air quality are proposed, one will probably not get the same WTP if the bid-vehicle is for example 'donations for improving public transport', or simply money units), *compliance bias* (if respondents give answers that they believe the questioners would find most satisfactory), etc.

Respondent experience (or information) of the environmental goods is accepted as an influence on CV survey results. Cameron and Englin (1997), for example, have developed an econometric framework to address the issue of whether the level and precision of WTP for environmental resources is systematically related to respondent's own experience with the good. Their findings support the view that some minimum experience is required before the referendum CV willingness-to-pay responses may be considered credible.

In order to avoid these potential biases, several authors and organisations have issued guidelines to CV surveys. The US NOAA guidelines, as already mentioned in this section, are the most popular in the world (see also Griffin et al. (1995), Brookshire and Neill (1992)). Here, a summary of the main recommendations is pointed out:

- Conduct direct interviews (in person) rather than on the telephone;
- Make the questions about a future, hypothetical occurrence rather than a historical event;
- Choose referendum formats in which respondents vote on a benefit with a known price (as opposed to open-ended questions);
- Begin interviews with a scenario accurately describing the benefits of the program;
- Remind in the survey that the payment for the new benefit reduces other consumption;
- Remind respondents in the survey that substitutes exist for the hypothetical benefit in question;

- Do follow-up questions to make sure that respondents understand the choices made.

Concerning the CV format, most of authors believe that the process of answering a dichotomous choice valuation question is more similar to an individual's actual purchase or voting decision (Ready et al. 1996; Boyle and Bishop 1988; US Federal Register 1993). While avoiding some of the biases inherent in the open-ended format, the CV referendum approach has less informational efficiency, as the analyst can only identify upper or lower bounds on the individual's underlying valuations.

Recently, McFadden (1994) found that open-ended welfare estimates were smaller than the comparable dichotomous-choice welfare measures for the case of protection of the wilderness. This led him to the conclusion that statistical congruence of both type of questions will depend on the type of good being valued. Procedural invariance is established by test of convergent validity of individual moments of the open-ended and dichotomous-choice distributions. If all 'moments' of both distributions are statistically congruous, procedural invariance is established. However, evidence on the statistical congruence of open-ended and dichotomous-choice questions is mixed: procedural invariance may occur for private goods but is not likely to occur when primarily estimating nonuse values (Boyle et al. 1996).

Seller et al. (1985) in a validation study of empirical measures of welfare changes, have also demonstrated that the open-ended format of the CVM provided very low estimates of consumer's surplus, and the negative values found in the cases studied indicate problems with this approach. However, the closed-ended format provided comparable estimates of consumer's surplus for the environmental assets valued with the ones that were derived from the application of other valuation techniques.
Cummings, Brookshire and Schulze (1986) referred to the use of mixed formats, e.g. using payment cards to establish initial bids and then conduct the bidding game from this starting point. This alternative survey strategy may lead one to think that mixed sequential CV formats might have a role to play in the valuation of environmental changes.

An extensive number of CV studies exist, and these will be discussed in the next chapter. However, there exists also an extensive number of potential problems to overcome. The problem of *embedding* (Kahneman 1986; Kahneman and Knetsch 1992) refers to the solicitation of WTP estimates for a good that is valued as a component of a larger one (e.g. if the survey analyst obtains a similar value for cleaning up one lake and two lakes). Existing studies found that embedding a good significantly lowers the amount that respondents say they would pay for the environmental good in question, compared to a non-embedded valuation (see for example Brown et al. 1995). This can be interpreted as indicating that people perceive related public goods to be close substitutes, so adequate information shall be presented to respondents in the CV survey. However, some recent critics of the CVM (such as Diamond and Hausman, 1994) present embedding as a theory inconsistency.

Other problems are referred to in the literature, such as *nesting* and *sequencing* (Horowitz 1993). The former occurs when different (but comparable) groups of individuals report a WTP for environmental improvements that does not vary with the scale (or scope) of the projects in question, and the latter occurs when various projects (e.g. environmental improvements) are being evaluated through sequential questions and WTP is lower for an alternative if it is second in the list (than in the case where it was the former).

**d) Major drawbacks and/or advantages if applied to value traffic noise**

Like any valuation method, the CV approach does not work well in all circumstances, and this is the case when information on the environmental good in question is low, uncertainties are considerable (e.g. health effects of noise suffered at home) or the effects are too complex (e.g. multiple or cumulative effects) to be described and understood by individuals. However, the CVM has already proved in various cases, e.g. in the valuation of natural resources, to be a reliable valuation technique and correct survey design and procedures followed during the survey aree fundamental. In the literature reviewed, several studies were found on comparisons between CV and other valuation methods, and Haneman (1994) states that more than 80 studies exist offering several hundred comparisons, and results are very close.

The use of the CVM in the context of valuation of noise externalities is possible, bearing in mind that potential biases shall be overcome. However, consumer surplus measures derived from this method have to be compared with other methods (i.e. alternative valuation approaches) in order to validate estimates (convergent validity). Table 2.4 makes a synthesis of the main items covered for the CVM method.

**Table 2.4: Sythesis Table of the Contingent Valuation Method.**

| | |
|---|---|
| **Origins** | Ciriany-Wanturp (1947)<br>Davis (1963)<br>Ridker and Henning(1967) |
| **Early Applications** | Davis (1963)<br>Randall et al. (1974)/air quality |
| **Type of Applications (Generic)** | WTP (and WTA) compensation |
| **Governmental and others acceptability** | US Water Resources Council in 1979<br>US NOAA (1992)- see Arrow et al.(1993) |
| **Preferred Suitability** | Benefits estimation/Environmental quality changes; Valuation of changes in the provision of environmental goods/services |
| **Assumptions** | Hicks welfare measures |
| **Necessary Data to Collect (Independent variables)** | Socio-economic variables (population): Income, Age, Sex, Education, etc.<br>Measures of noise levels |
| **Dependent Variable** | Maximum WTP or WTA |
| **Estimation Technique** | Multiple Regression Analysis/Maximum Likelihood. |
| **Consistency with Practical Issues** | Several potential biases to avoid (strategic bias, starting point bias, etc.), other problems to overcome (protest bids, WTA outliers, sample to be representative of the population) |
| **Validity** | It is not possible to validate the hypothetical responses (future noise changes) of the interviewed population through actual market behaviour; However, one can compare estimates of consumer surplus derived by the application of different techniques (convergent validity). |
| **More recent variants of the CV** | Dichotomous-choice format<br>Bidding games with information provided to respondents<br>Mixed sequential formats |

## 2.3.5 THE STATED PREFERENCE METHOD

### a) Early developments, applications and acceptability

Following the developments of the Stated Preference - CVM in the late 70s, other disaggregate valuation approaches using functional measurement and conjoint analysis have emerged from consumer, psychology and marketing research ideas (Luce and Suppes 1965; Green and Rao, 1971; Green and Srinivasan 1978). They have been first applied in the transport domain for fulfilling the needs of forecasting travel demand and behaviour in situations where traditional travel demand models were inadequate (for example due to poor quality or lack of data).

In the UK, SP techniques have already proved to be useful and reliable forecasting tools of travel demand (Wardman 1987, and Pearmain and Kroes 1990; Wardman and Fowkes 1991). SP techniques have been used with success for valuing non-market attributes such as time savings, at the local (Fowkes et al. 1985; Wardman 1987) and national level. Examples are the UK value of time study (MVA/ITS/TSU 1986) and the Netherlands value of time study (Accent Marketing and Hague Consulting Group 1994). Some applications of stated preference techniques for valuing traffic noise will be reviewed in Chapter 3. Other recent applications of SP techniques include the valuation of accidents (Rizzi and Ortúzar 2001) and atmospheric pollution (Ortúzar and Rodriguez 2002).

The family of Stated Preference (SP) techniques described in this section as SP-choice, SP-ranking and SP-rating rely on decompositional (disaggregate) methods for modelling individual's behaviour (e.g. housing choices) when they are faced with a set of mutually exclusive and exhaustive alternatives (e.g. apartment options) which are described as a bundle of attributes. The SP survey design is more complex than the CV one, but existing catalogues of plans/factorial designs based on number of attributes and correspondent levels (Cochrane and Cox 1957; Kocur et al. 1982) simplify the task to the survey analyst guaranteeing that main effects and interaction effects are independent of each other (zero correlation between attributes). The use of orthogonal designs (attributes are independently distributed) was questioned by Fowkes and Wardman (1993), as a certain degree of correlation can be desirable is some situations.

The taxonomy for SP methods presented in this section is based on the types of response data (see also Bradley and Kroes 1990):

1. *SP-choice* - the respondent chooses the best alternative from the set of possible ones (metric response scale from which the analyst can derive the strength of preference). In practice there is a tendency to limit the number of choices given to respondents and the number of its attributes per each alternative (maximum is usually 5), as a high number can affect the quality of respondent's answers due to fatigue. The process of estimation

of individual's preferences is based on random utility theory and uses discrete choice models;

2. *SP-rating or scaling* - the respondent rates or scores alternatives presented to them according to a numerical (e.g. on a scale 0-10) or semantic preference scale (response indicates strength and order of preference). The most common processes of estimating individual's preferences are Regression Analysis (scale assumed is linear and continuous) or Ordered Probit Analysis (an interval scale is assumed).

3. *SP-ranking* - groups of alternatives are compared against each other, so they can be ordered from individual's stated preferences (ordinal response or conjoint measurement derived from a series of trade-offs). Rank ordering can also be treated as a set of independent choices, such that discrete choice models can be used.

The applicability of statistical methods depends on the scale in which variables are measured i.e. *interval or metric scale*; *nominal; ranked or ordinal scale*, and the appropriateness of each estimation technique rely on statistical and choice modelling theories. Metric rating scales yield more information than ordinal scales (Wardman 1987; Mackenzie 1993). Ratings provide information on preference intensities and can uniquely represent respondent indifference, whilst ranking can only provide an upper or lower bound value estimate.

**b)Theoretical principles and assumptions**

SP techniques are mainly based on random utility theory or discrete choice theory (Ben-Akiva and Lerman, 1997; Ortúzar and Willumsen 1998). Early developments of probabilistic choice theory can be found in Luce and Suppes (1965) and Manski (1977) cited by Ben-Akiva and Lerman (1997).

Considering equation 2.1 (section 2.3.3), and if one individual has to choose between two different alternatives, if total utility for alternative 1 is higher that for alternative 2, there is no certainty in the statement of that 'alternative 1 is preferred', since the random error can influence the observation. However, other interpretation of the problem is possible, i.e. one can expect that the probability that an individual choose 'alternative 1' will increase if the deterministic (observable) utility increases. The specification of the absolute levels of ordinal utilities is irrelevant (utility can be defined in several different scales), and only their difference is of interest. Assuming different distributions for the error component leads to various probability choice models. The most known is the Multinomial Logit Model (Luce 1959; McFadden,

1974) where errors follow a type I extreme value (Gumbel) distribution (mode is μ, and the mean is μ+ γ /μ, γ is the Euler constant ~ 0.577, and the variance is $\Pi^2 / 6 \mu^2$) :

$$F(\varepsilon) = exp[-e^{\mu-(\varepsilon-\mu)}], \quad \mu>0$$

$$f(\varepsilon) = \mu e^{-\mu(\varepsilon-\mu)} \exp[-e^{-\mu(\varepsilon-\mu)}]$$

The multinomial logit (MNL) model assumes that errors are independently and indentically distributed (IID), and the same scale parameter affects deterministic utilities (this also implies that all the errors have the same scale parameter). This implies that the probability of choosing an alternative is not affected by the expansion/contraction of the choice set (this limitation can be avoided by the hierarchical logit model). For the case of two alternatives i and j , one can obtain a binary logit model (see equation 2.2. section 2.3.3). In the case of choices between two alternatives 1 and 2, the logit model can be expressed as for choice 1: $P_1 = \frac{1}{1+e^{V2-V1}}$.

The observable utility $V$ is related to other variables $X_i$ : $V_{ik} = f(\Omega\beta_{ik}, X_i)$ where $\Omega$ is a scale factor representing the effect of unobserved factors on choices. The scale factor is necessary for rescaling the vector of coefficients (that affect attributes selected to represent each alternative), taking into account the sensitivity of forecasts to response errors. There are two limiting cases of the MNL that result from extreme values of the scale factor: 1) As the scale factor tends to zero, the variance of errors tends to infinity, so that no information can be provided by the choice model (i.e. alternatives are equal), and 2) As it tends to infinity, the variance of the utility errors tends to zero, so one can obtain a deterministic choice model.

Relative valuations of the attributes (e.g. cost and noise levels) are usually expressed in monetary terms (e.g. value of noise per dB(A)). For example, assuming that our alternatives 1 and 2 (k=2) are expressed in terms of costs $C_i$ and noise levels $N_i$ the marginal monetary valuation of noise can be obtained by the following expression:

$$\partial V / \partial N_{ik} = \frac{\partial V / \partial N_{ik}}{\partial V / \partial C_{ik}} .$$

MNL models are usually estimated through maximum likelihood. Other multinomial choice models include the Random Coefficients Logit (allows the parameters that affect each attribute to be distributed across the population), Multinomial Probit (an extension of the RCL model, resulting from the assumption that the vector of errors is multivariate normal distributed), Ordered Logistic (it does not assume the maximisation of utility, as it represents choice as the result of a sequence of binary decisions - whether to accept the actual value or choose one more) and the Generalised Extreme Value Model (generalisation of the multinomial logit (McFadden 1978), such as the nested logit model).

**c) Theoretical Consistency**

The IIA assumption already mentioned in the case of the MNL implies that the ratio of choice probabilities of any two alternatives is not affected by the error components associated with other alternatives. This may be unrealistic in some situations.

The common use of fractional factorial designs (orthogonal) for SP experiments from existing catalogue plans rely mainly on zero correlation between attributes, in order to minimise standard error of estimates. However, as Fowkes and Wardman (1993) have demonstrated that there are situations (e.g. monetary valuation of attributes) where some degree of correlation between attribute levels in an SP design is necessary in order to reduce the standard error of the ratio of coefficients (for example in the value of time studies). This means also that the relaxation of the constraint of orthogonality allows for the inclusion, e.g. of a wider range of relevant boundary values.

The literature from psychology and decision research seem to indicate that the sole economic-based assumptions in the SP are sometimes not realistic in explaining how people behave. Following the results of Ampt, Swanson and Pearmain (1995) some guidelines can be drawn for improving SP practice:

1) The use of preliminary research to obtain information about the type of choice mechanism people use, and also to derive levels of attributes;
2) Establish the design of the SP experiment around the actual experience of respondents;
3) Present a high degree of realism and avoid presenting too much information at once;
4) Allow separate models for each respondent;
5) If the SP survey contains unfamiliar attributes or alternatives, use larger sample sizes.

SP data is usually composed of various choice observations from each respondent, and these observations may be conditional on other aspects of respondents' behaviour not predicted in advance of an experiment. Bradley and Daly (1993) showed that in the presence of 'taste variation' in the sample , adapting levels presented in SP designs on the basis of previous choices can lead to biased estimates. This is due to the fact that levels of the independent variables become correlated with the random error component. They suggest several options to overcome this problem, e.g. the use of market segmentation and prediction tests, so that one can obtain a homogenous sample if possible, and the use of exogenous variables such as income, journey purpose etc., to adapt the design levels in advance of the experiment. Random Coefficient Logit models allow for taste variation across the population (taste variation is treated as an additional source of randomness).

In recent literature several references that strongly advise the use of combined revealed and stated preference data can be found (Ben-Akiva and Morikawa 1990; Cameron, 1992; Hensher, 1992). One of the stated advantages is the efficiency gains derived from joint estimation of preference parameters using all available data. There are a few studies in environmental economics, however, that have combined RP and SP data to examine the effects of environmental quality changes (Adamowicz et al. 1994; Adamowicz et al. 1996).

- **Major drawbacks and/or advantages if applied to value traffic noise externalities**

The SP data has several advantages over RP data for the purpose of valuing noise using a controlled choice context (see also Morikawa 1994; Ben-Akiva et al. 1991):

1) Multicollinearity (e.g. between noise and air pollution attributes) can be easily avoided by design;
3) Range of attributes' levels is not limited to the availability of data and situations;
4) Elicitation of individuals preferences for future (not yet existing) alternatives is possible;
5) Various response formats can be obtained.

The advantages of the SP techniques when compared to RP ones can be destroyed if the analyst is not able to define a good design for the experiment, where there exists sufficient and sensible variation in the attribute levels in order to obtain useful valuations. Like the SP-CV method presented, SP-choice, rank and ratings suffer from the same potential biases, which can be overcome with a careful design (see potential biases to occur in the CV method in section 2.3.4). For a complete list of potential biases in stated preference see Pearce and Özdemiroglu et al (2002): a) hypothetical bias; b) strategic bias; c) payment vehicele bias; d) framing effects; e) starting point bias; etc.

One can expect the SP-choice format to have less potential biases, as there are more emphasis on trade-offs between market variables (e.g. transport costs) and non-market ones such as 'environmental quality' in order to obtain sensitive valuations according to individual's stated preferences and revealed behaviour (this can be used to define levels of the attributes). Table 2.5 makes a synthesis of the main items covered for the SP method.

**Table 2.5: Synthesis Table for the SP method.**

| | |
|---|---|
| **Origins** | Luce and Suppes (1965)/probabilistic choice theory<br>Luce (1959)/multinomial logit<br>Manski (1977)/probabilistic model of choice set generation<br>McFadden (1974)<br>Green and Rao (1971);Green and Srinivasin (1978) |
| **Early Applications in the UK** | For earlier studies (70s) see Ortuzar (1980)<br>Travel demand forecasting in 1981<br>Wardman, Bristow and Hodgson (1997) |
| **Type of Applications (Generic)** | Forecasting consumer/traveller behaviour<br>Valuation of non-market attributes (or its relative importance) |
| **Governmental and others acceptability** | SP/Guides to Practice exist<br>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;<br>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, Rankings. |
| **Estimation Techniques** | MLM: Maximum likelihood<br>Random Coeff. Logit: Maximum Likelihood using Monte Carlo Integration<br>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<br>SP for valuing environmental attributes |

## 2.4 SUITABILITY OF THE EXISTING METHODS FOR VALUING TRAFFIC NOISE EXTERNALITIES: SWOT ANALYSIS

Table 2.6 makes the SWOT analysis of the different techniques.

**Table 2.6: SWOT Analysis of the Main Valuation Approches.**

| Strengths | Weaknesses | Opportunities | Threats for valuing noise at the community level |
|---|---|---|---|
| | | **TRAVEL COST METHOD** | |
| Valuation of outdoor recreation environmental assets (land uses) with high travel costs of consumption, no substitution sites<br><br>Observed behaviour | Weak Complementarity; Welfare measurements; Sample Bias, Statistical Biases ; Averaging Independent Variables (Zonal TCM); Confidence Intervals are difficult to estimate Environmental attributes values biases (Hedonic TCM) Option, bequest or existence values cannot be estimated | Overcome limitations (multi-purpose trips, holiday makers, time and costs correlation, truncation, etc.)<br><br>Test criterion validity (estimates versus true values)<br><br>Random Utility TC model (discrete choice) | Aggregation Sample size |
| | | **HEDONIC PRICING** | |
| Marginal costs of air pollution or noise in the residential environment<br><br>Observed behaviour | Weak complementarity; Separability of the utility function; Market segmentation;<br><br>Non-use values cannot be estimated;<br><br>Require extensive market data. | Test of various functional forms for the HP equation; Explore degree of segmentation in the housing market; Establish confidence intervals; Use of SIGs for handling data at the micro level | Correlation between environmental attributes; Extensive data collection or availability of data (e.g. housing purchases) Need to get complementary data, e.g. on the real decision factors (validation) |

| SP-CONTINGENT VALUATION | | | |
|---|---|---|---|
| Valuation of proposed environmental changes (gains or losses)<br><br>US NOAA acceptability and guidelines (1993)<br><br>Allows a structured dialogue between policy makers and the public | Potential biases (strategic bias, hypothetical bias, etc.)<br>Problems to overcome such as protest bids, lack of familiarity with the good, embedding effects, sequencing, outliers.<br><br>Implementation of survey | Test convergent validity in new valuation contexts<br><br>WTP questions frame of reference and respondent's familiarity and experience with the good<br><br>Continuous testing and refinement (Blore, 1996) | Biases may affect estimates |
| **SP-CHOICE, RANK, RATING** | | | |
| Valuation of market and non-market attributes<br><br>More data for each respondent (use of repeated choices)<br><br>Various types of response data | Non-compensatory behaviour<br><br>Unfamiliarity with the good (bad) or its usual metric<br><br>Potential biases (strategic bias, hypothetical bias, repeated choices, etc.) | Respondent's taste variation, interaction effects of socio-economic, behavioural and other data (e.g. averting behavior)<br><br>Assess community preferences/ Individual level<br><br>Set novel valuation context for noise<br><br>Directions for a new economic analysis (e.g. test reference-dependence theory, etc) | Biases may affect estimates |

## 2.5 CONCLUSIONS

The theory of valuation of the "environment" saw the early developments in the late 1960s and 70s, with the 80s as a decade of theoretical refinements (e.g. in the USA with the contingent valuation method, and in the UK with Stated-Preference choice). In the 90s, there has been an intense debate on the use of specific valuation techniques, and a shift of priorities from the valuation of environmental assets to the valuation of environmental externalities from road transport. However, there is not yet an agreement towards the best valuation approach to use. The different classification criteria of the valuation methods reviewed reflect the need for some theorethical and applied research in the domain.

This chapter reviewed the main revealed preference and stated preference techniques Its suitability for valuing traffic noise externalities was assessed, after the critical analysis of each method. As the main objective is to assess preferences at the individual level (i.e. to derive marginal values' estimates of traffic externalities), several major findings can be outlined:

- Revealed preference methods based on actual behaviour do not necessarily reflect the underlying preferences of the individuals, since actual behaviour is conditioned on available opportunities. This is to say that actual behaviour needs to be complemented by individuals' data, e.g. on explaining the choices made.
- The use of revealed preference methods is usually contrained by a smaller variation in the levels, collinearity in the evironmental attributes, and these issues can be overcome by using constructed (experimental) markets or stated preference techniques.
- Stated preference techiques using a controlled experiment can elicit individuals' preferences for levels of the noise variable that actually do not exist, and therefore can be a useful modelling framework for environmental and transport policy purposes;
- Need to use more than one approach for valuing noise (same sample), bearing in mind the issue of convergent validity of noise values' estimates.

# CHAPTER 3:
# REVIEW OF VALUATION STUDIES ON TRAFFIC NOISE EXTERNALITIES USING STATED PREFERENCE METHODS

## 3.1 INTRODUCTION

This chapter reviews previous valuation studies on traffic noise that have used stated preference methods. As explained in chapter 2, the family of stated preference methods comprise rating, ranking, stated choice experiments (designated as SP-choice) and the contingent valuation method.

Section 3.2 presents a review of the SP studies. The studies are summarized considering a set of descriptors related to the context of choice, type of SP method and presentation, attributes considered in the experiment, presentation of noise to respondents, implementation survey method, sample, number of observations used in the analysis, values of the environmental good from modelling and income sensitivity. The findings of interest to the present research are also outlined. Section 3.3 provides a discussion and recommendations for research.

## 3.2 REVIEW OF SP VALUATION STUDIES ON TRAFFIC NOISE

In environmental economics, the use of choice experiments (or SP-choice) is relatively new (Boxall et al. 1996). Following Wardman et al. (1998), there was not a "great deal of work valuing transport related environmental externalities". This referred particularly to studies using stated preference choice modelling techniques (choice experiments) at the local level. Costs of road transport in the UK were based mostly on hedonic pricing estimates (Pearce 1996; DoT 1997, based on Soguel (1994), Levesque (1994), Pennington et al. (1990), Langdon 1978; Starkie and Johnson 1975). Following a recent literature survey (DETR 1999) cited by Vainio (2001), the range of noise values from hedonic pricing range between 0.08% and 2.3% decrease in property price per 1 dB(A) increase. Regarding the recent manual of "Economic Valuation with Stated Preference Techniques" conducted by Pearce and Özdemiroglu et al. (2002) for the UK Department of Transport, Local Government and Regions the use of stated preference-choice experiments is foreseen to expand in the near future. Since the application of stated preference-choice modeling to valuing environmental goods (bads) is emerging, the number of studies is limited. Next, the main studies reviewed are presented. The review is organized by country (in alphabetic order) and by descending year of data collection (valuation studies whose data collection occurred after the one in the presented study are not mentioned). After a brief summary of the study a set of features is summarized for each case.

### 3.2.1 Australian Studies

**Study Reference:** Daniels and Hensher (2000); Daniels and Adamowicz (2000).

This study aimed to evaluate the appropriateness of mixing attributes with a strong self-interest component (e.g. individual travel-time savings) with environmental costs and benefits (e.g. noise impacts, loss of open space) of a proposed road project that may be more distant in self-interest proximity. Two types of responses were asked for the same individual: a) individual user perspective and b) community perspective.

- Context of Choice: Proposed major urban road (M5 East) extension of 13 Km in Sydney.
- Type of SP method and presentation: SP-choice (binary choice between the current road and the proposed project with 2 options: ground level and higher environmental impacts or in a tunnel with higher construction costs and reduced environmental impacts); 2 choice experiments where responses were sought from a community perspective; 2 choice experiments as a user perspective (most recent trip was defined in the transport corridor as a one-way car trip of more than equal 20 minutes).
- Attributes of each SP-choice experiment: 3 groups: traditional benefits (travel time savings, operating costs, accident reductions); funding attributes (e.g. household levy as increase in local council rate; toll road, etc.); environmental/social impacts (noise; loss of open space; visual impacts; reduction in traffic on local streets; loss of bush land).
- Presentation of Noise in the SP experiment: as " Number of Houses moderately to highly affected by traffic noise in the region"; " Number Houses moderately to highly affected by traffic noise near the new road"; Traffic of local streets (% increases in traffic:10%,25%,40%).
- Implementation Survey Method: in person interview (market research company).
- Data collection year: 1996.
- Sample: 150 respondents in the vicinity of the transport corridor.
- Number of observations used in the analysis: 1582.

- Values of Noise from modelling: $0.06 per one percent increase in traffic on local streets (toll road payment for users).
- Income sensitivity: not statistically significant.
- Findings of interest to the present research study: when designing SP experiments environmental attributes that are distant in self-interest proximity (e.g. loss of open space) shall not be mixed with others with strong self-interest proximity (e.g. reductions in traffic in local streets) "unless noticeable gains in self-interest attributes accompany desirable levels of attributes".

### 3.2.2 Canadian SP studies

| **Study Reference:** Hunt, J. D. (2000) |
|---|

This study focused on urban form attributes and transportation in order to help the development of a long-range transportation master plan. Between the features explored traffic noise was included. Some features of the study are next presented.

- Context of Choice: new home locations alternatives in Edmonton, Canada.
- Type of SP method and presentation: SP-ranking (used 4 separate experiments; place in order of preference four alternatives as integrating the various elements of urban form and transportation); rating scale used from 0 (represents "terrible") to 10 (represents "excellent") and 5 represents "neutral".
- Attributes of each SP-choice experiment: a total of 10 attributes were randomly presented to each respondent (number of total attributes in the set was 20).
- Presentation of Noise in the SP experiment: "not noticeable", "occasionally just noticeable", "constant faint hum", "sometimes disturbing", frequently disturbing".
- Implementation Survey Method: paper interview.
- Data collection year: 1996
- Sample: 1277 randomly selected households.
- Number of observations used in the analysis: 15315.
- Values of Noise from modelling: $C89 per month (rent increase) for a "constant faint hum" of traffic noise.
- Income sensitivity: Higher income households had higher values of time (sensitivity to car travel time to work). Lower income households found increases in money cost more "onerous" than households with higher incomes.

- Findings of interest to the present research study: Estimation results showed that households who found locations with a constant hum of traffic had a lower value of noise than those who were sometimes disturbed. Frequently disturbing traffic noise locations are associated with a much lower value. Dwelling type, traffic noise and municipal taxes were found the most important features of location, followed by air quality, walking time to school, auto ride time to work and the classification of the street in front of the dwelling. Interestingly, the typical household is willing to face high increases in travel times and associated costs to work/shopping in order to stay with a single family dwelling type and have low traffic noise *ceteris paribus*.

### 3.2.3 Finnish SP studies

**Study Reference:** Vainio, M. (1995) and Vainio, M (2001).

The main aim was to compare to the contingent valuation (CV) and hedonic pricing value estimates of local traffic externalities (noise and air pollution) in Helsinki. Some features of the CV study are next presented.

- Context of Study: households living in apartments in the city of Helsinki.
- Type of SP method and presentation: Contingent Valuation, Open-Ended elicitation format and follow-up questions for zero bidders.
- Presentation of Noise in the CV experiment: as nuisance perceived indoors.
- Description of the WTP question: WTP for reducing traffic externality in this street to a non-disturbing level indoors (street marked previously by the respondent as causing more nuisance was used).
- Payment vehicle: no specific payment was mentioned (only marks per month was cited);
- Implementation Survey Method: mail questionnaire.
- Data collection year: 1991 (dwelling unit sales in Helsinki); October and November 1993 (mail survey).
- Sample: 699 households (20.1% gave protest zeros).
- Number of observations used in the analysis: 418 usable observations and 372 used in the analysis (protest zeros and outliers deleted).
- Values of Noise from modelling: The mean WTP was 341 marks per year (between 101 and 149 Euros per decibel); adjusted $R^2$ of the OLS models were 0.09-0.10.
- Income sensitivity: WTP as a percentage of income was 0.32% (standard deviation 0.82%).

- External validity and accuracy of values estimates: Divergence with hedonic pricing estimates (CVM values are 2-3 times higher); study took as assumption that Leq 55 dB(A) is a non-disturbing level at the household level; the "good" being valued may have differed across the HP and CV method (in the hedonic pricing data, the value of traffic externality relates to noise levels at the moment the house was shown to buyers, usually Sundays). The mean WTP of an household living in a dwelling unit that has a noise level greater than Leq 55 was 605 marks per month.
- Findings of interest to the present research study: traffic nuisance related to streets the respondent was familiar with seemed to work as a satisfactory representation of the bad being valued; need to address all possible bias, the role of experience in living at the site (CV data) and type of "good" effectively being valued when comparing value estimates. Further research was said to be needed on finding out how different people react to different time frames in the WTP questions, and if the values derived from answers given from the household head can be considered representative; the fact that the CV value estimates are 2-3 times higher than the HP seemed robust considering possible bias and other features but needs to be verified in other studies.

### 3.2.4 German SP studies

**Study Reference:** INFRAS/IWW (1995)

This study on the external effects of transport studies conducted for the UIC integrates a comparison of existing studies on noise costs. These are expressed as share of GDP. For road transport, studies using stated preferences techniques (WTP format) found a range of values for traffic noise between 0.5% to 0.6 % (1991 study reference of Weinberger) and 0.52% of the country GDP (1990 study reference by PLANCO).

### 3.2.5 Norwegian SP Studies

**Study Reference:** Saelensminde (1999) and Salensminde and Hammer (1994).

The author states that this study was the first to value environmental goods in Norway using Stated Choice experiments. The Norwegian Public Roads Administration had used results of this study since 1995. The emphasis of the research was related to air pollution and noise caused by urban traffic (car and public transport), and outputs of the study aimed to serve as main inputs for cost-benefit analysis. The set of features of the study is as follows.

- Context of Choice: Local journeys undertaken by the respondent and mode used (car or public transport) undertaken by the respondent.
- Type of SP method and presentation: SP-choice; 3 pairwise comparisons (choose between 2 alternative journeys); five choice experiments (1,2,3,4,5) were conducted for various modes; a non-choice option was not available.
- Attributes of each SP-choice experiment: Four - in vehicle travel time and cost and: (1) seat availability (public transport); Walking time (car users), (2) local air pollution; dust and dirt from road wear (3) Dust and dirt from road wear and $CO_2$, (4) Noise; Air Pollution, (5) Dust and dirt from road wear and $CO_2$; Environmental attributes were related to the consequences of using new types of fuel and tyres.
- Presentation of Noise in the SP experiment: % reductions and increases from the current situation; pictures showed volume of traffic reductions.
- Implementation Survey Method: Portable Computers.
- Data collection: 1992.
- Sample (car/public transport): (1) 897/580; (2) 596/373; (3) 289/196 ; (4)1179 ; (5)683.
- Number of observations used in the analysis: range: 558 to 5812.
- Values of Noise from modelling: range 45-90 (1993 NOK) per unit of percentage point of change per year per household.
- Indirect Values of Noise: WTP of the total population of Oslo/Akershus : 923 –1845 Mil 1993 NOK per year); WTP per annoyed person: 3550 – 7100 NOK per year.
- Income sensitivity: not included.
- External validity and accuracy of values estimates: not analysed.
- Findings of interest to the present research study: improve presentation of environmental changes; include a non-choice alternative and a "don't know" and/or "equal" alternative; account for various types of bias.

**Study Reference:** Navrud (2000).

The objective of this Contingent Valuation study was to assess the benefits of a program to reduce transportation and community noise. Two communities in Oslo are selected (600 households affected). The program is expected to eliminate indoor noise, reduce outdoor noise annoyance by 50% and eliminate noise annoyance in some parts (recreational forest area). The set of features of the study are next described.

- Context of Study: Local Community (recreational and residential land use) in Oslo and Ullensaker.
- Type SP method and presentation: Contingent Valuation, Open-Ended and Closed-ended elicitation formats.
- Presentation of Noise in the CV experiment: description of the program of noise reduction (as 50% decrease) or total elimination of annoyance indoors and outdoors.
- Description of the WTP question: WTP format and follow-up questions (closed-ended format) to reveal protest behaviour.
- Payment vehicle: Increased community taxes.
- Implementation Survey Method: in-person interviews.
- Data collection year: June-July 1999.
- Sample: 406 persons with outdoor road traffic noise levels above 60 dB(A) in the community of Oslo; 204 persons exposed to one or more sources in the community in Ullensaker.
- Number of observations used in the analysis: 600.
- Values of Noise from modelling: mean WTP per household per year of 1320 to 2200 NOK (Oslo) and 2000-3320 NOK (Ullensaker) from closed-ended format; this was 1.3 to 3.3 times higher that the estimate from the open-ended WTP question.
- Income sensitivity: WTP increased with income (Closed-ended WTP).
- External validity and accuracy of values estimates: not analysed.
- Findings of interest to the present research study: WTP decreases with lower education levels and age, and increases with level of annoyance from indoor noise; validity of the closed-ended WTP format (probability of supporting the program and pay increased community tax decreases as cost increases). The data from Ullensaker was intended to test the impact of combined noise sources and did not show a clear pattern. Some weak evidence showed that combined noise sources increase WTP to avoid noise annoyance. The WTP estimate is said to be a conservative estimate of the total social benefits of the program.

### 3.2.6 Spanish SP studies

**Study Reference:** Barreiro et al. (2000)

This Contingent valuation study aimed to address the problem of reducing traffic noise in a medium size city. The acoustical map of this city conducted in 1997 showed that 59% of the noise measurements were above 65 dB(A). The set of features of the study is as follows.

- Context of Study: Pamplona (Spain).
- Type SP method and presentation: Contingent Valuation, the one and one-half-bound model proposed by Cooper and Haneman (1995).
- Presentation of Noise in the CV experiment: noise reductions were a result of implementing measures; day time noise reductions were presented as those equivalent to a switch from current position (neighbourhood in a weekday during work hours) to the level that exist during the weekday at 9.30pm; night-time noise reductions were presented as those changes from the level of noise Saturday night to a Monday night.
- Payment vehicle: interval of cost estimates 500 pts (3.12 Euros) to 10000 pts (62.5 Euros) was presented (cost of measure is uncertain). Three pairs of bids were presented for the lower and upper bids (3.12 to 21.87 Euros; 12.5 to 43.75 Euros; 25 to 10.000 Euros).
- Implementation Survey Method: telephone interviews.
- Data collection year: December 1998 to December 1999.
- Sample: 600.
- Number of observations used in the analysis: to be concluded.
- Values of Noise from modelling: Household WTP for a noise reduction was found to be around 38.6 Euros per year.
- Income sensitivity: Household WTP represented 0.19% of total annual income.
- Findings of interest to the present research study: CVM elicitation format of more complexity to be explored (if duration of the interview is not a constraint).

### 3.2.7 Swiss SP studies

| **Study Reference:** Pommerehene (1988). |
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The main objective of this study was to compare the hedonic technique with the contingent valuation method for noise reductions (external validation of estimates). Road traffic noise and aircraft noise were included in the same study. The net rent function of the hedonic pricing was used to simulate the WTP for a decrease of the base noise level by half using the difference of rents that would correspond to a 50% decrease in noise. The features of the study are next described, and include the hedonic experiment (HP).

- Context of Study: households in the city of Basle covering different types of dwellings: one family house, multi family house, etc.; 3 classes of road traffic noise are used.
- Type SP method and presentation: Contingent valuation.
- Presentation of Noise in the CV experiment: as 50% reductions from the current base level at the dwelling.
- Description of the WTP question: No direct WTP question was asked. The method used: step 1) Background information on noise levels nearby dwellings and at other well-known places was provided to respondents. The respondents selected the location(s) that corresponded according to his/her perception to a 50% reduction in noise levels from the current situation (actual noise level); step 2) the household was told that an improvement of the actual situation could be achieved by moving to that selected location (other characteristics besides noise levels were said to be equal), and that the moving costs would be funded by city government; step 3) the respondent was asked to state the maximum accepted increase in the monthly rent.
- Payment vehicle: increase in dwelling rent per month.
- Implementation Survey Method: in-person interview.
- Data collection year: 1982.
- Sample: 223 households.
- Number of observations used in the analysis: 217.
- Values of Noise from modelling: see Findings of interest.
- Income sensitivity: WTP was found higher for higher income households, assuming other variables equal.
- External validity and accuracy of values estimates:
- Findings of interest to the present research study: a) Hedonic Pricing and the correspondent simulated WTP function: 1 dB increase was found to be equivalent to a

1.25% net rent decrease (hedonic pricing); rent depreciation depends on the base noise level at the dwelling. Higher income groups had higher WTP, ceteris paribus. For the same household income level, the WTP increases if the base noise levels are worse. "For instance, a middle income household earning 4000 Sfr monthly and living in a dwelling exposed to a low noise level (of 30 dB) would be willing to pay somewhat less than 60 SFr for a noise reduction by half, while this willingness-to-pay figure would increase to about 95 Sfr in the case of a high noise level (75 dB)." The elasticity of WTP with respect to the noise level differs from income groups; b) the mean difference in the WTP estimates (from simulated HP and CVM) was around 7 Sfr (8% in terms of the Marshallian consumer surplus measure); it is difficult to understand that for aircraft noise the WTP values were higher than the simulated HP ones (opposite direction to those in the case of road traffic noise).

| **Study Reference:** Soguel, N. (1996) |
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This contingent valuation study aimed to estimate the WTP for a traffic noise reduction in a mid sized Swiss town. A set of features of the study is next describe.

- Context of Study: Households living in the town of Neuchâtel.
- Type of SP method and presentation: Contingent Valuation.
- Presentation of Noise in the CV experiment: noise levels were linked to the housing environment (the respondent was told the quieter the house the higher was the rent); noise expressed as halving from the current situation (this is a 10 dB(A) reduction).
- Description of the WTP question: "What increase in your monthly rent would you agree to pay in order to halve your housing noise level?" (if the respondent could not answer, a starting bid of 40 Swiss francs was posed, and iterative bidding follows); zero WTP questions were asked to be explained.
- Payment vehicle: monthly rent.
- Implementation Survey Method: in-person interview.
- Data collection year: February-March 1992.
- Sample: 200 households.
- Number of observations used in the analysis: 111 (sample of volunteers) and 141 (sample of receptives).
- Values of Noise from modelling: the mean WTP bid for a 10 dB(A) reduction was 70.45 1992 Swiss francs (standard deviation = 119.13).
- Income sensitivity: household income was a major influential variable of WTP bids.

- External validity and accuracy of values estimates: free riders were identified; value estimates were compared with those derived from Swiss studies such as hedonic pricing.
- Findings of interest to the present research study: The major explanatory variables of the WTP bids were gender, number of children (if one or more), household net income, sensitivity to noise nuisance and education level.

### 3.2.8 UK SP studies

| **Study Reference:** Garrod, G. Scarpa, R. and Willis, K. (2000) |
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This study aimed to assess the benefits (reductions in speed, traffic noise, length of pedestrian waiting time) derived from traffic calming schemes on through routes in three English towns. This study was novel in estimating the benefits of traffic calming with SP-choice experiments. A set of features of the study is next described.

- Context of Choice: three towns where traffic calming measures are planned to be implemented: 1-Haydon Bridge on the A69 (west of Hexham); 2- Rowlands Gill on the A693 (near Gateshead); 3-Seaton Sluice on the A193 (between Whitley Bay and Blyth).
- Type of SP method and presentation: SP-choice (8 pairwise comparisons per person); a non-choice option was available.
- Attributes of each SP-choice experiment: 5 attributes: 1-speed; 2- traffic noise reduction; 3- reduce length of waiting time for pedestrians to cross the road; 4-appearance of the scheme; 5-annual cost per household as increased local taxation.
- Presentation of Noise in the SP experiment: 3 noise levels were used (60,70 or 80 dB); respondents were exposed to pre-recorded traffic noise at the home.
- Implementation Survey Method: in-person interview.
- Number of observations used in the analysis: 3312 that correspond to 414 usable interviews.
- Values of Noise from modelling: Negative WTP values were obtained in some situations involving noise changes.
- Income sensitivity: household income was not collected.
- Findings of interest to the present research study: distance from the road has a higher importance on WTP than reducing noise or speed limit; WTP for noise reductions is lower for local households living outside the visible and audible range of road traffic (noting that road noise was audible within the house only in 30 cases, and in 77 was visible).

**Study Reference:** Maddison and Mourato (1999)

This Contingent Valuation study aimed to find the heritage benefits associated with the construction of a 2 kilometre tunnel for the A303 passing nearby Stonehenge located in the South-West region of Britain (archaeological site), including the closure of the A344 (road providing a view to the site). The tunnel scenario was compared to the alternative of maintaining the current road. The expected benefits associated to the construction of the tunnel are due to the elimination of traffic noise, land severance and visual intrusion as road would be invisible from visitors at the stones. At the current situation, visitors to the site can hear traffic noise from the existing road. A set of features of the study is next described.

- Context of Choice: Construction of a tunnel as an alternative to the current road A344 in Stonehenge which is distant around 50 metres from the stone circle.
- Presentation of Noise in the CV experiment: "*Traffic noise can clearly be heard*" (as now) and "*It will be impossible to hear the traffic*" (tunnel option) plus colour photographs of the options.
- Description of the WTP question: maximum WTP to secure the construction of the tunnel or not by means of a payment ladder (interval data).
- Payment vehicle: Increase in tax (necessary for the construction of road); 25 payment intervals were specified on the payment card.
- Implementation Survey Method: face-to-face questionnaire (market research company).
- Data collection year: March 1998.
- Sample: 500 households (interviewed off-site) and 300 visitors (interviewed on-site).
- Number of observations used in the analysis: 357 (129 visitors).
- Values of Noise from modelling: values are aggregated and refer to changes in noise levels, visual intrusion and land severance from the current situation; the mean WTP was £ 12.80 (tunnel scenario) and £ 4.80 (current situation); the net benefits due to tunnel construction were £ 149 million, and these were higher than the value of time and accident savings.
- Findings of interest to the present research study: "the monetisation of heritage benefits allows the possibility to find the "full" benefit-cost ratio"; Follow-up questions showed the main reasons for a protest zero (major reason was the inability to pay higher taxes).

**Study Reference:** Nelson, P. (1998)

This research study was centered on the valuation of environmental impacts from road transport, in order to derive monetary estimates to be included in the cost benefit analysis of road transport infrastructures. This study included discussion (focus) groups and their opinions to rate the environmental impacts of road transport to include in the SP experiment. Traffic noise was excluded as a result of the attitudinal questions. A set of features of the study is next described.

- Context of Choice: Trunk road schemes (western Bedford); environmental impacts were said to be due to a bypass being built around Bedford.
- Type of SP method and presentation: CVM to identify the range of willingness-to-pay for decreases in local traffic levels (WTP for a reduction in traffic near their house by 10%, 30% and 50%); SP-rating experiment with 9 repeated binary choices (strength of preference was expressed on the following numerical scale: definitely prefer orange card; probably prefer orange card; No preference both the same for me; probably prefer white card; definitively prefer white card).
- Attributes of each SP-choice experiment: four (road safety, air pollution, road tax, journey to central Bedford).
- Presentation of Noise in the SP experiment: Noise was not included in the SP design. Air quality was presented as percentage less vehicles than base situation, plus number of cars and vehicles per amount of time (e.g. for the air quality attribute card showed "50% less vehicles pass your house in the morning peak time and 12 cars and 1 heavy vehicle (bus or lorry) every 5 minutes"; other alternatives included graphs, pictures and pictures and text).
- Implementation Survey Method: focus groups; pen and paper exercise.
- Sample: 222 respondents.
- Number of observations used in the analysis: 222.
- Values of the environmental good from modelling: Values of air quality ranged between £1.09 and £1.25 per 1% decrease in traffic. The value per year of air quality correspondent to a 50% decrease in road traffic is £ 56 (the WTP value was around 2 times higher £100).
- Income sensitivity: WTP values were not sensitive to household income. It was mentioned that it might be the case that the total household income was not the best indicator of disposable income. However, when total household income divided by the number of people living in the house was used, no significant relationship was found.

- Findings of interest to the present research study: Female respondents had a higher WTP than males (at the 50% reduction in traffic levels' scenario). It was expected that the WTP values to be higher than the SP values due to the impact of strategic bias, but this did not occur.

**Study Reference:** Wardman et al. (1998)

This stated preference-choice experiment aimed to assses households' and firms' preferences in Edinburgh for different levels of environmental quality (air pollution and noise), accessibility and payments. The set of features of the study is as follows.

- Context of Choice: housing location (households' survey) and small firm's locations (firms' survey).
- Type of SP method and presentation: SP-choice; 16 pairwise comparisons (choose between 2 alternative locations); 2 choice experiments were conducted for households and firm; a non-choice option was not available.
- Attributes of each SP-choice experiment: Five. Households: inter-zonal journey car time; inter-zonal journey bus time; noise; air pollution; level of council tax; Business: Walk time to and from the office; noise levels; air pollution; business rates.
- Presentation of Noise in the SP experiment: % increases and reductions from the current situation (households); location specific descriptions (these were familiar locations that were compared to the current situation) for firms; outdoor changes in noise levels were used as reference.
- Implementation Survey Method: Portable Computers.
- Data Collection: September-November (1996): households' survey.
- Sample: 403 households.
- Number of observations used in the analysis: 3978 (households); Businesses (391).
- Values of Noise from modelling: range: 3.23 - 5.5 pence per % change per week per household; 396 pence per week to avoid a 10% deterioration in noise levels for firms.
- Income sensitivity: included; in the households experiment the cost coefficient was segmented by income group which showed marginal values to increase with income; in the firms' experiment, marginal values were higher for higher turnovers.
- Findings of interest to the present research study: households had problems with interpreting change in levels as "twice as good" and 100% improvement; the use of location specific descriptions worked well as a means of presentation; deteriorations in environmental quality had greater valuations than improvements; needed further research to related values to current conditions and the physical noise measures.

**Study Reference:** Walker, R (1997)

The study aim was to value the amenity benefits of a road closure proposal in Oxford, following the Oxford Integrated Transport Package. A set of features of the study is next described.

- Context of Study: Closure proposal of High Street/St Aldgates in Oxford and creation of a pedestrian zone; random sample of the population who was expected to benefit from the road closure.
- Type of SP method and presentation: Contingent Valuation (WTP); Bidding games.
- Presentation of Noise in the CV experiment: as "much reductions of noise experienced today"(not quantified).
- Description of the WTP question: WTP (to gain the benefit of having less traffic congestion, noise and air pollution) and debriefing questions for zero bidders. (Introductory text and final question "How much would you be willing to pay ?"); valuation of travel inconveniences by asking the amount of extra time able to spend on a journey or traffic jam).
- Payment vehicle: local tax for residents (plan told the respondent that it would need to be financed by a new local tax) and entry fee for tourists. If a bid was stated, the respondent was asked whether that referred to a payment per visit, per week or per year. Higher bids were then offered until maximum bid.
- Implementation Survey Method: on-street interview.
- Data collection year: 1994.
- Sample: 117 (69 were collected on a Saturday and 48 on a weekday).
- Number of observations used in the analysis: 67.
- Values of Noise from modelling: The overall average WTP to gain benefits for reduced congestion, noise and air pollution was £24.90 per year (50 p per week). The total WTP for the proposal was £2.1 m per year. The value of travel inconvenience cost was higher £2-3 m per year.
- Income sensitivity: low sensitivity to income (the mean WTP/year for the £0-8,000/year income group was £23.50 and for the highest income group considered >£51,000/year was only £2.5 more. Considering all income groups (five), there was no monotonic relationship of WTP with income.
- External validity and accuracy: confidence intervals for benefits and cost estimates had not been done.
- Findings of interest to the present research study: Weak Sensitivity of the WTP questions to income.

**Study Reference:** Baughan and Savill (1994)

These TRL authors conducted an exploratory contingent valuation study involving 25 people in High Wycombe living in houses alongside busy roads. Respondents were asked to state their WTP or WTA compensation to obtain or avoid changes in the good being valued (halving or doubling of traffic or traffic nuisance). A set of main features of the study is next described.

- Context of Choice: houses along busy roads with continuous stream of traffic (High Wycombe area, nearby A40 and A4010).
- Type of SP method and presentation: Contingent Valuation; respondents were asked to state their WTP or WTA compensation to obtain or avoid changes in the good being valued.
- Presentation of Noise in the SP experiment: as halving, as doubling of traffic, remove all the through traffic; remove traffic nuisance; reduce the traffic nuisance by 3 points in the nuisance rating scale.
- Implementation Survey Method: in-person interview, paper.
- Number of observations used in the analysis: 25.
- Values of Noise from modelling: The study could not quantify objectively the changes being valued, so that money value per unit measure could be derived. As the sample size was very small, the range of WTP bids and number of respondents was reported: for removing of through traffic: 50 p (1 respondent) to £20 (1 respondent), and for reduction of traffic nuisance by 3 scale pts: £2 (1 respondent) to £50 or more (1 respondent).
- Income sensitivity: household income was included in the data collection.
- Findings of interest to the present research study: There was no problem regarding to individual's acceptability. Increases and decreases in traffic and related noise nuisance had been said to be understood; respondents had different opinions in terms of the payment vehicles (increase of value added tax was not acceptable, and preference tended to be towards income tax, council tax or petrol tax); the willingness-to-pay compensation questions did not work well as most respondents were not willing to receive money compensation for increases in traffic levels or nuisance. Further research is needed in quantifying the noise changes outdoors and describing the changes being valued.

| **Study Reference:** Langdon, F. (1978) |
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The contingent valuation questions were integrated in this large-scale survey of noise nuisance due to road traffic in the Greater London Area. A set of main features of the study is next described.

- Context of study: 53 sites in Greater London area involving 2933 residents.
- Type of SP method and presentation: "How much do you think it would be worth per week to you to keep down the traffic to a reasonable level ?"(card with seven possible values in the range 0 to £5 were presented).
- Presentation of Noise in the SP experiment: ratings of dissatisfaction with traffic noise (seven-point scale).
- Implementation Survey Method: In-person , paper questionnaire.
- Number of observations used in the analysis: 1433.
- Values of Noise from modelling: Mean WTP (all sample) of 65.5 p per week; 32% of the respondents gave zero bids, and 19.5% "don't know" answers. The correspondent annual value was £ 34.06 (1972 data).
- Income sensitivity: household income was a major influential variable of monetary estimates.
- Findings of interest to the present research study: this study found that the relationship between dissatisfaction and noise was linear; the relation between the monetary values of quiet and dissatisfaction was exponential; the major determinant of values of quiet were household income, followed by age and % of heavy vehicles. Noise as physically measured ($L_{10}$ over 12 hours) was significant in the case of free-flow sites, but not in the case on non-free-flow sites.

## 3.3 CONCLUSIONS

The literature review of SP valuation studies on traffic noise was mainly centered on those that were conducted before the present research study. Most past experiments dealt with the simplest form of SP experiments designated as Contingent Valuation. Results of these studies vary and seem to be related to some extent to the type of elicitation format used and presentation of the good (bad) being valued in each context. CV studies that explored respondents' experience with current noise levels and used 50% noise changes from the current situation (Pommerhene 1988; Soguel, 1996; Navrud 2000) had performed better in terms of WTP in being sensitive to household income and other segmenting socio-economic variables. One advantage is that a 50% noise change is physically equivalent to a 10dB(A) change. The CV studies lead to a much lower number of observations for modelling in relation to stated choice experiments, and this affects the robustness of the models in comparative terms.

A common preoccupation to all the SP-choice experiments was on the most effective means of presentation of "noise" to respondents. Some studies explored more than one presentation format (Nelson 1998; Wardman et al. 1998). Results of Wardman et al (1998) showed that presentations as percentage changes can be difficult to understand. On the other hand, the use of familiar location specific descriptions in relation to the actual and perceived levels seemed to work well for the case of air pollution. This finding was in line with the previous assessment of the CV studies on traffic noise.

Wardman et al (1998) recommended further research on the link between the presentation of the noise metric and the physical noise measures. Although individuals seem to react to what they perceive, objective values of quiet/noise need to be derived using the physical measures.

This needs an appropriate SP design in relation to the choice context devised to simulate the "market for noise". If respondents cannot understand the "environmental good" they are supposed to purchase they cannot value it without a large random error.

Most valuation studies were based in outdoor noise situations or in the vicinity of the dwelling, and therefore used noise levels outdoors. This is acceptable if the objective is to calculate the property depreciation prices due to traffic noise, or to define the impacts of traffic noise on location decisions at the strategic level (within zones of residence or work). However, if the objective is to focus on the traffic noise impacts when individuals are indoors, the use of the exterior noise levels (e.g. as perceived) may not be acceptable.

Taking 1999 as a time reference, few studies were concerned with the convergent validity of the noise estimates (Pommerehene 1988; Vainio 1995; Soguel 1996). This is a limitation that needs urgently to be addressed.

The comparison of values of quiet obtained in different contexts using different SP methods seems to be difficult, since no common base line conditions can be set for such a diversity of contexts. This results from the fact that studies used different noise metrics, collected different explanatory variables, had a different final number of observations in the models estimated, besides other particular features related to the aim of study, implementation and analysis. The incomplete definition of the context makes it difficult, if not impossible, to compare noise values across different studies since the potential biases and divergences in the contextual variables cannot be fully identified. Further advances need to be made progressively by following the best practice in terms of noise valuation and by making successive improvements. This is only possible if more resources can be dedicated to experimental research.

The range of problems found in the valuation studies showed that valuing traffic noise is not a simple economic problem. Further insights from other scientific areas that have the good to be valued (quiet/noise) as an object of study need necessarily to be explored. The development of the survey aims to follow the main research directions outlined.

# CHAPTER 4:
# DEVELOPMENT OF THE SURVEY

## 4.1 INTRODUCTION

This chapter considers the development of the computer survey model for valuing traffic noise externalities. The context set for valuation was the residential one, when individuals are in their homes. Considering the review on chapters 2 and 3, it was concluded that this valuation model was to be centered in the Stated Preference–choice method (SP). Moreover, more than one valuation approach should be considered in order to deal with the issue of convergent validity of noise values' estimates.

The location of the study and characteristics of the housing market acted as an important issue in designing the survey. The context of valuation is presented in section 4.2. The Lisbon housing market comprising households living in apartments within buildings of different types is used. Overall, the computer survey model was the result of an interdisciplinary exercise, integrating contributions from various fields. Section 4.3 presents the main items considered in the survey development other than transport modelling and econometrics: psychophysics and psychoacoustics, psychological theories such as the reference dependence theory and community noise studies using physical noise measures. The main features of the SP design and survey structure follows in section 4.4. The structure of the computer survey is outlined in section 4.5. Section 4.6 concludes with the main methodological innovations introduced.

## 4.2 CONTEXT OF VALUATION

Individuals can experience traffic noise externalities in a variety of contexts. The context defines the boundaries of the problem i.e. where the various negative impacts of traffic noise are perceived and experienced. The context set for valuation was the residential environment, when individuals are in their homes (apartments). Following Tognoli (1987) "home" is both a physical place and a cognitive concept, and thus not only the physical characteristics of the place play a role in individuals' minds. When individuals are indoors, traffic noise is usually the main cause of reported nuisance (Williams and McCrae 1995). In metropolitan areas such as Lisbon, many residential areas are located in the vicinity of main roads, and traffic noise is often cited as the main cause of disturbance. In economic terms, considering all possible known adverse impacts of noise on individual's well being[1] (social and behavioural effects, annoyance, interference with intended activities, performance effects, etc.), significant costs are omitted from the market transactions. Most households when choosing an apartment to live cannot afford to avoid a public bad (traffic noise).

As a result of the development pressures, the housing market in Lisbon is highly dominated by apartments located in tall buildings (see Appendix 4).

## 4.3 DEVELOPMENT OF THE SURVEY

### 4.3.1 Contributions from Psychoacoustics and Psychophysics

One of the crucial aspects for the development of the survey is to understand the psychological effects of the physical stimulus on humans, its perceived magnitude, as well as the nature of the acoustic event (noise emitted by road traffic). The main issues covered in this research phase are going to be addressed next.

#### 4.3.1.1 Sound and noise

Sound is a periodic fluctuation of air pressure that propagates from the source as a longitudinal wave motion (ISIS 1997). The frequency of sound is the ratio of the velocity of propagation and the wavelength. The human auditory system is sensitive to a very wide range of frequencies of sound. The lowest intensity (i.e. the energy flow transmitted per unit of area normal to the direction of propagation) detectable is below 20 Hertz (Hz) and the highest 20,000 Hz. The intensity of sound (I) is proportional to the square of the sound pressure (*p*), assuming the sound wave can propagate without hindrance from obstructions, as follows (Berglund and Lindvall 1995; The Open University 1997):

$$I = \frac{p^2}{\rho \cdot s} \qquad (4.1)$$

where $s$ is the velocity of propagation and $\rho$ is the static mass density of the medium, for air at atmospheric pressure and temperature of 20 °C this is 410 Watts per square meter ($W/m^2$). Since the sound pressure levels to which the human listener is sensitive are between $10^{-5}$ and $10^2$ Pascal, the sound intensity levels exhibit a large variation in practice.

[1] For a complete review of the effects of noise on humans, see Berglund and Lindvall (1995) and Berglund et al. (1999).

Therefore, these are usually expressed on a logarithmic scale (decibels, dB). The sound pressure level in decibels is defined as:

$$L_p = 10 \cdot \log_{10}(p / p_0)^2 \qquad \textbf{(4.2)}$$

where $p_0$ is the reference sound pressure level, 20 micropascal (μPa) which also corresponds to the threshold of hearing. The threshold of pain is usually taken as 120 Pascal (Pa). The sound intensity levels (equation 4.1) are equivalent to the sound pressure levels (equation 4.2) for a single sound wave at a point distant from the source (see proof, for example in Howard and Angus 1996). As noted by Howard and Angus (1996), the above equivalence does not apply when there are additional pressure waves due to reflections.

Sound and noise share the same physical definition. Thus, following the measurement instrumentation the sound pressure levels are often referred to as "noise measurements". However, psychologically the meaning of "noise" for one individual may differ to another, depending on other various non-acoustical factors (not related to the physical characteristics of the sound). This is because sound is mainly a "sensory perception" in which context, experience, relationships (e.g. between stimuli), judgment, meaning, and memory play a role (Schiffman 1996). Therefore, noise is commonly defined subjectively as an "unwanted sound". Those sounds perceived as "noise" interfere with individual's well-being and quality of life. Knowledge of the major factors that affect individual's perceptions of "noise" in the relevant context is thus an important issue when assessing community preferences for quiet.

#### 4.3.1.2 Intensity of sound and loudness

The perceived magnitude of the physical intensity of sound refers to the psychological dimension of audition known as loudness (Berglund and Lindvall 1995; Schiffman 1996). However, the relationship between loudness and intensity depends also on frequency and duration, and is far from being linear. Since the advent of Fechner's law in 1860[2] several psychophysical laws have been derived to relate the physical intensity of the stimuli with its subjective magnitude. According to the Steven's power law (Stevens 1956; Stevens 1961), the perceived magnitude (P) is a power function of the physical intensity of the stimuli (I) as follows:

$$P = k \cdot I^n \qquad \textbf{(4.3)}$$

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[2] Fechner's law states that the perceived magnitude is a logarithmic function of the stimulus.

where $k$ is a scale factor and $n$ was found later by Stevens in 1972 to be equal to 0.33 for loudness (see also Warren 1999). Stemming from the fact that our hearing system is non-linear with regard to the physical intensity of sound, in practice loudness levels are related to scales of loudness. Several weighting curves exist that consider the different responses to the range of possible frequencies. In the assessment of traffic noise, the known A-weighting curve is normally followed: at 1000 Hz the weight is 0 dB and at 250 Hz it is –9 dB, giving a focus to the mid-frequency values to the detriment of the low and high range. Measurements are usually in dB(A), as these weighting curves are incorporated into existing sound level meters.

The minimum perceived change in intensity of a sound is between 1 to 2 dB. Changes of 3 to 4 dB are clearly noticeable in real life, and a change of 10 dB corresponds to a doubling of loudness (ISIS 1997). A doubling in loudness means that the intensity of sound is tripled. In the environmental psychology literature (see for example, Veitch and Arkkelin 1995) these issues are usually referred to as "stimulus detection" (detect energy changes), "stimulus recognition" (what the stimulus is), "stimulus scaling" (measurement of stimuli) and "intensity discrimination" (increased intensity in the stimuli above its current level to be perceived as a difference in the level). The inverse square law of sound propagation states that there is an inverse square relationship between sound intensity $I$ and the distance from the sound source $r$ as follows.

$$I = \frac{E}{4\Pi r^2} \qquad \textbf{(4.4)}$$

where E is the power of the source (W/m2).

#### 4.3.1.3 Relation between different stimuli

The branch of acoustics designated as 'Psychophysics' has dedicated substantial research on studying the relationship between the physical and psychological dimensions (sensory experience) of the different stimuli (e.g. sound pressure levels as measured and perceived). As noted by Warren (1999) the history of loudness measurement is a "*long history of controversy*".

Shepard's theory (Shepard 1981) states that it is primarily the relationship between stimuli and not the magnitudes themselves that are perceived by the individuals. Therefore, two individuals 1 and 2 may perceive the same stimuli $z$ (measured physically) as different quantities $x_1$ and $x_2$ respectively. This will be related to their reference stimuli $r_1$ and $r_2$.

However, the difference or ratio of these stimuli (e.g. $x_1 - r_1$ and $x_2 - r_2$) may exhibit some constancy.

The above theory provides an interesting base from which to explore changes in the levels (as perceived or measured) from a specific reference level. This approach will be used in this research.

#### 4.3.1.4 Reference stimuli

According to the psychological analysis of value, the use reference levels (often the *status quo* or current situation) is supported by several psychological theories. Following the reference-dependence theory (see for example, Kahneman and Tversky 1979; Tversky and Kahneman 1981; Tversky and Kahneman 1986) individuals value gains and losses relative to a reference point. According to the adaptation level theory (Helson 1964) individuals' judgments are proportional to deviations to a specific level (adaptation level).
The literature in environmental, experimental economics and marketing supports the test of the theory of reference dependence (Hogarth and Reder 1986; Hartman et al. 1991; Bateman et al. 1997; Bell and Lattin 2000). This research study will explore the role of reference noise levels (e.g. experienced at the current apartment) in influencing the value of quiet.

#### 4.3.1.5 Noise emitted by road traffic

The noise emission from traffic can be seen as equivalent to sound waves spreading cylindrically from a line source. Noise levels are mainly influenced by the traffic flow, its composition and speed, besides other factors such as road geometry and gradients, ground absorption, height above ground, existence of natural or artificial noise shields and distance to the noise source. In Portugal[3], the prediction of noise levels follows the French procedures (CETUR 1980). The energy equivalent continuous sound pressure level, Leq dB(A), is used (noise indicator most used in other EU countries). The A-weighted sound pressure level in dB(A) represents an average measure of the sound pressure level over the measurement period T as follows:

$$L_{Aeq,T} = 10 \cdot \log_{10} \cdot \left[ (1/T) \cdot \int_0^T 10^{L_A(t)/10} dt \right] \quad \textbf{(4.5)}$$

For free-traffic flow conditions, the noise levels follow a Gaussian distribution (Alexandre et al. 1975; Tang and Au 1999). The typical values of noise emission from road traffic are

[3] In the UK, procedures for the calculation of road traffic noise can be found in DoT (1988).

shown in Table 4.1. Obstacles such as noise barriers cause the diffraction and attenuation of sound waves, and need to be considered in the relevant context.

**Table 4.1: Typical Noise Emission Values from Road Traffic.**

| Noise Levels dB(A) | Descriptions |
|---|---|
| Outdoors (at a distance of 10 m) | |
| 70-80 | Heavily trafficked road, 40,000 vehicles |
| 60-70 | Trafficked road, 10-20,000 vehicles |
| 50-60 | Less busy road, <3,000 (outdoors at a distance of 10 m) |
| Indoors (window closed) | |
| 50-60 | Noise in a room overlooking a heavily trafficked road |
| 40-50 | Noise in a room overlooking a busy road |
| 30-40 | Noise in a quiet residential street in a city at night |

Source: ISIS (1997).

During am and pm peak hours, traffic speeds decrease and vehicle engines are the main source of noise, whereas during free flow conditions the rolling noise (interaction of vehicle tyres with road pavement) dominates. In a residential area where traffic noise is the dominant source, the levels of indoor noise may not correlate with those outdoors. Indoor noise levels are affected by the different characteristics of the buildings (materials, disposition, surface occupied by windows, type of insulation of the elements, etc.), additional interior insulation such as secondary glazing, floor level, type of furniture (e.g. reflecting surfaces) and shielding effects motivated by terrain elevations or noise barriers.

#### 4.3.1.6 Annoyance from road traffic

Although individuals may not be aware of all negative impacts of traffic noise on health, they usually feel some of these effects through the "annoyance" they cause. Guski et al. (1998) show that the concept of annoyance is a multi-faceted attitudinal concept, since it may be highly associated with direct behavioural effects such as nuisance, disturbance, unpleasantness, interference with intended activities, and with evaluative aspects such as "getting on one's nerves" and "irritation". It is usually accepted that noise from different sources produce different dose-effect responses (CEC 2000).

Typically, individual's response to noise levels differs from the community response, due to the influence of other nonphysical factors such as personal and situational variables (Fidell 1979; Job 1991; Fields 1993). The common use of dose/exposure-response curves (% of highly annoyed as a function of noise indices) rely on steady state conditions and on the high correlation between annoyance and noise levels at the community level (following Boulder (1998), individual non-noise differences tend to average out). Examples of exposure-response for transportation noise can be seen in Schultz (1978) and Fidell and Schultz (1991) and are reviewed by Miedema and Vos (1998). As noted by Boulder (1998), most dose-response curves (response is annoyance) relate to steady state traffic conditions, but this relationship may not hold if individuals are exposed to a sudden change in traffic levels.

### 4.3.2 Contributions from Combined Social and Acoustical Noise Surveys of Community Reactions to Traffic Noise

Studies of community reactions to traffic noise provide information on the range of factors that may affect individuals' response to road traffic noise. By "response" it is meant individual's perceptions and attitudes (including annoyance effects). Guidelines on reporting information from community surveys provide insights into the most adequate metric for the response variable. To this end, the work of the International Commission on the Biological Effects of Noise (Fields et al. 1997) is useful. The list of existing traffic noise studies is vast. Fields (2001) review contains 521 social surveys of residents' reactions to environmental noise (1943-2000), including this research. Table 4.2 provides a summary of main findings considering the variables influencing response to noise in most studies. This was based on Fields (1991,2001) and other complementary studies reviewed.

Most studies focused on noise annoyance effects. However, following the reported health effects of noise on humans (Berglund et al. 1999) annoyance is only a part of the "whole" package of possible effects. On the other hand, annoyance at the individual level was found to have a low correlation with common noise metrics such as Leq dB(A). Considering the objectives of the present research, a fundamental issue is to assess the way preferences for quiet (noise) indoors can vary at the individual level using noise levels as perceived and measured. Therefore, the presentation of the response variable in the survey shall address the attribute "noise" and not "annoyance".

**Table 4.2: Summary of Variables Influencing Community Reactions to Traffic Noise.**

| Variable | Study and relevant findings |
|---|---|
| Age | Low effect on noise ratings, younger respondents tend to be more annoyed (Taylor and Hall 1979); Low effect on noise annoyance (Fields 1993); noise annoyance is moderately correlated to age: young persons 10-29 and aged more than 50 are less annoyed (Miedema and Vos 1999). |
| Education Level | Low effect on noise ratings (Taylor and Hall 1979); Low effect on annoyance (Fields 1993); slightly higher annoyance reported by higher educated people (Miedema and Vos 1999). |
| Distance from highway | Small effect on noise annoyance, after controlling for noise level (Kastka et al. 1983). |
| Average Time spent home | Related to attitudinal variables (Taylor and Hall 1979). |
| Behavioural reactions | Related to different noise levels (Lambert et al. 1984). |
| Length of residence | Reactions to noise did not change within 2 years (Jeon and Fricke 1998); Strongly correlated with attitudes (Taylor and Hall 1979). |
| Complaint activity | Correlated with households with higher incomes (Taylor and Hall 1979). |
| Gender | Men and women react in a similar way (Miedema and Vos 1999); Low correlation with annoyance (Fields 1993). |
| Height of the apartment or floor level | Related to noise annoyance (Radulov 1974); Floor number greater than four (Daz et al. 1987), increase and decrease with height. |
| Housing type (apartments) | For the same noise level, respondents in detached houses were more annoyed than those in apartments' blocks (Relster (1981); Sato et al. 1997; Björkman et al. 1998). |
| Home ownership | Related to noise annoyance (Lercher 1992); Low effect on noise annoyance (Fields 1993). |
| Household Income | Strongly related to ratings of noise (Taylor and Hall 1979)<br>Residents with higher income levels were more annoyed by noise at the same noise level (Ko and Wong 1980); Low effect on noise annoyance (Fields 1993). |
| Individual's Sensitivity | Individuals' personality features were not related to reported annoyance (Griffiths and Delauzun 1977); Highly sensitive respondents are more annoyed (Fields 1993; Yano et al. 1991; Miedema and Vos 1999). |
| Neighborhood features | Related to noise annoyance (Aubree et al. 1971; Jonah et al. 1981;Yano et al. 1991). |
| Noise barriers | Annoyance did not decrease as much as expected with noise barriers (Vallet et al. 1992); Reduced noise levels and annoyance (Lambert 1978). |
| Number of persons in the household | Low effect on reported noise annoyance (Miedema and Vos 1999). |
| Position of room | More annoyed respondents located on the noisy side of the house (Lang 1975; Fidell and Schultz 1991). |
| Number of noise events | Öhrström (1995) showed that for 50-60 dB(A) levels the number of noise events shall not exceed 16 per night not to cause sleep disturbance (laboratory study). |

**Table 4.2 (Continuation): Summary of Variables Influencing Community Reactions to Traffic Noise.**

| Variable | Study and relevant findings |
|---|---|
| Shielding effects | For the same noise levels, respondents who were shielded from the road were less annoyed (Taylor and Hall 1979). |
| Use of the noise source | Noise annoyance is moderately related to the use of noise source (Miedema and Vos 1999). |
| Vibration | More annoyance by the same level of traffic noise in presence of vibration (Sato 1988). |
| Changes in traffic noise exposure | An increase or decrease in noise exposure (traffic levels' increase or decrease) has a stronger effect on annoyance than when traffic levels are relatively stable (Griffiths and Raw 1986). |

## 4.4 MAIN FEATURES OF THE SP DESIGN

The transport and marketing literature has a vast list of studies dedicated to SP design issues (Fowkes and Wardman (1988); Pearmain and Kroes 1990, Swanson and Loughead (1992), Ampt et al. 1995, Wardman (1998), Swanson (1998), Louviere et al. (2000), Pearce and Özdemiroglu et al. 2002). However, the application of stated preference techniques to valuing environmental goods (bads) is recent (see discussion in the review in chapter 3), and some design issues represent a challenge in valuing quiet/noise. These are discussed below.

### 4.4.1 Experimental context

One of the important features of the SP design is the degree of realism of the choice context. If this is realistic then respondent's answers are more likely to be consistent with the "true" behaviour (real market decision). This means the attributes of the choice context shall include significant variables in explaining individuals' decisions. To this end, respondent's familiarity may be important. As noted by Carson et al. (2001) "no standard microeconomic text has ever stated that prior experience is a precondition to rational decision making". This means that experience and familiarity can be relevant but these cannot be taken as a necessary condition for a rational choice. Indeed, many market decisions involve unfamiliar (new) products. However, familiarity in "constructed markets" such as the SP-choice experiment minimises possible hypothetical bias.

This study aims to value quiet/noise when individuals are indoors. Therefore, the residential context was chosen. The challenge was to relate the salient features of the context with different noise levels in familiar situations to respondents. It was decided to focus on the micro level of housing location decisions in the same residential area. Considering the set of variables that usually influence household decisions within zones, noting that these are related to the location of the residential zone and the housing characteristics (Hunt et al. 1994), the micro level of analysis will allow the SP design to concentrate more on the features of the apartments. If choices are presented in the same block (lot) variables such as accessibility by road and public transport are the same. In this study, respondents are asked to consider a similar apartment to that in which they live but with a different exposure to the road and/or a different floor in the same building (or lot). This aimed to explore respondents' familiarity with the noise levels at the current apartment and other nearby situations.

To classify each apartment, a general noise exposure measure was adopted. This measure was chosen after receiving from the developer (EPUL) the internal layout of the apartments (position of rooms, number of rooms, etc.). An apartment is considered exposed to "Front" (Fronting the main road) if the bedroom or sitting room is exposed at fronting the main road. Usually two windows of the apartment are exposed to the main road in this case (considering a typical apartment layout this is normally the bedroom of the respondent and another household member). An apartment is considered exposed to the back (quieter façade) only if both the bedroom and sitting room of the respondent is exposed at the back. If any room is exposed laterally to the road but either the bedroom or sitting room is fronting the main road, the apartment is classified as "Front". Using this rationale, one apartment at floor *X* located at the Back, Front or Lateral is designated as *X*T, *X*F or *X*L respectively (in Portuguese "T" is the abbreviation for "Back"). In this study, this measure is designated as "general apartment exposure" or, simply, exposure to Front (example).

### 4.4.2 Type of Choice Experiment: Repeated Binary Choices

Considering the general apartment exposure defined above, a household living in an apartment at floor 10 fronting the main road (10F), for example, can be confronted with an alternative choice in the same floor for another apartment exposed to the back façade (10T). In the same way, this same household can face an alternative in a lower extreme floor, in the same façade (1F) or opposite façade (1T). This mimics a binary choice situation at a time, exploring the maximum possible noise variations in the context.

Binary apartment choice situations at the level of the block are thought to be 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. In exploring these situational variables, an acceptable variation in the levels of the attributes should be achieved. On the other hand the number of binary choices offered to the same household benefits if limited to a certain number in order to avoid fatigue effects and possible inconsistent choices. This is also related to the type of experimental design.

### 4.4.3 Presentation of Noise to Respondents

One important feature of the SP design is to present the environmental good (bad) to be valued i.e. quiet/noise using a measure easily understood by the respondent. This is very difficult because most people do not understand the physical meaning of dB(A). On the other hand, as explained in the previous section this task is complicated for the case of noise since there is no common definition of noise to all respondents. The presentation method has to deal with this reality.

The issue of representation of attributes and its use was already extensively discussed in an earlier paper (Arsenio et al. 2000). Noise has an objective measurement unit but most individuals are expected not to relate with dB(A), since this metric is rarely used in their everyday decisions. The use of categorical descriptors such as 'very noisy', 'noisy', 'quiet noisy', 'neither noisy or quiet' and so on, or pictorial descriptions indicating the level of annoyance or an impact on behaviour were already used (Hoinville, 1976; Hensher and Battelino, 1992; MVA and Accent Marketing, 1993; Maddison and Mourato, 1999). The main problem when valuing noise is to relate these categories to the actual noise levels, and to know the levels in dB(A) change that lead to changes from one level to another. If individuals experience noise levels that are physically very different (e.g. 55 dB(A) and 45 dB(A)), but they remain in the same category (e.g. "noisy"), this change will have apparently no value. Another way of presenting noise to respondents was to use percentage changes from the current situation (Pommerhene 1988; Baughan and Savill 1994; Soguel 1994; Wardman et al. 1998; Saelensminde 1999). However, some respondents find this means of presentation too difficult to conceptualize, and it remains the problem of how to link percentage changes with the actual physical noise measurements and hence to validate the noise value estimates. The use of laboratory simulations and other methods based on short term noise exposures to noise fails to consider the respondent's experiences and of attitudes towards noise as a result of living in the apartment for a longer period. This issue can be of importance when assessing respondents' preferences for quiet.

In chapter 3, the review of SP studies showed that a wide variety of presentation methods had already been used. From the studies reviewed, it was shown that the use of familiar location specific descriptions in relation to the actual and perceived levels worked well (Pommerhene 1988; Soguel; 1996; Wardman et al. 1998).

Considering the experimental context defined above, noise was presented to respondents as a "perceived stimuli" in specific apartment situations (example: noise as you perceive in your apartment; noise as you perceive in apartment 10F). The objective was to explore respondents' experience with the current noise levels (current apartment) and use familiar apartment situations in the same block (lot). The differences between a façade exposed to fronting the main road and at the back (quieter façade), as well as variations across opposite extreme floors along the same and different facades and floor of the respondent were used. The link of respondents' perceptions to familiar situations would make it easier to relate the perceived stimuli with the real physical noise measures (Figure 4.1).

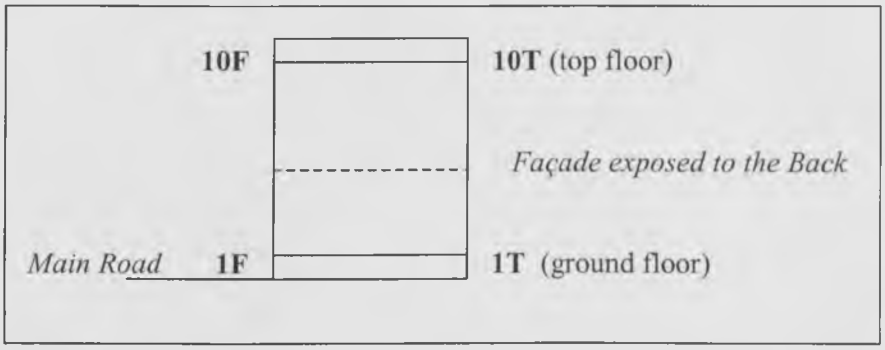



**Figure 4.1: Perceived stimuli at four apartment situations (block).**

Figure 4.1 refers to a SP situation in the same block of the respondent. In situations where apartments located at the quieter façade did not exist, choices involving the quieter façade at the back were said to be in the same lot. For example, if 1F is the current apartment, 10F is still presented as noise in the top floor (noise as you perceive in 10F), but noise as in floor 10T and 1T would be in a building in the lot at a quieter location (usually the lot forms a square of buildings, and the other building is located nearby). Photos were shown to respondents in this case (see Appendix 4).

In order to use (and test) the familiarity of the respondent to these apartment situations a numeric rating scale with bipolar adjectives "very quiet" (corresponding to 100) and "very noisy" (corresponding to 0) on the extremes was used for the case of noise and also other attributes. Each attribute was placed on the middle of this continuous scale, and respondents rated each attribute according to their perception of the levels. The scale used took into account the scales used for assessing attitudinal stimuli (Eagly and Chaiken 1993).

### 4.4. 4 The Experimental Design: Selecting the Attributes and their Levels

In Lisbon, published information by estate agents on apartments available to purchase include as attributes' descriptors: sun exposure, view, number of bedrooms, existence of garage and price of flat and other particular features of the interior. The attribute "quiet" is rarely quoted for urban locations, but it appears to distinguish a quieter environment for example in a rural area. At the micro level of analysis (same block of the respondent) the price of the various apartments typically does not vary much if the number of rooms is similar. Buildings of symmetrical layout usually are in this situation. When choosing the payment vehicle (cost variable) in the SP design, the main preoccupation is to simulate a real market using a familiar money measure to respondents. In the study area, households are mostly familiar with a monthly payment for maintenance of the building (including regular cleaning, lift service, etc.) that is the "housing service charge". Therefore, respondents shall understand easily increases (decreases) in its levels, reflecting better (worse) levels of the variables. The measurement of the cost variable is 1999 Escudos per month.
The number and type of attributes in the SP design took into account respondent's tendency to simplify tasks that are not familiar or are excessive. This may cause difficulties on trade-offs (Bates 1998). In this study four attributes were selected: view, noise, housing service charge and sunlight. Noise had necessarily to be selected since it is the central attribute to this study. View and Sunlight are additional environmental factors published by estate agents and that usually influence housing decisions in the context. For example, upper floors tend to be associated with a better view and are more expensive in general than lower floors.

The four variables selected varied across four levels each. A full factorial design would result in 256 possible choice alternatives. Therefore, a fractional factorial design and an orthogonal main effect's plan is used (experimental plan code 26 from Kocur et al. 1982 in Appendix 5). This means that the selected attributes are not correlated (each attribute is orthogonal to the others), although it real life they can be. This gave 16 possible choice situations, 12 of which were randomly presented to each household. This gave a more acceptable number of choices to each respondent, since this task would require time to think.

The SP designed was based on the differences in utility between two apartment alternatives denoted as A and B (e.g. the difference between perceived noise in apartment 1T and noise in apartment 10F). The four equivalent variables expressed as differences (DVIEW, DNOISE, DHSCH, DSUNL) were constructed as differences between the current level at each respondent's apartment and the other level in another apartment. Designating the level of the attribute experienced at the current apartment as *CA*, the levels of the attributes were established as represented in Table 4.3. In this table the differences in levels are represented as the levels perceived in each apartment situation. It shall be noted that a zero difference in the noise variable (level 0) was not allowed to occur, since the objective is to have an adequate variation in the noise levels. Zero differences were allowed to occur in the other two environmental variables (View, Sunlight).

**Table 4.3: Attributes of the SP-Choice Experiment and Levels.**

| Attribute | Levels (0,1,2,3) |
|---|---|
| **DVIEW**<br>Differences in the levels of View as perceived in: | 0: View at the current apartment (CA) – CA<br>1: CA – apartment in same floor, opposite façade<br>2: CA – apartment in the same façade, extreme opposite floor<br>3: CA – apartment in the opposite extreme floor and opposite façade |
| **DNOISE**<br>Differences in the levels of Noise as perceived in: | 0: If current apartment (CA) was rated as the quietest: CA- (worse level)<br>0: If CA was rated the worst level: CA – best level<br>0: Otherwise: CA – other level that maximises differences<br>1: CA – apartment in same floor, opposite façade) level<br>2: CA – apartment in the same façade, extreme opposite floor) level<br>3: CA – apartment in the opposite extreme floor and opposite façade |
| **DHSCH**<br>Housing Service Charge increases from the base: | 0: CA + 15% CA (Pilot study: 10% increase)<br>1: CA + 20% CA (Pilot study: 15% increase)<br>2: CA + 25% CA (Pilot study: 20% increase)<br>3: CA + 35% CA (Pilot study: 25% increase) |
| **DSUNL**<br>Differences in the levels of Sunlight as perceived in: | 0: Sunlight at the current apartment (CA) – CA<br>1: CA – apartment in same floor, opposite façade<br>2: CA – apartment in the same façade, extreme opposite floor<br>3: CA – apartment in the opposite extreme floor and opposite façade |

When presenting the alternatives to respondents, alternative B was always quieter (better level of the noise variable as rated) and more expensive. View in alternative B was always better since it is aimed for the respondent to value one or more attributes of apartment, whereas the level of sunlight can be better or worse than alternative A. Whenever DVIEW or DSUNL had the level 0, the choice task would be simplified to respondents. As the attributes were presented as "View as (you perceive) in flat 10F (example), Noise as (you perceive) in flat 10T,etc. the ratings did not appear in the screen, and the fact that option B was always quieter was not evident to the respondent but to the researcher. If a respondent lives in a floor below the integer number computed as the maximum number of floors in the building divided by two, then it is considered as a lower floor, and the extreme opposite floor presented would be the upper floor (e.g. floor 10 if this is the top floor).

Binary choices of apartment alternatives (A and B) were presented one at a time. Therefore, respondents could compare in relative terms the attributes perceived in those apartment situations. This is in line with the relative perception's theory by Shepard (1981) already discussed. Other attributes (not mentioned) were equal in all situations. Ratings are expressed to provide more information than the physical quantities. According to Cave (1998), "perception is the process of interpreting and making sense of the information which we receive via our senses", and therefore if situations are familiar to respondents perceptions will reflect other attitudes of the respondent towards the selected variables.

### 4.4.5 Data Collection Strategy and Selection of a Computerised Survey

Considering the SP design, the objective would be to survey respondents located in the vicinity of main roads located in upper and lower floors, having a sampling strategy that could give an approximate proportion of cases in each situation. Since the SP design is based on respondent's perceptions and these are used to generate the apartment alternatives to offer in each case, it was thought more efficient to administer a computer survey. The main advantages are as follows:

- the automatic classification of alternatives takes seconds;
- levels of the variables (e.g. housing service charge) considering the current payment in each situation are automatically computed, and alternatives are shown (without interviewer possible errors of mixing up the adequate scenarios to present in each case) i.e. automatic random selection of choice sets is easily made;
- since the computer aided personal interview is supported by the help of an interviewer, respondents will find the tasks easier;
- the data can be captured and stored in readable output files by other programs;
- higher acceptability since people are more likely to accept innovative products;
- reduced chance of omitted questions as the respondent cannot step without an answer.

One of the disadvantages of the computer survey is the increased complexity of the data analysis process, since programs need to be made to read the output files and store the information in the right format and validate answers. In this research, the information related to each question was stored in lines. A subsequent program re-organised the data by blocks of information stored in columns. On the other hand, it will require trained interviewers for using it, and this will require coordination between using the computer and how the information is read to the respondent. An adequate training and monitoring can overcome this difficulty.

## 4.5 STRUCTURE OF THE COMPUTER SURVEY

A paper version of the computer survey is presented in Appendix 1. This was an integrated survey focusing on the SP-choice experiment, but other complementary information and methods are included. Considering that this would be a novel experiment for valuing quiet/noise it was aimed to test a wide range of variables (socio-economic, attitudinal, behavioural, etc.) on the marginal valuations.

The structure of the survey is represented in Table 4.4. Questions are grouped by type but their order in the survey were placed such that more difficult (less acceptable) questions were placed later (e.g. information on household income levels), and giving priority to the SP-choice part and necessary input information. The survey aimed to integrate the possible influential variables that were found to affect community reaction to traffic noise (see subsection 4.3.2). The initial part of the questionnaire (codification of block and apartment) is prepared in advance to each interview, having information of each apartment layout. The questionnaire started with an introduction to the research study and warm-up questions. In order to avoid possible strategic bias the respondent was told that the survey was about environmental attributes in the residential area. By the time the SP-choice experiment was shown to respondents, the respondents were already supposed to be familiar with the environmental attributes (gathering of the RP information on housing choices had already occurred, as well as the rating of the attributes). This would help to construct a realistic market for valuing quiet/noise when individuals are indoors.

Complementary questions on perceptions of noise during the day and night and annoyance were placed in the last part of the survey. In this study, annoyance variables were tested as possible influential variables in the marginal values of quiet/noise. Questions about age, educational level, household net income were placed at the end of the interview since these can be considered more personal questions and hence affect the acceptability of the survey if placed at the start.

**Table 4.4: Structure of the Computer Survey.**

| Components | Variables |
|---|---|
| CODIFICATION of block and apartment | Orientation relative to main road; block type; position of bedroom and sitting room relative to main road |
| HOUSEHOLD DESCRIPTION | Socio-economic information of the household (respondent and members): sex, age, number of people by household and living at the place, education level, employment status, number and type of vehicles used, net household income. |
| INFORMATION ON HOUSING TENURE | Owned (or rented); price of apartment (or rent); date of purchase; mortgage; housing service charge. |
| FAMILIARITY WITH APARTMENT CHARACTERISTICS | Price, housing service charge, number of rooms, area and number of parking spaces ; ratings for view, sunlight, noise. |
| APARTMENT LOCATION CHOICE FACTORS (RP) | Main reasons to choose the residential area; main reasons to choose current apartment. |
| LENGTH OF RESIDENCE | Number of years living at the current apartment. |
| LIFE STYLE | Number of hours spent at home on average during the day (7 am-10pm); most usual place in the home for staying; Most usual activities conducted when indoors; if normally work/study over the weekend and/or stays home. |
| AWARENESS OF THE NEGATIVE IMPACTS OF NOISE ON HEALTH | If respondent is aware of the negative impacts of noise on health. |
| HOUSEHOLD SENSITIVITY TO NOISE | If household members suffer any noise-related health effects (list). |
| BEHAVIOURAL ACTIONS | Have normally windows open (closed) during the Spring/Summer; measures taken at home to reduce the impact of noise (type, year of installation, costs); if changed location of rooms due to traffic noise. |
| APARTMENT CHOICE IF NOW | Same *ex ante* choice set; if choice was different state main reasons. |
| WTP QUESTIONS | Open-ended questions, Contingent Valuation |
| PERCEPTION OF NOISE AND ANNOYANCE | Day-time and night-time noise levels (ratings); most important cause of disturbance indoors; how noise interferes with intended activities; How much annoyed (ratings). |

### 4.5.1 Complementary Valuation Methods to the SP-choice

This research is centered on the SP-choice method for valuing quiet/noise. The SP experimental design as set requires time for respondents to think and decide, especially in rating attributes (view, noise, sunlight) in four apartment situations and assessment of the twelve binary choices.

The use of other complementary valuation approaches should not constrain the acceptability of the survey by increasing substantially the duration of each interview. Therefore, it was decided to gather data on the Revealed Preference of housing purchases made by the same respondents. Because apartment purchases were made some time ago, the respondent was also asked to consider a choice "now" (i.e. at the moment the survey was conducted) assuming the same choice set as before (*ex ante* RP choice). The RP approach (*ex ante* and *ex post* choice) is discussed in chapter 8 in detail.
Considering that the contingent valuation method is a simple case of the SP approach (see also chapter 2), this study aimed to test the open-ended elicitation format using as a frame of reference the individual's perceptions of the levels of quiet/noise in the same apartment situations (one single situation was then offered to each respondent, considering either an improvement or deterioration in the levels or both). The design of the WTP questions is discussed in chapter 9 in more detail. These methods would allow the comparison of values, and assess their possible convergence or divergence.

## 4.6 CONCLUSIONS

One of the interesting features of the computer survey was to explore 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 block or lot. This conveyed a greater level of realism in the SP experiment. This fact was expected to minimize the hypothetical bias. Whereas the use of respondent's perceptions is not new in choice experiments, the link of the "perceived stimuli" with apartment situations fronting the main road and at the quieter façade and with lower - upper floors was novel in simulating a real market experiment involving apartment purchases.

Kihlman (2001) pointed out the importance of dwellings in noisy areas having at least a quieter façade in order to be able to solve "the city noise problem". Situations involving front-back situations represent much higher variation in the physical noise levels than along the same façade of the respondent.

Having received contributions from different disciplines, 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 would serve as test variables when assessing the major determinants of individual's preferences for quiet when indoors. Complementary valuation methods were devised: the revealed preference information on actual choices (choices *ex ante and ex post*) and willingness-to-pay questions. These constituted a compromise between the duration of the survey (not to affect respondent's acceptability) and use of information (links with SP-part).

# CHAPTER 5:
# THE PILOT AND MAIN SP NOISE SURVEYS

## 5.1 INTRODUCTION

This chapter presents the data collection methodology in the pilot and main SP noise surveys implemented at "Telheiras" residential area in Lisbon. The data collection was a very expensive item of this research study, since it involved face-to-face interviews at each home, an extensive collection of noise measurements inside (and outdoors) at apartments, and in a smaller extent traffic data. There was a preoccupation of gathering high quality data. Therefore, the data collection required qualified human resources (acoustic and traffic technicians of the LNEC).

The remainder of this section is organised as follows. Section 5.2 describes the general data collection methodology, sampling strategy and desired sample size. Section 5.3 describes the noise data collection. Section 5.4 describes the testing of the questionnaire design (pilot study). Section 5.5 focuses on the main SP survey data collection. Section 5.6 concludes on the success of the survey.

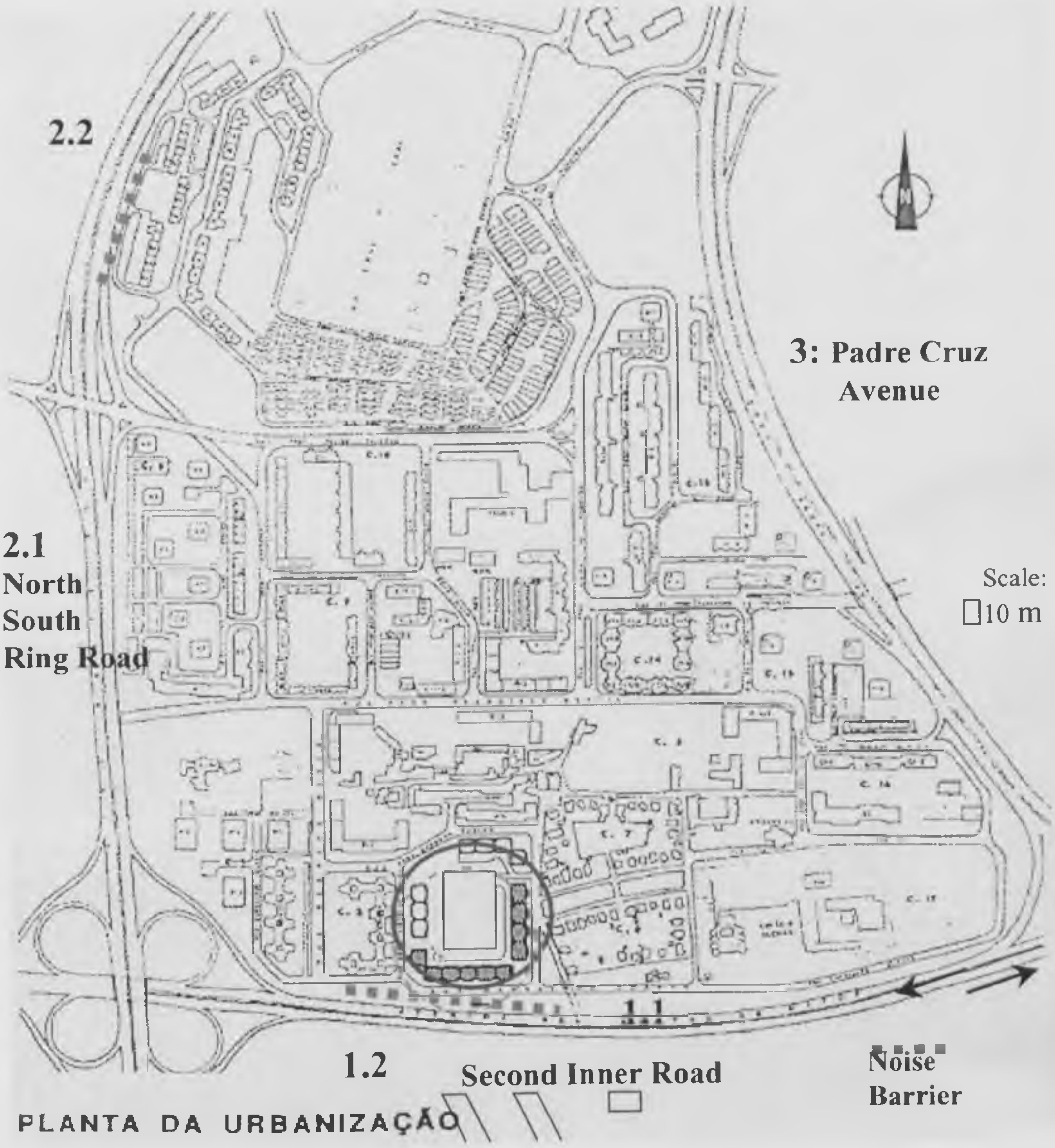
## 5.2 THE DATA COLLECTION METHODOLOGY

### 5.2.1 The Study Area, Sampling Strategy and Desired Sample Size

The study area is in the Lisbon Metropolitan area (LMA). Around 25% of the national population of mainland Portugal lives in the LMA, a total of 2,571630 inhabitants (INE 2000). In the LMA, 21% of the area is occupied by construction, and this is 2.5 times the national average. The housing market is highly dominated by apartments in tall buildings.

The residential area of Telheiras is represented in Figure 5.1. Three major roads with almost continuous traffic levels all day limit the study area: 1- Second Inner Road; 2- North-South Ring Road; 3- Padre Cruz Avenue. There is no industry or railway infrastructure nearby. Therefore, road traffic is the dominant noise source. Air turbulence is not a relevant effect in this urban area, due to its location in the fringe of the Lisbon city council. Overall, the main roads in the study area are mostly used for commuting between Lisbon and other external zones. The residential area of "Telheiras" was selected as a pilot area considering the heterogeneity of buildings and respective apartments in terms of various physical attributes.

The buildings have been continuously built since the 90s until the present time, according to different development phases (these are designated as lots). One of the objectives of its main developer – the EPUL (Public Development Enterprise of Lisbon) was that this residential area would be a social mixture in terms of their inhabitants.




**1.1:** Flow direction Lisbon to other destinations (Benfica); noise barrier installed.
**1.2:** Flow direction into Lisbon ("Olivais").
**2.1:** Road is around 3 to 4 meters elevated in relation to ground floor buildings.
**2.2:** Road segment with noise barrier installed.
Note: Location of the Pilot Study lot marked with a circle (Map Source: EPUL).

**Figure 5.1: The main survey area.**

Considering Figure 5.1 households located in the vicinity of the main roads were surveyed (buildings located in the squared or rectangular lots were selected).

The sampling strategy aimed to interview at least 8 households in each building type, having half of the respondents in upper floors and the other half in lower floors, fronting and at the back façade in a similar proportion. Considering the SP-design this would generate a minimum of 96 households per building (segment). Considering the recommended sample sizes for stated preference experiments, an often quoted rule is to use a range of 75 to 100 respondents per segment (Bradley and Kroes 1990). Considering sampling theory, the required sample size would be related to the desired precision of the value of quiet aimed for a specific segment (e.g. households with income more than *x* per year). Information on the socio-economic characteristics of the households (income, age, level of education, etc.) did not exist. On the other hand, reference values of quiet derived from primary valuation studies in Lisbon did not exist at the time. Nevertheless, the main developer (EPUL) of the residential area provided important published information relative to the apartments (buildings) to survey, including their internal layout and characteristics. By this way it was possible to plan in advance a group of interviews. Considering the prices of apartments given by the EPUL, upper floors (floor number equal four) were on average more expensive than the lower ones. Therefore, households with higher income were expected to occupy upper floors. The sampling strategy also considered this effect, by aiming to achieve an equilibrated proportion of respondents in each situation. Considering the wide range of variables included in the survey (Chapter 4), it was aimed to cover respondents in various segments (age, level of education, etc.). Characteristics of the sample were monitored continuously since the data was stored in output files that could be transferred into files and analysed step-by-step. An approximate sample size of 400 interviews was aimed at considering the budget given by sponsors for the data collection that included the noise measurements. The aim was to get as much variability in the data as possible (in order to test the range of possible influential effects of the marginal values of quiet, following several segmentations).

### 5.2.2 The Overall Data Collection Methodology

The data collection comprised several steps as follows:

1 - Information on the research study and on planned computer survey at the home: a letter was sent to households around 3 days in advance to the planned interviews. The letter was a formal one (logos of the Ministry of Transport, Planning and Territory Administration and the LNEC) and signed, indicating the sponsors of the research study. The contents of the

letter did not contain any word such as "noise" or "quiet", so as not to bias results. The letter explained that the research study was on "attributes of your residential environment".

2 - Computer aided personal interviews at the home: Face-to-face interviews with the help of portable computers were conducted at the blocks and lots in the vicinity of the main roads. This followed a plan to achieve an approximate number of households living in lower and upper floors (SP design). Myself (and the accompanying person) were positioned at a table at each household's home with the computer. This allowed the household the necessary time to think, especially for rating and choosing. Most households seemed to be pleased that their opinions had been sought.

3 - Noise measurements at the apartment: after each CAPI interview was finished, a time was fixed with the household for a next visit in order to collect the noise data indoors and at the exterior façade, when convenient to the household.

4 - Traffic and Noise Data collection outdoors: the characterization of the study area in terms of outdoor noise levels and traffic levels were the last task. Traffic and outdoor noise measurements occurred simultaneously. During the pilot survey the levels of noise outdoors were measured during the day. This was a test procedure to assess that noise measurement indicators were relatively stable during the noise reference day period (7am-10pm).

### 5.2.3 The Computer Aided Personal Interviews at the Home of the Household

#### 5.2.3.1 Duration and acceptability

The duration of each CAPI interview was between 30 to 45 minutes (minimum and maximum duration). By using the computer the data gathered from each respondent was automatically stored in output files, and the SP apartment alternatives could be quickly randomized considering the ratings given by each respondent. The use of a computer survey contributed to a higher acceptability and interest of the households in participating. In cases where the members of the household were at home all the family wanted to join the questionnaire. There were cases of respondents in the same building who were interested in participating in the research, and either phoned the LNEC phone line or spoke directly to me during the data collection. This was a surprising result. However, increased acceptability by using CAPI were found in earlier studies (Polak and Jones 1993; Firmin 1995; Ortúzar and Iacobelli 1998). In Lisbon, the outcome was even higher than expected because it was innovative in the context. Also, the survey seems to have been perceived by some households as an educative tool, namely to those households with children, since they all wanted to participate. The response rate was high, close to 100%.

#### 5.2.3.2 Implementation constraints

One of the constraints of implementing the survey was that the majority of the households were only home after 5pm. This limited the maximum number of interviews per day. 82% of the interviews took place between 5pm and 9:30pm, only 12% were set before 5pm, and 6% after 9:30pm.

#### 5.2.3.3 Data Collection, monitoring and data screening

The final data set can be considered of high quality. Specific issues relating to the monitoring and the screening of data are referred to in the sections that deal with the pilot and main survey. The initial computer survey was revised in some parts as a result of the pilot.

#### 5.2.3.4 Household interviewee

Each respondent was an adult aged more than 18 years old representing the household. The housing location choice is often the result of a group decision. Since, all the households had chosen before the residential area in which to live, the hypothesis that the household representative could be a proxy of the group decision can be considered reasonable at the level of the block or lot in the same residential area.

## 5.3 THE NOISE DATA COLLECTION

### 5.3.1 The Portuguese Noise Regulatory Framework and the Noise Metric in Leq dB(A)

The Portuguese Noise Regulatory framework is defined by the Decree-Law N. 292/2000 of $14^{th}$ November ("Regime Legal sobre Poluicao Sonora"). This updated the previous Decree-Law N. 251/87 of $24^{th}$ June ("Regulamento Geral sobre o Ruido"), and introduced several changes. One of the changes was to recommend the use of Leq dB(A) instead of the $L_{50}$ dB(A) noise measure, an obligation on local councils to elaborate noise maps, including an explicit link with the planning process in the classification of land uses, etc.). The Portuguese noise regulation classifies areas in terms of the outdoor noise levels according to the following criteria:

- If the zone is classified by an existing development plan as sensitive (e.g. residential land use), then the noise level outdoors in Leq dB(A) cannot exceed 55 dB(A) during the day period (reference noise period is 7am to 10pm), and 45 dB(A) during the night period (10pm-7am);

- If there is no established land use classification, the zones are termed “mixed” and the noise levels outdoors cannot exceed 65 Leq dB(A) during the reference day period; the same penalty of 10 dB(A) is considered to discount for the night period.

In this study, the noise levels outdoors and indoors were assessed in terms of the Leq dB(A). During the pilot and data collection outdoors other additional noise indexes ($L_{50}$, $L_{90}$, $L_{95}$, $L_{min}$ and $L_{max}$) were collected at several location. Results showed that the difference between Leq dB(A) levels during off-peak and peak periods in the measured points were close to 2dB(A) in the area influenced by the Second Inner Road. In the area influenced by the North South ring road, the difference in noise levels across different locations along the noise reference day period were less than 1 dB(A). These results suggested that outdoor levels were relatively stable during the day period.

### 5.3.2 Measurement Inside Apartments and at the Exterior Façade

Considering the SP experimental design (Chapter 4), the noise data collection objective is to collect indoor and outdoor physical measures for the upper and lower floors at each apartment. The most efficient methodology had to be defined considering the height of the buildings and its disposition to main road: a) main façade is parallel to main road and b) main façade is perpendicular to main road. The methodology adopted had already been applied in the same study area by the LNEC, Division of Acoustics (Domingues, 1997). If the disposition of main façade is parallel to main road, there exists successive buildings along the same alignment, then alternate measurements are conducted per floor (floor 1, floor 3, etc.). A noise measurement taken in floor 10 (building 1) can be used in another apartment (in either floor 10 or 9) in another building 2, contiguous to building 1, if these apartments have the same window types and have the same exposure (e.g. fronting the main road). Because households in the same building may have different window types, two simultaneous noise measurements were undertaken using two contiguous rooms at the façade that defines the flat general exposure (e.g. if bedroom of the respondent is exposed fronting the main road and sitting room at the back façade, then the noise measurement indoors takes place at the bedroom and the other contiguous room used is exposed to the same facade). These noise measurements were used to derive the mean noise insulation factors considering each window type (Chapter 6). If the main façade is perpendicular to the main road, and the contiguous buildings develop on the perpendicular alignment to main road, then the noise measurements were sought at the two exposed facades, usually occupied by different households. The same methodology was followed as indicated previously. If the buildings were of squared layout, usually two households per floor are exposed fronting the main road and two at the back. Therefore, if window types were the same, there was only the need to conduct measurements at the lower and upper floors (at the front and at the back). As one of the objectives were to be able to replace householders' perceptions of the noise levels indoors by the equivalent physical noise measures, the noise data collection guaranteed that all interior situations could be covered making using of the criteria of nearest apartment whenever possible. The total noise measurements indoors needed were 220. Two simultaneous measurements in two contiguous rooms needed to be conducted in 143 apartments.

### 5.3.3 Instrumentation and Procedures

The noise data collection followed the International standards, namely the ISO 1996: Acoustics – Description and measurement of environmental noise. This corresponds to the equivalent Portuguese Standard NP 1730-1 and 2 (1996). In the measurement of the internal room noise levels, the microphone of the sound meter was at a distance of 1.5 metres from the façade (front to an exposed window) at a distance not less than 0.5 metres for the side walls. Modular Precision Sound Level meters type 2231 of Brüel & Kjaer were used. The LNEC's acoustic technicians undertook the calibration and programming of instruments each day. A-frequency weighting was used, as recommend for the measurement of traffic noise (Berglund and Lindvall 1995; Berglund et al. 1999). Noise samples of 15 minutes were taken. Measurements over shorter time periods were undertaken in similar situations with success, since noise levels outdoors are relatively stable (ISIS 1997). For the outdoor noise measurements at each floor, the microphone was positioned at the balcony (if existing) or at 1.5 m from the façade using a specific cable extension through the existing window (Appendix 4). This aimed to reduce the impact of any reflective surface motivated by the nearest apartment exterior design features. Assuming that all instructions were followed the accuracy of the noise measurements is on average ± 2dB(A).

The outdoor measurements across different locations in the study area were undertaken considering simultaneous measurements, one at the façade fronting the main road and another at the back. This considered the SP design. A total of 104 exterior samples were collected within the pilot area in the reference day. These were taken along 3 normal consecutive days (Tuesday, Wednesday, Thursday), and simultaneous traffic noise measures were taken.

### 5.3.4 The Traffic Data

Cross sectional traffic data along the living period of the respondent at the current apartment was not available. One of the automatic traffic devices of the then recently created Lisbon Metropolitan Area Traffic Control Authority (LMATA) had been broken due to a car accident at the time (Second Inner road), and there was no counting device installed for the main road 3 (Padre Cruz Avenue). Therefore, in order to characterize the typical traffic at the study area, traffic data needed to be collected. This task benefit from the collaboration of the Traffic and Safety Division of the LNEC. Traffic levels were measured for 3 normal weekdays by means of video recording and inductive loop detectors. Other traffic data was later available by the LMATA on traffic composition, flows, and occupancy, and were given to this research. Complementary vehicle speeds were undertaken using the Laser equipment of the LNEC.

## 5.4 TESTING THE QUESTIONNAIRE DESIGN: PILOT STUDY

The testing of the SP noise computer survey was done through a pilot study in April 1999. I conducted the interviews accompanied by other two persons. Notes were taken during each interview. The main objectives of the test were to validate the computer survey in terms of its overall structure considering the ease of response or difficulties experienced and to assess possible problems with peoples' acceptability, data collection methodology and its implementation through the various sequential steps. The lot of the pilot test was "Jardim dos Ulmeiros" in the vicinity of main road 1 (Second Inner Road). This lot is marked with a circle in Figure 5.1.

A total of 16 respondents was considered at minimum for the pilot test. A total of 17 CAPIs were undertaken, and this yielded 204 observations. Results of the pilot showed the following:

- Acceptability of the computer survey: the households cooperated with the research study and none refused to answer or rejected the second visit for the subsequent noise measurements;
- Ratings of the attributes as perceived: while each respondent was rating the four flats in terms of the attributes (view, noise, sunlight) it seemed clear that they adjusted the ratings in order the get the relative values right; this was an indication that they took the experiment seriously.
- Compensatory behaviour: during the SP-choice experiment households seemed to make trade-off between the chosen attributes in a natural way. This confirmed the importance

of those environmental attributes to households. Comments were taken during the interview that justified their options (e.g. "*don't like too much sunlight*"...*I prefer B because this is quieter*...."). Two households commented that this part was very tiring as they had to think a lot.

- Levels of the SP attributes: The housing service charge needed to explore more variation in the levels since alternative A (always worse in terms of noise) and cheaper (i.e. less monthly payments as housing service charge) was only chosen by 4 households.
- Preliminary estimation results (Table 5.1): The view and noise coefficients had the right expected sign and were all statistically significant at the 5% level of significance. The housing service charge (cost) attribute and sunlight had the expected sign. Considering the small sample size and choices made, these were not statistically significant at the 5% level of confidence.

**Table 5.1: Estimation Results from the Pilot Study.**

| Variables | Estimate (t-stats) |
|---|---|
| VIEW | 0.03508 (3.2) |
| NOISE | 0.05330 (4.3) |
| HOUSING SERVICE CHARGE | - 0.0002198 (1.8) |
| SUNLIGHT | 0.009688 (1.3) |
| Final Likelihood: -95.3336 ; $\rho^2$ w.r.t. zero: 0.3258 ; $\rho^2$ w.r.t. constants: 0.1690 | |

Note: Effect of repeated observations is not considered.

As only 4 out of 17 respondents had preferred B (less expensive option), the levels of the housing service charge were increased. This fact was indicated in the SP experimental design in Table 4.3 (Chapter 4). The levels of housing service charge aimed to cover the wide range of variation of monthly payments and incomes in the sampled area.

- Further tests to the experimental design: If reference marginal values of quiet had existed for the Lisbon context (i.e. known values of quiet in the residential context), the use of simulation tests could have helped to improve the design in defining the acceptable range of values. This would have helped in verifying that no improvements could be made to lower the standard error of the coefficients (Ben-Akiva and Lerman 1997). Usually various synthetic populations are used, where the coefficient of the environmental attribute is allowed to vary, and as well the variance of the error term, and the cost coefficient is set to one. The scale factor is found by selecting the variance of the error term to give a typical likelihood ratio index.
- Problems during the questionnaire: During the WTP questions (CVM part after the SP-choice experiment) 13 respondents raised several concerns and uncertainty: "*I have no*

*idea about the amount…*", "*I don't understand this question…*", "*I don't think I shall pay…*", etc. However, only four respondents refused to state an amount (protest zeros), and the other 9 respondents stated a bid value. One respondent gave a bid value in a different money unit (350 thousand of escudos for 2 years and 700 thousand of Escudos for 2 years, respectively for gains and losses). This was a very high value and can be considered as an outlier.

It was decided to keep the WTP questions and conduct verbally a reformulated question to the respondent (instead of written text) asking for households' maximum WTP per month either to improve the current noise levels (or to avoid a noise deterioration) considering the ratings given to the four apartment situations.

## 5.5 THE MAIN SP SURVEY

### 5.5.1 Logistics and Monitoring of the Data Collection

In real life data collection is usually undertaken by contracting marketing companies. If so, the monitoring of the data collection process is an essential step, as well as data screening through the process in order to produce reliable estimates at the end. Since this SP computer survey was the first one to be implemented in Lisbon some difficulties had arisen in the context. A marketing company aimed to be contracted to reduce the total survey period. The major difficulty was to find a company with suitable human resources, as the majority of good available interviewers were not familiar with computers. The main survey had to be delayed to September-November in order to find and train the interviewers. CAPI interviews were conducted in parallel by myself in complementary apartments in order to increase the sample size.

### 5.5.2 Data Screening Process

The number of surveys totalised 473. The process of data screening occurred gradually as the data was being collected. Some anomalies were detected during the survey work:

- ❑ 23 households wanted to rush the questionnaire and seemed not to reason in the SP-choice experiment by always looking at one attribute. This was detected by their comments;
- ❑ 38 households gave inconsistent choices: since equal ratings to view and sunlight were given to all apartment situations, this generated dominated preferred alternatives in

specific cases; it was not clear if "similar ratings" did corresponded to respondents' true perceptions or if this was an effect to simplify the ratings task.

- Some interviewees had not followed all the instructions for the SP-choice experiment (when choices were in the same lot of the respondent, they failed to indicate that the opposite floor was not in the same building). This anomaly was noticed in advance (data screening during the field work), and also during the implementation (this was associated to a particular interviewer). The manager of the marketing enterprise confirmed this fact, and 93 interviews had to be repeated. In order not to have biased results (and to fully test the hypothesis that written procedures had not been followed), a second letter was sent to the same respondents indicating that the second phase of the research study they had participated was going to take place. This letter asked their participation again, and the majority agreed (87%). A shorter version of the program was used (only SP-part). Interviews to other households in the same block were conducted to replace the respondents who were not available.
- Some respondents seemed not too keen to reveal personal data to the Marketing enterprise since they said they could give the information to others. Variables in this case were coded as missing data.
- The final sample size, after data screening included 412 CAPI interviews generating 4944 observations for analysis.

## 5.6 CONCLUSIONS

The data collection methodology was implemented successfully. Nevertheless, some difficulties arose as a result of implementing a novel computer survey in Portugal. On the other hand the use of computers seemed to contribute to higher respondents' acceptability. This had been suggested as a result of earlier SP experiments using portable computers
The pilot study proved to be a necessary step for testing the questionnaire design, in absence of reference values of quiet in the context and to test a novel survey technique. The initial range of housing service charge proved to be inadequate. A sample size of 4944 observations was generated for the SP analysis.

The implementation costs of the overall data collection were very high considering the collaboration of the Acoustic and Traffic LNEC's staff. The expenses were covered in some extent through my part-time collaboration in parallel with my research in contract works/projects at the LNEC with other organizations on the domain of transport economics and planning.

# CHAPTER 6: ANALYSIS OF THE SITUATIONAL, SOCIO-ECONOMIC, BEHAVIOURAL AND ATTITUDINAL DATA

## 6.1 INTRODUCTION

This chapter considers the sample of 412 householders interviewed by means of the SP Computer Assisted Personal Interviews (CAPI) at each apartment, the noise measurements that were taken indoors and outdoors and the traffic levels. The statistical analysis conducted in this chapter considers the wide range of variables (socio-economic, behavioural, attitudinal, etc.) collected during the main survey that may influence householders' preferences for quiet when indoors. This analysis is useful for the subsequent modelling chapters, in order to assure consistency of the householders' preferences for quiet with the sample characteristics. Also, a complete definition of the study context and main descriptors is thought to be of central importance for future studies focusing on valuing quiet when individuals are in their homes, particularly to provide consistent comparisons of the values of quiet estimated in this study and others.

Section 6.2 provides a description of the main apartment characteristics of the study area, and the households' most important location choice factors. Section 6.3 considers the socio-economic characteristics of the households and their sensitivity to noise according to reported health problems, awareness of the negative impacts of noise on health and length of time living at the apartment. Householders' exposure to traffic noise when in their apartments is shown in section 6.4. Household's behaviour when indoors and their attitudes towards averting noise are analyzed in section 6.5. Section 6.6 considers householders' perceptions of the internal noise levels and its relation with the real physical noise measures, considering absolute and relative measures. Several aggregate models for relating relative perceptions and relative physical noise measures (difference in noise levels relatively to the experienced noise level in each current apartment) are explored in order to be of comparative use in other studies. The stated levels of annoyance during the day and night are subsequently analyzed in section 6.7, and their variance is discussed considering the noise ratings given for the day and night reference periods. The main section conclusions are outlined in section 6.8.

## 6.2 CHARACTERISTICS OF THE STUDY AREA

### 6.2.1 Apartments' Characteristics

The location of the study area already was presented in chapter 4 due to its importance for the development of the SP computer noise survey. Table 6.1 represents a summary of the main apartment characteristics, and the mean and median value in the sample.

**Table 6.1: Summary Statistics of Range of Apartment Characteristics.**

| Apartment Characteristics | Attribute Values [Range] | Sample Mean (Median) |
|---|---|---|
| Price (Million of Escudos) | 10 - 65 | 23 (19) |
| Housing Service Charge (Escudos per month) | 400 - 42000 | 7750 (6500) |
| Number of Bedrooms | 1-5 | 2 (2) |
| Area ($m^2$) | 80-370 | 112 (100) |
| Parking spaces in garage | 0-2 | 0.3 (0) |
| Number of floors per building | 5 -11 | 8(8) |
| Year of building construction | 1985-1999 | 1995 (1994) |

1 Euro=200,482 Escudos

### 6.2.2 Households Location Choice factors

*Choice of residential area*

Table 6.2 reports the percentage of households who ranked each residential choice factor as either first or second most important, considering the total sampled households.

**Table 6.2: Location Choice Factors for the Residential Area.**

| Location factor | Ranked 1st | Ranked 2nd |
|---|---|---|
| Proximity to work | 30.8% | 16.3% |
| Price of apartment | 20.9% | 18.9% |
| Quiet | 10.7% | 14.8% |
| Public Transport | 2.9% | 3.6% |
| No Industry nearby | 1% | 4.1% |
| Car accessibility | 3.6% | 11.2% |
| School for children | 3.4% | 7.8% |
| Neighbourhood quality | 12.1% | 12.6% |
| Housing quality | 10.7% | 7.8% |
| Other (*) | 3.9% | 2.9% |

(*) Most frequent stated: location within Lisbon city council.

Table 6.2 shows that 47.1% of the sampled households ranked proximity to workplace as either the first or second most important location choice factors. The price of the apartment was mentioned by 39.8% of households. Quiet and neighbourhood quality were mentioned each by 25% of the respondents.

*Choice of apartment in the block or lot*

Table 6.3 reports the percentage of households who ranked each apartment choice factor (list in the main survey) as either first or second most important, considering the total sampled households.

**Table 6.3: Location Choice Factors for the Residential Area.**

| Location factor | Ranked 1st | Ranked 2nd (*) |
|---|---|---|
| View | 10% | 8.2% |
| Price of flat | 30.8% | 20.5% |
| Number of rooms | 13.8% | 23% |
| Less noise from road traffic | 2.9% | 5.7% |
| Type of construction | 4.4% | 6.5% |
| Sunlight | 12.4% | 10.2% |
| Enclosed parking | 1.2% | 6% |
| Housing Service Charge | 0.7% | 2% |
| Availability | 16.5% | 10.2% |
| Safety | 3.9% | 4.3% |
| Other | 3.4% | 3.4% |

(*) 60 households only referred to one choice factor.

Table 6.3 shows that "less noise from road traffic" was only referred by 2.9% of the households as the most important factor, and was ranked second by 5.7%. Considering the third, fourth and fifth most important choice factors the mentioned attribute was stated by 13% of the households. It shall be noted that this were the location factors at the moment they had purchased the flat, which may differ from those at the time the SP noise interviews were conducted. This issue will be further discussed in chapter 8.

### 6.2.3 Road Traffic Levels

In the study area road traffic is the dominant noise source. Taking into account the availability of the traffic data and data collection procedures described in chapter 5, the traffic levels represent a typical situation of the road traffic characteristics at the time the survey was conducted. Since in this study the determination of traffic noise outdoors and indoors was made using real measurements *in situ*, the traffic data (flows, proportion of heavy vehicles, speed) is presented in Appendix 2 for reference. The traffic information relative to the context might be useful for future studies that aim to compare noise values following a common methodology.

### 6.2.4 Outdoor Noise Levels considering the Front and Back Façades (Ground Floor) and the Portuguese Noise Regulatory Framework

The outdoor noise levels' data collection followed the methodology described in chapter 5. A total of 101 simultaneous noise measurements were conducted considering the façade exposed to traffic and the other façade at the back. Considering the noise data, 89 noise levels (90% of the surveyed building locations) exceeded the 55 Leq dB(A) noise standard set by the Portuguese Noise regulatory framework (this assumes this residential area is classified as "sensitive" following the development plan). Taking into account the WHO guidelines for noise (Berglund and Lindvall 1999), it can be expected that individuals will be seriously annoyed during daytime and evening. Table 6.4 represents the variation in noise levels at the building façades fronting the main road and at the back.

**Table 6.4: Range of Outdoor Noise Levels, at the Ground Floor Between the Façades Fronting the Main Road and at the Back.**

| Main road segment | Leq dB(A) range of values | | Range Leq dB(A) |
|---|---|---|---|
| | Front | Back | |
| **1.1** | 61.9 | 60.7 | 1.2 |
| **1.2** | 73.9 | 62.1 | 11.8 |
| **2.1** | 66.4 | 55.8 | 10.6 |
| **2.2** | 54.9 | 53.5 | 1.4 |
| **3** | 66.4 | 60.5 | 5.9 |

Table 6.4 shows that the variation of noise levels between the front and back façades is very small along road segments 1.1 and 2.2 due to the presence of noise barriers (see also Figure 5.1, chapter 5). The impact of noise barriers is not significant for upper floors (greater equal than four floors) as demonstrated by the simultaneous measurements taken at each floor at the façades front and back to main road. This reflects the importance of considering the noise measurements at each floor level, when assessing community preferences for quiet. Moreover, Tang and Au (1999) noted that studies that have considered indoor traffic noise are only a few. Most studies used the noise measurements outdoors as an implicit proxy of the conditions indoors, ignoring the transmission of traffic noise through the buildings' façades and other factors. If one's aim is to value quiet (noise) indoors, this approach may not be acceptable in all situations. Considering the diversity of the building types (with different degrees of insulation and layouts), the collection of the noise data of the levels heard indoors was made.

### 6.2.5 Levels of Noise Indoors by Floor and Façade Fronting the Main Road and at the Back

The noise data collection followed a consistent methodology described in chapter 5. This had already been used in other noise studies conducted by the LNEC, Division of Acoustics.

The number of noise samples collected indoors and outdoors were 220. Two simultaneous measurements in two contiguous rooms needed to be taken for 143 cases. Mean insulation factors were computed using the simultaneous noise measurements (indoors and outdoors) for each window type, considering the same façade of building. The mean insulation factors were used as correction factors in the Leq dB(A) SP file. This is because during the SP experiment we have told the household to consider for the other flat options presented that all characteristics not mentioned (this includes of course the same window types) were the same as in his/her present flat. The mean insulation factors for each building and window type are represented in Appendix 3. These were computed considering the average of the simultaneous noise measurements (indoors and outdoors, at each floor level) for the same exposed façade (standard deviation of the mean is less than 2dB(A)).

Considering the buildings surveyed in the vicinity of each road segment, Table 6.5 shows the range of variation of the noise levels measured indoors and at the exterior façade.

**Table 6.5: Range of Indoor and Outdoor Noise Measurements, Leq dB(A)**

| Main road Segment | Number of Observations | Indoors Min , Max | Outdoors Min, Max |
|---|---|---|---|
| **1.1** | 113 | 26.6, 45.7 | 51.7, 74.9 |
| **1.2** | 23 | 31.5, 61.5 | 61.5, 75.9 |
| **2.1** | 111 | 23.4, 46.1 | 57.2, 73.2 |
| **2.2** | 111 | 25.1, 45.4 | 54.2, 72.5 |
| **3** | 54 | 21.9, 49.5 | 58.2, 75.9 |

Table 6.5 shows a wide variation between the indoor and outdoor noise levels. The measures segmented by floor number are presented in Appendix 3. The WHO guidelines values for dwellings indoors are between 30 to 35 dB(A), a threshold for moderate annoyance and speech intelligibility during the daytime and evening period. Considering the noise measurements taken indoors, 243 cases (59%) had noise levels indoors of greater than 35 dB(A).

## 6.3 SOCIO-ECONOMIC CHARACTERISTICS OF THE HOUSEHOLD AND SENSITIVITY TO NOISE

The sample of households had the characteristics as follows:

Gender of the Household Representative - 257 females (62.4%) and 155 males (37.6%). The effect of gender will be tested in section 6.4, considering the number of hours that normally a male spends home in comparison to a female. In Lisbon females tend to arrive at home much earlier in comparison to their male partners, as a result of their professions and childcare. Most SP CAPI interviews were conducted after 5:30pm, as this was the time period that most households have indicated they were at home and able to be interviewed.

Age of the Respondent – There was no respondent on the last age category (>75), so the sample is not representative of this age group. The age group from 30 to 49 represents 56.8% of the sampled households (Figure 6.1). The number of respondents who refused to refer their age was 39 (9.5%).

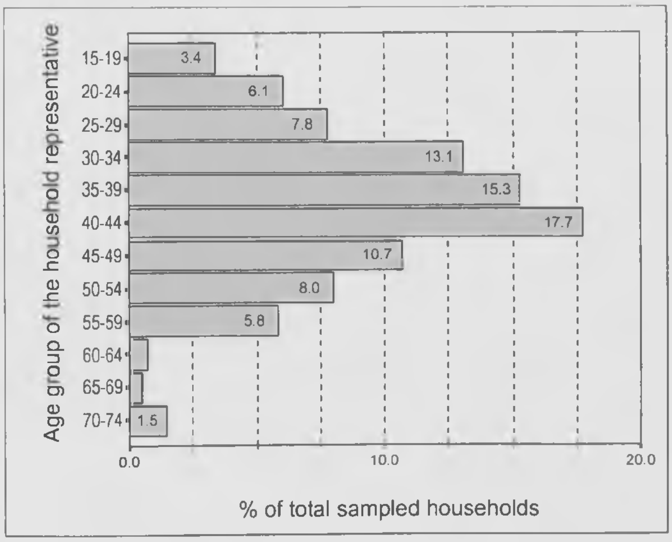



**Figure 6.1: Age group of the household representative.**

Education Level of the Respondent – The sampled area had a high percentage of graduate respondents (45.4%), and this fact might explain the high acceptability of the SP Noise computer survey. The number of cases of missing information is 40 (9.7%). The segmentation of sample with regards to education is represented in Table 6.6.

**Table 6.6: Education Levels of the Respondent.**

| Education Level | Number of cases (%) |
|---|---|
| Primary School | 8 (1.9%) |
| Secondary School | 72 (17.5%) |
| Technical | 20 (4.9%) |
| Polytechnic or Bach. | 32 (7.8%) |
| Graduate | 187 (45.4%) |
| Posgraduate Master Level | 11 (2.7%) |
| PhD or equivalent | 3 (0.7%) |

Employment status – The analysis shows that 68.5% of the sampled households have a full-time employment (Figure 6.2). The number of cases with missing information was 40.

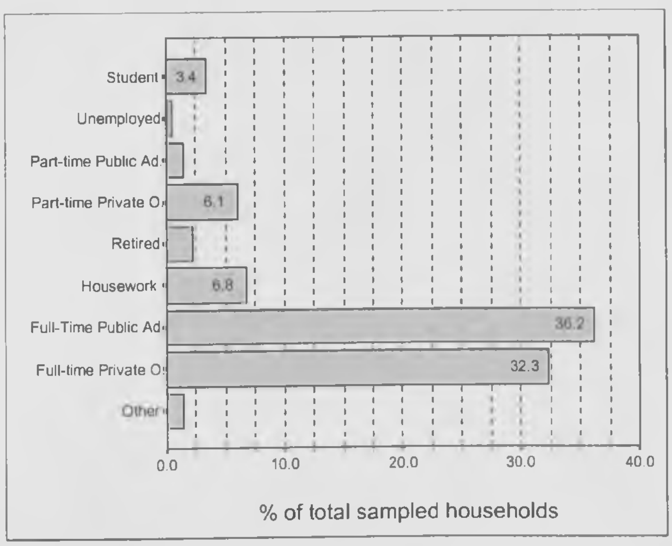


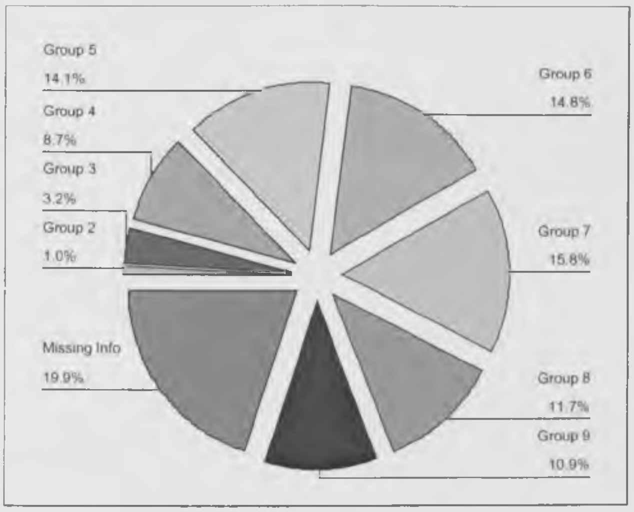

**Figure 6.2: Employment status of the household representative.**

Household Net Income (units: x1000 Escudos per month, 1999 prices) - The distribution of households by the various income categories is represented in Figure 6.3. Group 1, the very low income less than the minimum wage salary is not represented. The number of households who did not want to state their income was 82 (19.9%).

Number of People by Household - The mean value of the sample is 3.14 (range from 1 to 7).

Number of People who live permanently in the flat – The mean value of the sample is 2.99 (range from 1 to 7).

Number of children per household – The number of households without children living as a couple or alone were 183 (44.4%), 112 (27.2%) had 1 child, 82 (19.9%) had 2 children, 16 (3.9%) had 3 children and 2 (5%) had 5 children. The number of cases with missing information was 17 (4.1%). This disaggregate information will be used to compute the adjusted household income, considering household composition




Groups ($10^3$ Escudos per month per household):

1: <65
2: 65-245
3: 245-425
4: 425-605
5: 605-785
6: 785-965
7: 965-1145
8: 1145-1325
9: >1325

**Figure 6.3: Distribution of households by income categories.**

Health status of the household (all members) – This variable was considered as an indicator for noise sensitivity. The distribution of households is represented in Table 6.5. Around 12.9% of the households' representatives said to suffer some of the listed (noise related) health problems, being in the majority of cases insomnia. This does not mean necessarily a cause and effect relationship with traffic noise, as other interacting variables are not being examined in this study such as diet, life style, levels of noise at the workplace, etc. Therefore, the impact of the health status of the household on preferences for quiet is going to be tested in the modelling chapters.

**Table 6.7: Health Status of the Household.**

| Member | **Insomnia** | **Hearing Problems** | **Heart disease** | **Blood pressure** | **Other (*)** |
|---|---|---|---|---|---|
| Representative | 26 (6.3%) | 3 (0.73%) | 9 (2.1%) | 15 (3.6%) | - |
| Partner | 14 (3.4%) | 9 (2.2%) | 12 (2.9%) | 10 (2.4%) | 7 (1.7%) |
| Person 1 | 11 (2.7%) | 3 (0.73%) | - | - | 4 (0.97%) |
| Person 2 | 13 (3.2%) | 3 (2.7%) | - | - | 4 (97%) |
| Person 3 | 17 (4.1%) | 11 (0.7%) | - | - | - |

(*) Most frequent answer was asthma and respiratory related diseases.

Awareness of the Negative Impacts of noise on health –This is also an indicator for sensitivity to noise. Householders who are aware of the negative impacts of noise on health may be more sensitive to noise in comparison to those who are not, and may have higher preferences for quiet. In the sample, 130 (31.6%) households said to be aware of the negative impacts of noise on health, whereas 272 (66%) gave negative answers. The number of observations with missing information was 10 (2.4%).

Number of motorized vehicles per household – Only 31 (7.5%) of the respondents said they had no car. The distribution of cases is as follows: one car per household in 146 cases (35.4%, being 31% gasoline), 2 cars per household in 192 cases (46.6%), 3 cars per household in 30 cases (7.3%) The other 13 cases (3.1%) said to have a motorcycle and at least a car.

Number of Years Living at the flat – Considering the length of residence as an indicator of the experience of the respondent related to the qualitative attribute being valued (quiet indoors), it is represented in Figure 6.4 the wide variety of experiences covered. Overall, 196 households (47.6%) said to live in the site for a number of years equal or greater than five. The number of cases with missing information is 6 (1.5%).

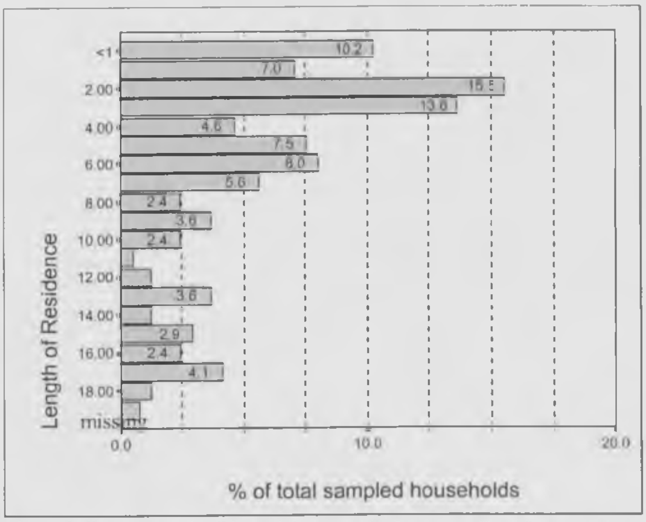



**Figure 6.4: Length of residence (number of years).**

## 6.4 EXPOSURE TO TRAFFIC NOISE

### 6.4.1 Buildings' Orientation Relative to Main Road and General Flat Exposure

The buildings orientation relative to main traffic road is as follows:

1 - Main façade is parallel to main traffic road: 294 (71.4%);

2 - Main façade is perpendicular to main road (28.6%).

More façade area is exposed to traffic noise in case 1 relative to case 2.

From the buildings surveyed, 230 (55.4%) have four households per floor (2 at the front façade and 2 located at the back façade), whereas the other 182 (44.2%) live in buildings with two or three households per floor. The number of households who are affected by shielding effects (terrain elevations and noise barriers are 98 (23.8%). These householders are the respondents in lower floors that are in the influence of nearby natural or artificial obstacles that are expected to reduce traffic noise.

Table 6.8 represents a summary of the households' positions in the building (lower or upper floor) and the general exposure to main road as defined in chapter 4.

**Table 6.8: General Flat Exposure of the Sampled Householders.**

| General Flat Exposure | LOWER FLOORS | | UPPER FLOORS | |
|---|---|---|---|---|
| FRONT to main road | 119 | | 123 | |
| BACK to main road | 62 | | 71 | |
| LATERAL to main road | 20 | | 17 | |
| Total | 201 | **48.8%** | 211 | **51.2%** |

Considering the SP design, one of the objectives was to have a sample of individuals living in upper and lower floors of similar proportion.

### 6.4.2 Window Types

In general, windows are acoustically poor elements of an exposed façade, especially due to its much lower density (see equation 4.1 in chapter 4). In the study area the households do have different window types, and these influence the levels of noise heard indoors. The distribution of window types is represented in Table 6.9.

**Table 6.9: Window Types in the Apartments.**

| Window types | N (%) |
|---|---|
| **Window type 1 (hinged opening)** | 60 (14.3%) |
| **Window type1, double glazing** | 42 (10.2%) |
| **Window type 1, and secondary glazing*** | 17 (4.1%) |
| **Window type 1, double and secondary glazing*** | 15 (3.6%) |
| **Simple Window, type 2(open/closes horizontally)** | 122 (27.2%) |
| **Window type 2, double glazing** | 36 (8.7%) |
| **Window type 2, secondary glazing *** | 85 (20.6%) |
| **Window type 2, double and secondary glazing** | 35 (8.5%) |

* Includes situations with interior features such as closed window balconies.

## 6.5 HOUSEHOLDERS' BEHAVIOUR WHEN IN THEIR APARTMENTS AND ATTITUDES TOWARDS AVERTING NOISE

### 6.5.1 Length of Time Spent at Home and Type of Activities

In Lisbon females tend to spend more time at home as a result of their professions and childcare. Figure 6.5 represents the error bars (two standard deviations above and below the mean) for a 95% confidence interval for the mean number of hours spent home (NH) during the day by females and males.

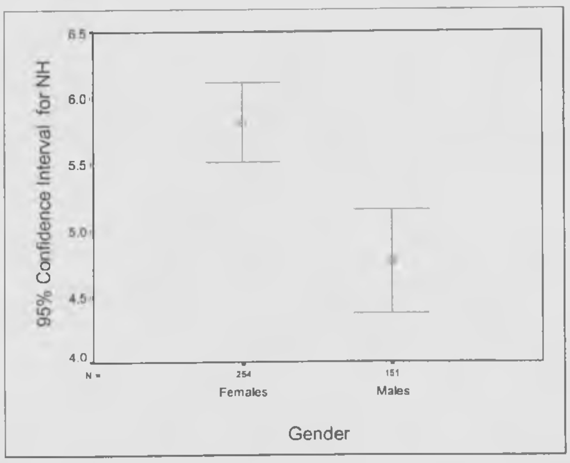



**Figure 6.5: Error bars for the mean length of time spent home during the day (7am-10pm) by females and males.**

Considering the different sample size for male and females represented in our sample, it is necessary to conduct an Independent-samples t-test to assess the statistical significance of the differences of mean number of hours (NH) that are usually spent home during the day (7am-10pm) by respectively females and males. The results of this test are represented in Table 6.10. It shall be noted that the number of observations with missing information on this variable was seven.

**Table 6.10: Independent Samples t-test (Output from SPSS).**

Independent Samples Test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| NH | Equal variances assumed | .382 | .537 | 4.211 | 403 | .000 | 1.05 | .25 | .56 | 1.54 |
| | Equal variances not assumed | | | 4.198 | 312.319 | .000 | 1.05 | .25 | .56 | 1.54 |

The Levene's test for equality of variances shows that the variance of mean length of time is very similar for both cases (males and females). The t-test for equality of means t (403)=

4.211, p=0.000 (p<0.01). Therefore, the mean length of time spend home by females is significantly higher than the case for males.

Besides the number of hours spent home, the behaviour of the whole household indoors with regard to the room (and related exposure to main road) often used more than 50% of time when home, and the type of activities normally conducted may be important. Whereas some activities such as listening to music or watching TV might offset in a certain extent the traffic noise that can be heard from external sources, other activities such as studying or reading may inflate the presence of the environmental stressor. Table 6.11 shows the room where the respondent spends more than 50% of the time when home, and its exposure to main road and

**Table 6.11: Room (and its Exposure to Main Road) where the Household Representative Spends More than 50% of the Time when Indoors.**

| Room → Exposure | Bedroom | Kitchen | Sitting Room | Other (*) |
|---|---|---|---|---|
| **Back** | 9 | 19 | 93 | 10 |
| **Front** | 17 | 40 | 171 | 8 |
| **Lateral** | 3 | 6 | 28 | 3 |
| **Total** | **29 (7%)** | **65 (15.8%)** | **292 (71%)** | **21 (5.1%)** |

(*) Most frequent answer was room used as office.

Results show that the majority of households (71%) spend their time in the reference day period in the sitting room. Around 96% of these respondents said they watch TV.

The place where the household usually spends the weekend was also surveyed, as this may constitute an incremental factor (or not) in valuing quiet. The analysis showed that 252 households (61.2 %) usually spend weekends at home. From these households who normally stay home during weekends, 186 (73.8%) said to study or work. Households whose children were attending school may justify this high proportion.

The fact that householders may need to work during weekends might not be a major influential factor when valuing quiet as traffic levels are lower than in normal weekdays. This factor is examining in subsequent modelling chapters.

### 6.5.2 Noise Averting Behaviour

Noise averting behaviour reveals a preference for quiet indoors, as well as a disposition to pay considering the available budget. 25% of the households (N=104) have conducted some noise averting measure indoors, whereas the majority (75%) did not. The analysis of the general exposure to traffic noise of the former effective noise averting householders shows that 71 over 104 cases (68.3%) are located front to main road, whereas 27 are back and 6 are lateral. Therefore, general exposure as specified is expected to be an important influential factor for preferences for quiet. Table 6.12 indicates the averting behaviour profile of these respondents, considering the preferred type of measures. Their location in terms of the main road they face is indicated there.

**Table 6.12: Averting Noise Measures Indoors.**

| Type of Measure | Number of cases | Situation in relation to main road | | |
|---|---|---|---|---|
| N=104 | | MR1 | MR2 | MR3 |
| **Double glazing** | 63 | 29 | 20 | 14 |
| **Secondary glazing** | 65 | 16 | 24 | 25 |
| **Shadow Ceiling** | 6 | - | 6 | - |
| **Shutters Outside** | 16 | 6 | 8 | 2 |
| **Others (*)** | 12 | 4 | 5 | 3 |

(*) Insulation of the internal devices of shutters placed indoors.

From Table 6.12 above, it shall be noted that some households have taken more than one type of measure indoors (sum of cases is greater than 104, the number of householders who have conducted noise averting measures). The most effective measure (double glazing) was taken more times by householders nearby main road 1 (Second Inner Road). This fact reflects not only the traffic levels, but also the higher income of most households relative to other cases. In the survey, 19 respondents (4.6%) said they changed the use of one of the rooms (e.g. from front to back), and only 2.1% said they did that due to traffic noise. In general, internal mobility is constrained by the apartment areas and layout.

### 6.5.3 Other Behavioural and Attitudinal Variables

Behavioural factors such as the habit of having the window open during Spring/Summer can reveal a reduced preference for quiet in comparison to other indoor attributes such as a degree of ventilation (or temperature). On the other hand, this might be a confounding factor if individuals take this action for short periods for ventilations purposes and/or mainly during the night when levels of noise are lower. Around 87% of the buildings surveyed do not have air conditioning. 68 % of the respondents (278 cases) said to have normally the windows open during Spring/Summer. When analyzing further these householders, 153 (55%) were located fronting the main road. This behaviour might indicate less preference for quiet in relation to the ambient temperature indoors (trade-off of attributes).

There was no formal question on complaints made. However, notes taken during the survey work have reported that 25 householders (6%) made formal complaints either against the main developer or to the local council. Twenty of these householders were located in upper floors. The physical noise data shows that the noise levels indoors are on average higher for upper floors. On the other hand, these householders may have a higher disposition to react to noise considering other variables such as socio-economic or health related issues.

## 6.6 HOUSEHOLDERS' PERCEPTIONS OF THE INTERNAL NOISE LEVEL AND ITS RELATION WITH THE REAL PHYSICAL NOISE MEASURES

From chapter 4, it is known that the same objective environmental condition (e.g. 55 dB(A)) can result in very different subjective perceptions at the individual level. During the SP experiment, households rated the internal noise levels experienced in their apartments and in three other flat alternatives in the same building/lot of the individual (chapter 4, Figure 4.1). They used a continuous scale, from 0 (represents a "very noisy" situation) to 100 (represents a "very quiet" situation). They rated the four flat alternatives at the same time (as all flat choices appeared in the same computer screen) as shown in Figure 6.6.

Considering the SP experimental design, one stimulus is experienced by the respondent at his current apartment (status quo), whereas the other stimulus can be designated as perceived sensations (familiarity is taken into account, but not necessarily experience) in relation to the status quo.

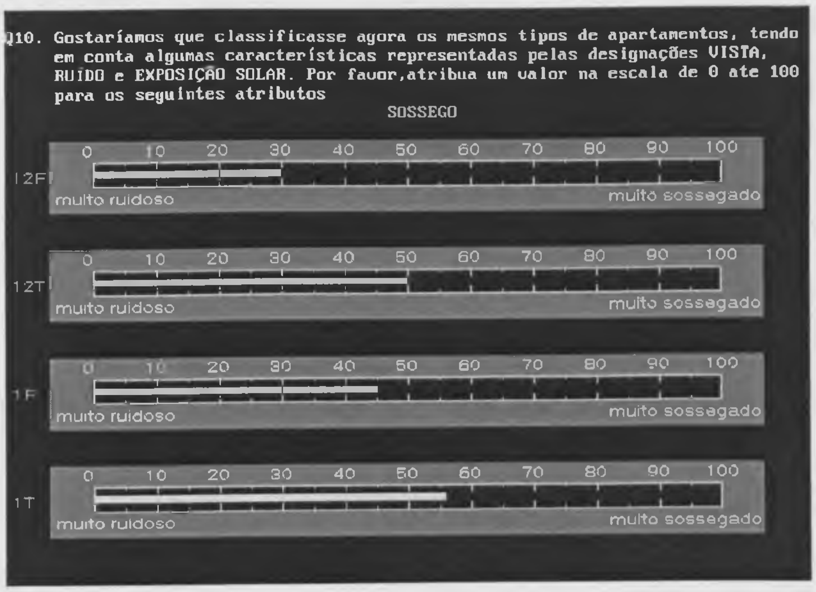



**Figure 6.6: Example of ratings scales (computer screen).**

### 6.6.1 Absolute Perceptions versus absolute Leq dB(A)

In this section the strength and direction of the relationship between absolute perceptions and the real physical noise measures will be assessed. This is considered an important indicator for validating the replacement of perceptions with physical data in the subsequent modeling chapters. The correlations between absolute perceptions of quiet/noise (ratings) for the four types of apartments and the correspondent Leq dB(A) measures taken in each situation is represented in Table 6.13. The total number of observations is 412 respondents.

**Table 6.13: Correlations Between Absolute Perceptions and Leq dB(A)**

| Noise Ratings | Leq dB(A) |
|---|---|
| Current apartment | -0.414, p=0.000 (sig. 2 tailed)* |
| Same floor opposite façade | -0.371 ,p=0.000 (sig. 2 tailed)* |
| Extreme floor, same façade | -0.125 , p=0.011 (sig. 2 tailed)** |
| Extreme floor, opposite façade | -0.315, p=0.000 (sig. 2 tailed)* |

*Correlation is significant at the 0.01 level and at **the 0.05 level (2-tailed).

Table 6.13 shows that there is a statistically significant negative correlation between ratings and the physical noise measures in the sample. It has the right expected sign, due to the different scales used (a higher rating means less noise whereas an higher Leq dB(A) means a noisier situation). The Pearson's product-moment correlation between the two measures (subjective and objective) is higher for the case of respondent's apartment. This is expected as households will have higher familiarity with the situation they experience everyday. The correlations between absolute perceived levels and the absolute physical noise measures for apartments at different floors on the same façade of the respondent are not as good as for apartments located at the opposite facades of the current apartment. Along the same façade other confounding factors interact simultaneously with respondents' perceptions and also with the sound propagation in height, such as the existence of noise barriers or natural terrain elevations that shield traffic noise, and averting behaviour such as change of window types.

Next it will be assessed how respondents perceived the variation of noise along the same façade, following an independent samples t-test, considering two groups of respondents (those who live in upper floors and those who live in lower floors). It is considered as cut-off point in the analysis floor number (FN) equal to 4, considering that in the Lisbon housing market state agents usually make this segmentation. Results of the test are shown in Table 6.14 (QX represents the ratings for respondents' current apartment).

**Table 6.14: Independent Samples t-test for Testing the Mean Difference in Perceptions of Noise between Extreme Floors in the Same Façade.**

**Group Statistics**

| | FN | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| QX | >= 4.00 | 208 | 46.6683 | 23.3902 | 1.6218 |
| | < 4.00 | 204 | 51.7010 | 24.1039 | 1.6876 |

**Independent Samples Test**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| QX | Equal variances assumed | .061 | .805 | -2.151 | 410 | .032 | -5.0327 | 2.3399 | -9.6324 | -.4330 |
| | Equal variances not assumed | | | -2.150 | 408.998 | .032 | -5.0327 | 2.3406 | -9.6338 | -.4316 |

Results show that the mean difference of perceptions of noise between upper floors (greater equal 4) and lower floors (less than 4) is negative -5.0327 (t=0.032 <0.05). Considering the rating scale (decreasing magnitude means increase in noise) this means that upper floors are perceived as noisier.

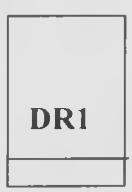
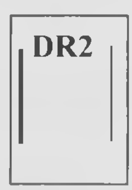
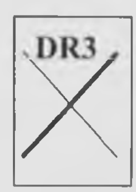
Conducting the same test for the case of physical noise measures, it turns out that upper floors (as defined) are noisier on average by 2.243 dB(A) more. This difference is statistically significant (p=0.000<0.05).

### 6.6.2 Relative Perceptions versus Relative Leq dB(A)

#### 6.6.2.1 Sample correlations

As already noted in chapter 4, considering the reinterpretation of the results of direct psychophysical judgment in terms of the relation theory (Shepard 1981) it is primarily the relationship between the *stimulus* and not the individual magnitude themselves that are perceived by the individuals. Therefore, it is expected that the degree of association between relative perceptions and relative noise measures will be higher that in the case of absolute values. Respondents' relative perceptions of the noise levels indoors were calculated, considering the difference in ratings between the ones given to their own flats and 1) the flat in the same floor and located in the opposite façade (DR1); 2) the flat in the same façade but located in the extreme floor (DR2); 3) the flat located in the opposite façade and the opposite extreme floor (DR3). The correspondent difference in terms of Leq dB(A), respectively DLeq1, DLeq2 and DLeq3, are computed in the same way, considering the noise measures at each apartment in Leq dB(A). Table 6.15 represents the Pearson correlation coefficients (2-tailed) between relative perceptions and relative noise measures in each case.

**Table 6.15: Correlations between Relative Perceptions and Relative Noise Measures, Expressed as Differences from the Base.**

| |  DR1 |  DR2 |  DR3 |
|---|---|---|---|
| **DLeq1** | -0.568, p=0.000 | - | - |
| **DLeq2** | - | -0.147, p=0.003 | |
| **DLeq3** | - | | -0.533,p=0.000 |

Results show that the correlation coefficients had the right expected sign and are all statistically significant at a high level of confidence (0.01 level). Their magnitude is higher than the relationships found for absolute levels.

#### 6.6.2.2 Aggregate Models for the Relation between Relative Perceptions and Relative Physical Noise Measures

This section uses multiple linear regression to derive the relationship between relative perceptions and the relative physical noise measures. Relative measures are expressed as differences in the levels (current level of noise minus the other level of noise in another apartment situation). The interest on deriving this relationship resides on the possibility of using a simple model for the initial impact analysis of future residential developments in the context. Whereas individuals' ratings are impossible to known at the planning stage of any future development, the physical noise measures can be easily available either through direct measurements or by using noise prediction models based on actual and future traffic characteristics. Therefore, noise levels expressed in ratings can be converted to the equivalent noise metric in Leq dB(A).

Models on the relationship between ratings and physical noise measures were estimated using linear and non-linear regression analysis. The models with higher goodness-of-fit measures and theoretical plausibility are as follows:

$$DR = \phi \cdot Lbase^{\theta} - \phi \cdot L^{\theta} \ , \qquad (6.1)$$

$$\begin{aligned} DR = & (\phi \cdot Lbase^{\theta} - \phi \cdot L^{\theta}) + \beta \cdot (\phi \cdot Lbase^{\theta} - \phi \cdot L^{\theta}) \cdot DumBack + \\ & + \varphi \cdot (\phi \cdot Lbase^{\theta} - \phi \cdot L^{\theta}) \cdot DumBtyp + \alpha \cdot (\phi \cdot Lbase^{\theta} - \phi \cdot L^{\theta}) \cdot Height \cdot Fn \end{aligned} \qquad (6.2)$$

where DR is the difference in ratings, *Lbase* is the physical noise level at the current apartment, *L* the other level in Leq dB(A), *DumBack* is a dummy variable for flat exposure at the back façade, *DumBtyp* is a dummy variable for choice within the same lot, *Height* is the height of building (computed as maximum number of floors times the average height of each floor which of 3 meters) and *Fn* the floor number of the respondent. Although a wide range of variables had been explored, estimation results (Table 6.16) showed that only a few additional effects to the base model were statistically significant.

**Table 6.16: Regression of Relative Perceptions on Leq dB(A) Measures.**

| Parameters (t-stats*) | Base Model (Equation 6.1) | Final Model (Equation 6.2) |
|---|---|---|
| $\phi$ | -0.000414 (15.1) | -0.000501 (4.669) |
| $\theta$ | 3.1 (5.0) | 3.0 (**) |
| $\beta$ | n.a. | 0.356899 (2.369) |
| $\varphi$ | n.a. | -0.431101 (5.233) |
| $\alpha$ | n.a. | -0.001128 (17.968) |
| Adj $R^2$ | 0.165 | 0.182 |
| NOBS | 1236 | |

*asymptotic t-stats; n.a.: not applicable; (**) entered as constraint in estimation for simplification (round number as power).

The properties of the final model (equation 6.2) are as follows:

- If the base noise level (*Lbase*) at the current apartment is equal to the other physical level *L* (other apartment in the same block or lot), then the equivalent perceived difference in ratings (*DR*) is zero;
- Assuming a constant noise change, equation 6.3 shows that as *Lbase* increases (becomes noisier) a higher decrease in ratings is expected (therefore *DR* becomes more negative). The sign is consistent with the ratings scale used (a decrease in ratings means a noisier situation). This is also theoretically plausible as individuals are expected to be more sensitive to noisier situations. Also, for the same noise levels (in the current and the other situation), the difference in ratings increases with height and floor number and if the flat exposure is at the back façade, as expected. The ratings' difference is smaller if the rated situations refer to apartment situations in the same lot of the respondent in comparison to more familiar situations within the same block of the respondent.

Using the final regression model (equation 6.2), Table 6.17 shows the expected difference in ratings (perceived changes) for different situations, assuming that apartment choices are within the same building of the respondent (in this case, *DumBytp* in equation 6.2 is equal to zero), and that the floor number (*Fn* in equation 6.2) is equal to 10.

**Table 6.17: Expected Difference in Ratings (DR).**

| **Lbase dB(A)** | **L dB(A)** | **Floor number** | **DR** | |
|---|---|---|---|---|
| Height = 30 m (10 floors) | | | **Front** | **Back** |
| 40 | 35 | 10 | -10.9 | -14.7 |
| 55 | 35 | 10 | -62.3 | -84.4 |

## 6.7 ANNOYANCE LEVELS DUE TO ROAD TRAFFIC DURING THE DAY AND NIGHT

### 6.7.1 Rated Noise Levels During the Reference Day and Night Periods

Table 6.18 represents the contingency table of ratings given by the households for the noise levels during the day (NLD) and night (NLN), considering the Portuguese noise regulatory reference periods. The scale used was a five point scale: 1-Very Noisy; 2- Noisy; 3- Neither Noisy or Quiet; 4 - Quiet; 5- Very Quiet.

**Table 6.18: Noise Levels During the Day (7am-10pm) and Night (10pm-7am).**

| | | NLD | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| NLN | 1 | 46 | 33 | 9 | 1 | | 89 |
| | 2 | 14 | 36 | 34 | 8 | | 92 |
| | 3 | 5 | 26 | 51 | 38 | | 120 |
| | 4 | 1 | 4 | 10 | 62 | 10 | 87 |
| | 5 | | | | 5 | 7 | 12 |
| Total | | 66 | 99 | 104 | 114 | 17 | 400 |

(*) Missing data on 12 cases.

Table 6.18 shows that 202 respondents (51%) have given equal ratings to the noise levels during the day and night, whereas the other 49% thought differently. Considering the different number of observations for each group, and in order to assess the statistical significance of the mean difference between the mean ratings given for the reference day and night periods, a non-parametric Wilcoxon Signed-Rank is next conducted for the two related samples. Table 6.19 shows the result of this test.

**Table 6.19: Wilcoxon Signed Rank Test (Output from SPSS).**

**Ranks**

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| NLD - NLN | Negative Ranks | 65[a] | 100.79 | 6551.50 |
| | Positive Ranks | 133[b] | 98.87 | 13149.50 |
| | Ties | 202[c] | | |
| | Total | 400 | | |

a. NLD < NLN

b. NLD > NLN

c. NLN = NLD

**Test Statistics[b]**

| | NLD - NLN |
|---|---|
| Z | -4.452[a] |
| Asymp. Sig. (2-tailed) | .000 |

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

The Z score value is –4.452 ($p=0.000<0.01$). Therefore, there is a statistical difference in ratings between the day and night period. Considering the rating scale used (a higher score means quieter), the day reference period as defined (7am-10pm) is considered noisier than the night. It shall be noted that the Portuguese noise reference day period includes the 75% of the evening reference noise period (7pm-11pm) plus the day period (7am-7pm) of the EU proposed noise regulatory framework (CEC 2000), not yet implemented. The information on time of day that was considered noisier for households was not collected during the survey, but some comments from households have referred they did not like to wake up hearing traffic noise, and that they are often forced to wake up earlier than needed. In the next section the hypothesis that the noisier period during the day is also more annoying is tested.

### 6.7.2 Levels of Annoyance During the Reference Day and Night Periods

The sample considered in this section refers to those households who said that either day or night is noisy or very noisy. The number of households annoyed in each reference period is represented in Table 6.20.

**Table 6.20: Households Annoyed During the Day and Night Reference Noise Periods.**

| Levels of Annoyance | Day | Night |
|---|---|---|
| **1. Very much** | 80 | 82 |
| **2. Moderately** | 69 | 76 |
| **3. A little** | 15 | 23 |
| **4. Not at all** | 1 | 1 |
| **Total** | 165 | 182 |

*Missing data: 12 cases.

- Correlation between noise ratings (very noisy; noisy) with Levels of Annoyance during the day *(N=165):* Kendall's tau correlations is represented in Table 6.21. Kendall's ι (tau) = 0.635 (p=0.000; p<0.01). Therefore noise ratings are strongly correlated with levels of annoyance.

**Table 6.21: Kendall's tau_b Correlation between Noise Ratings and Levels of Annoyance during the Day.**

**Correlations**

| | | | NLD | LAD |
|---|---|---|---|---|
| Kendall's tau_b | NLD | Correlation Coefficient | 1.000 | .635** |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 165 | 165 |
| | LAD | Correlation Coefficient | .635** | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 165 | 165 |

**. Correlation is significant at the .01 level (2-tailed).

- Correlation between noise ratings (very noisy; noisy) with Levels of Annoyance during the night (N=182): Kendall's tau correlations is represented in Table 6.22 ι (tau) = 0.510 (p=0.000; p<0.01). Therefore noise ratings are strongly correlated with levels of annoyance during the night.

**Table 6.22: Kendall's tau_b Correlation Between Noise Ratings and Levels of Annoyance during the Night (N=182).**

**Correlations**

| | | | NLN | LAN |
|---|---|---|---|---|
| Kendall's tau_b | NLN | Correlation Coefficient | 1.000 | .510** |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 182 | 182 |
| | LAN | Correlation Coefficient | .510** | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 182 | 182 |

**. Correlation is significant at the .01 level (2-tailed).

Considering the different sample sizes in each annoyance group (day versus night), a Wilcoxon Signed Rank test is conducted to assess if there is a statistically significant difference in mean ratings of annoyance for the day and night reference periods. This test is presented in Tables 6.23 and 6.24.

**Table 6:23: Contingency Table, Annoyance Levels: LAN- during the day and LAD- during the night**

| | | LAD | | | | Total |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | |
| LAN | 1 | 57 | 14 | | | 71 |
| | 2 | 12 | 30 | 4 | | 46 |
| | 3 | 4 | 3 | 4 | | 11 |
| | 4 | | | | 1 | 1 |
| Total | | 73 | 47 | 8 | 1 | 129 |

**Table 6.24: Wilcoxon Signed Rank Test (Output from SPSS).**

**Ranks**

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| LAD - LAN | Negative Ranks | 19[a] | 20.89 | 397.00 |
| | Positive Ranks | 18[b] | 17.00 | 306.00 |
| | Ties | 92[c] | | |
| | Total | 129 | | |

a. LAD < LAN

b. LAD > LAN

c. LAN = LAD

**Test Statistics**[b]

| | LAD - LAN |
|---|---|
| Z | -.754[a] |
| Asymp. Sig. (2-tailed) | .451 |

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Results show that the Z score value is –0.754 (p=0.451 >0.01). Therefore, there is no significant difference in annoyance ratings at the 1% level of confidence for the day and night period. Those households who said they were at least a little annoyed, moderately or very much annoyed by noise during the day and night (Table 6.20), and when asked on how noise disturbs them more, they stated as main disturbance effect during the day (7am-10pm) "difficulty in resting/falling asleep" (78 cases) and during the night this answer was given also by the majority (54 cases). Only 21 households (8 were for the day period) have considered noise as causing frustation and irritation.

In the study area 93% of the sampled individuals said traffic noise was the most important cause of disturbance in their homes. 1.6% and 1.3% of the respondents referred noise from neighbours and construction, respectively. As this question was posed near the end of the questionnaire, it can be concluded that traffic noise was the main source of noise. This was expected from the preliminary selection of the study area, taking into account its characteristics. The SP experiment is set to value noise traffic externalities in the home.

## 6.8 CONCLUSIONS

The main descriptors of the sample of households and respective context were comprehensively analyzed. The statistical analysis is a useful base for the subsequent modelling chapters (when it will be assessed the nature and extent of householders' preferences for quiet indoors) in order to assure consistency with sample characteristics. This will serve as additional criteria for assessing the theoretical plausibility of the models. Moreover, for future noise studies using a similar SP experimental design, but conducted in different locations, this analysis will provide a rich basis for a consistent comparison of values of quiet (noise) across different circumstances.

The residential area selected as pilot showed to have a very satisfactory diversity in terms of their inhabitants, buildings and apartment characteristics. The sample is representative of the average and higher incomes groups, and it is under-represented in the lower income range. It shall be noted that the Lisbon Metropolitan area (LMA) has the highest socio-economic indicators in the country. The purchase power index is 155 for the LMA whereas this value is 100 for the whole country. On the other hand, considering the 18 councils that comprise the LMA, Lisbon has a purchase power index around four times higher than the average (INE 2000). The sample of respondents had higher education levels than the country average, and most households accepted well the computer survey.

The range of noise measurements outdoors (ground floor) at the front and back façades of the buildings showed a very small variation in the situations where noise barriers had been installed. The range of indoor (outdoor) noise measurements taken at each apartment floor had a larger range of variation. This reflected the wide variety of buildings and situations (terrain elevations, noise barriers, façade parallel, height of buildings, etc). Considering that the buildings surveyed were all in the vicinity of the main roads, the effect of distance to road is highly correlated with floor number.

Considering the WHO guidelines for dwelling indoors (30-35 dB(A)) to prevent moderate annoyance and to affect on speech intelligibility during the daytime and evening period, it was shown that 243 households (59% of the sample) had noise levels greater than Leq 35 dB(A). As 93 % of the sampled individuals reported road traffic was the main disturbance factor, it can be concluded that traffic externalities manifest themselves in the home by reduced levels of acoustical comfort.

Individuals' perceptions of the internal noise levels and the existence of a quieter-noisier façade plays a central role in the SP- choice experiment. In the sample of respondents, correlations of perceptions with the physical noise measures were higher for relative measures (difference in levels relative to the situation experienced in respondent's apartment). The Independent samples t-test shown than respondents perceived upper floors as noisier than lower ones in terms of mean perceived levels. This fact was in agreement with the real mean variation in Leq dB(A). This is consistent with the topographic and physical characteristics of the study area and noise barriers *in situ*.

Relative ratings could be related with the relative physical noise measures in Leq dB(A). However, the multiple regression models estimated with higher fit with the data showed that the variables that were statistically significant were only a few: exposure at the back façade, apartment choices within the same lot of the respondent, floor number and height of building. The explanatory power of the relationship was not high, and this fact limits the applicability of the model outside the present context.

The Wilcoxon signed rank test showed that there is a statistically significant difference for the ratings given for the night and day reference periods. The reference day period (7am-10pm) is considered noisier. This finding is consistent with the traffic patterns identified: main roads are used for commuting into Lisbon, whereas traffic levels are substantially lower during the night (pm peak traffic flows are typically lower than in the am peak, Appendix 2). Kendall's tau statistical test showed that mean noise ratings at the extremes of the scale ("very noisy", "noisy") were highly correlated with the annoyance levels both during the day and night noise reference periods. This issue can be the subject of further investigation in the future in community noise studies.

# CHAPTER 7:

# ANALYSIS OF THE STATED PREFERENCE-CHOICE DATA

## 7.1 INTRODUCTION

The objective of this chapter is to present the range of discrete choice models that were developed to estimate the marginal values of quiet (noise) using the Stated Preference-choice data (SP) collected in Lisbon. The data comprises 4944 flat choice observations that correspond to 412 computer aided personal interviews to householders (12 repeated observations per household). This final number of observations was achieved after having excluded all interviews with inconsistent responses and responses from respondents with lexicographic behaviour[1], as a result of the applications of data screening and validation process. Considering the design of the SP computer survey, the effects of a wide range of variables (situational, socio-economic, behavioural, etc) on the marginal values of quiet (noise) were assessed.

The models estimated comprised binary logit choice models (with additional variables) for repeated observations, and mixed logit models (ML). The former models are designated in this thesis as standard multinomial with additional variables (MNL-INT). The mixed logit models combine standard additional variables of the MNL-INT with random parameters specifications.

In the SP-choice experiment each household was shown twelve random pairwise combinations of apartment profiles. These were described by four main attributes: "View as, "Noise as, "Housing Service Charge" as and "Sunlight as (you perceive it)." The main features of the SP design were already described in chapter 4. As the SP-choice experiment was driven by respondents' perceptions of qualitative housing attributes when indoors, it can be expected *a priori* that discrete choice models based on perceptions will perform better than those based on the equivalent physical noise measures (*Research hypothesis*).

[1] *Lexicographic behavior* is not consistent with the compensatory decision structure of the multinomial logit model. Households who had always preferred the apartment option with the highest level of one sole attribute were excluded on the basis of their reactions during the SP interview, e.g. denoting an intention to rush the task or not reasoning (number of cases: 23, chapter 5).

Therefore, three types of discrete choice models were estimated in order to test the above mentioned research hypothesis:

- Models based on respondents' perceptions where the noise variable is expressed as the perceived noise levels indoors (as rated by the household);
- Models based on the physical noise measures indoors at each apartment (Leq dB(A));
- Models based on the outdoor physical noise measures where the noise variable was expressed as the measured noise level at each apartment floor exterior façade (Leq dB(A)).

The first stage of the discrete choice modelling work comprised the development and estimation of multinomial logit models with additional variables that could consider the effects of a wide range of variables collected on the marginal values of quiet (noise). The interest was to model in a progressive and structured way householders' heterogeneity of preferences for quiet (noise), and to understand the relevant factors underlying the implicit marginal values. These MNL-INT models were estimated using the ALOGIT and also GAUSS econometric packages. To my knowledge and considering the literature reviewed in chapter 3, this modelling work is novel in considering householders' heterogeneity (nature and extent) of preferences on the marginal valuations of traffic noise externalities in the home.

The second stage of the modelling work considered both the effect of repeated observations made by the same household, and the investigation of alternative modelling approaches such as Mixed Logit, to treat the issue of households' preference heterogeneity towards quiet and the other qualitative variables (taste variation). These models were estimated using GAUSS and adapting Kenneth Trains' mixed logit code for panel data[2]. The objective of the work was to test the research hypothesis that the combination of classic additional variables (observed heterogeneity considered in MNL-INT models) with random parameters' specifications that allow random (unobserved) heterogeneity over the referred deterministic heterogeneity (observed), can provide a better fit with the data, and therefore improve the explanatory power of the model. In conducting this task, the best specification for each random parameter (distribution) was found through several sequential tests. It is postulated that the development of these mixed logit models would result in progress towards the comprehension of the factors underlying householders' heterogeneity of preferences for qualitative attributes such as quiet.

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[2] http://elsa.berkeley.edu/~train/software.html

The discrete choice models reported in this chapter are those with highest goodness-of-fit measures and that are theoretically plausible, and all include the effect of repeated observations.

The remainder of this chapter is organized as follows. The first two sections present the general modelling methodology and the principles followed during the econometric research. The next three sections present, respectively, the MNL-INT models based on perceptions, physical noise measures indoors and outdoors. A section on mixed logit modelling then follows. The final section provides a summary of the main findings.

## 7.2 MODELLING METHODOLOGY

The best model specification was derived for each type of model following a step-by-step methodology, where the effect of repeated observations is considered:

1. Estimate a simple binary logit model including only the four attributes in the SP experimental design (unsegmented base model). These are called main effects;
2. Test the statistical similarity between the quiet (noise) parameters for losses in quiet versus gains in quiet, and for size of change effects. It shall be noted that the SP design was based on generic attributes. Nevertheless, it was aimed to test the effect of gains and losses relative to the situation experienced by each household by this way. Although not all SP experts found this procedure as the most adequate, it shall be noted that the correlation between variables (i.e. gains and losses in quiet) was found to be low (0.188).
3. Test the impact of various socio-economic, situational, behavioural and attitudinal variables on the marginal utility of quiet. Appropriate statistical tests were performed in order to assess improvements in the model;
4. Analysis of the income effects: these were modelled through the interaction of household income and the cost variable used (Housing Service Charge) through several functional forms;
5. Build general models with all variables whose effects were found to be statistically significant and proceed with the joint estimation of the parameters;
6. Re-check functional forms of the additional variables and parameters' similarity and conduct likelihood-ratio tests to ensure that no significant statistical improvement can be gained by any change;

7. Find the discrete choice models with higher goodness-of-fit measures and interpret results considering the statistical significance of the parameters, the underlying theory and previous expectations.

## 7.3 PRINCIPLES UNDERLYING THE ECONOMETRIC RESEARCH

### 7.3.1 The Base Binary Logit Model for Repeated Choices

The microeconomic justification of the random utility models estimated is described in detail in Ortúzar and Rodriguez (2002). The main variables presented in the SP experiment are considered in the specification of the deterministic component of the conditional indirect utility functions: View (VIEW), Quiet (QUIET), Housing Service Charge (HSCH) and Sunlight (SUNL). Considering household $i$ facing two apartment alternatives 1 and 2 at a choice occasion $k$, the conditional indirect utility functions can be written as:

$$V_{ik1} = \beta \cdot QUIET_{ik1} + \eta \cdot VIEW_{ik1} + \chi \cdot SUNL_{ik1} + \gamma \cdot HSCH_{ik1} \quad , \qquad \textbf{(7.1)}$$

$$V_{ik2} = \beta \cdot QUIET_{ik2} + \eta \cdot VIEW_{ki2} + \chi \cdot SUNL_{ik2} + \gamma \cdot HSCH_{ik2} . \qquad \textbf{(7.2)}$$

where i =1, 2,...,412 represent the number of householders in the sample and k =1,2,...,12 the number of repeated choice observations made by each household. All the variables are expressed in ratings in a scale from 0 to 100, representing the worst and the best level of the variable respectively. Therefore, the sign of the quiet coefficient in equations 7.1 and 7.2 is expected to be positive, whereas the cost coefficient is expected to be negative.

The effect of a dummy associated with alternative 2 (note that this alternative is always better in terms of quiet) was also tested, but as expected the alternative specific constant was not statistically significant. Since the attributes that characterize each alternative do not refer all to the current apartment location, the "inertia effect" or *status quo* bias is expected to be low. Other studies (see for example Ortúzar and Rodriguez 2002) found this effect important when the current location was presented to respondents.

### 7.3.2 The Main Econometric Principles, Underlying Theory and Expectations

In this sub-section, the main principles that were followed in the econometric research are described. These principles are illustrated considering the final MNL model with additional variables estimated if needed in order to make the text more comprehensive.

Assuming the utility maximizing framework outlined earlier in chapter 4, the challenge here is to adequately specify the deterministic component of the utility and to find the best functional forms for the range of effects modelled. The deterministic component is a function of the main observed attributes shown during the SP experiment (view, quiet (noise), housing service charge, sun exposure), and the interaction of quiet (noise) as perceived (and measured) with a range of influential variables (socio-economic, situational, behavioural, etc) collected during the main survey. The aim is that the estimated function will have desirable properties, confirming existing *a priori* expectations concerning the sign, magnitude and statistical significance of the parameters following acceptable principles of existing theories, or from existing evidence on community noise studies on the expected functional forms of the relationships between quiet and other variables. It shall be noted that the SP choice context used in this research study is novel, and the range of community noise studies reviewed are not conclusive with respect to the expected impacts of some variables. Therefore, a certain degree of flexibility is allowed by testing alternative functional forms for the explanatory variables in this case.

#### 7.3.2.1 Functional forms

The choice of functional form is a fundamental issue in the specification of the deterministic component of the conditional indirect utility function. The choice of functional form to represent the interaction between two variables is usually a result of *a priori* expectations on the form of the relationship and underlying theories from economics and also from psychology in this study. In general, powered functional forms are used for testing non-linear effects. This was used, for example, to explore a diminishing marginal utility of quiet with size of good or/and bad (research hypothesis), as shown in equation 7.3 (the conditional indirect utility function for alternative 1 is used):

$$V_{i1} = \beta \cdot QUIET_{i1}^{\lambda} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot HSCH_{i1} \qquad \textbf{(7.3)}$$

The $\lambda$ coefficient is thus expected to be less than one if the above research hypothesis is true.

Inverse functional forms (e.g. Quiet divided by the number of years living at the site) were tested in several cases, such as to explore the effect of number of years living at the site (YL>0). Other functional forms tested have considered the quiet variable divided by this continuous variable, YL to the power $n$ (n was searched for considering the maximum likelihood criteria), following equation 7.4 for alternative 1 (example).

$$V_{i1} = \beta \cdot \frac{QUIET_{i1}}{YL^{n}} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot HSCH_{i1}. \quad (7.4)$$

This specification was then compared to other alternative functional forms tested to explore the effects of number of years on marginal utility of quiet. The best fit was found for a dummy variable specification for a specific number of years, indicating that the marginal utility of quiet decreases only after a certain threshold (YL) is reached.

It shall be noted that considering the lack of evidence on the form of some relationships, various functional forms needed to be tested for the same variable, and results were interpreted following main properties of the model.

### 7.3.2.2 Gains (improvements) or losses (deteriorations) in quiet

The use of alternative specific coefficients was used to test possible asymmetry in the values of quiet (noise) concerning losses and gains in quiet. This research hypothesis aimed to test recent findings from marketing science and consumer research (Bell and Lattin 2000; Niedrich, R. *et al.* 2001) on reference price effects and prospect theory (Tversky and Kahneman 1991) that choice might depend on the reference level or *status quo* of the respondent and that losses in quiet might have a greater impact than gains. Following prospect theory, for example, this will imply that the value function is *S* shaped, concave above the reference point (gains), and convex below it (losses). Following loss aversion behaviour, the disutility of facing one unit deterioration in the levels of quiet is greater than the utility of one unit improvement.

In the SP design, apartament alternative 2 was set to be always quieter than the current situation (respondent's apartment), whilst apartament alternative 1 was noisier than the current situation. Therefore, considering the two base conditional indirect utility functions of the binary discrete choice models $V_{i1}$ and $V_{i2}$, where the subscripts 1 and 2 stand for apartment options 1 and 2, respectively, and *i* for the household number are shown as equations 7.5 and 7.6, a condition was imposed that the coefficients of the quiet variable $\beta$ and $\lambda$ are different for each apartment alternative.

$$V_{i1} = \beta \cdot QUIET_{i1} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot HSCH_{i1} \quad (7.5)$$

$$V_{i2} = \lambda \cdot QUIET_{i2} + \eta \cdot VIEW_{i2} + \chi \cdot SUNL_{i2} + \gamma \cdot HSCH_{i2} \cdot \qquad (7.6)$$

Using the variance-covariance matrix information (output from econometric software used in the estimation), the asymptotic $t$ test is used to assess that the coefficients β and λ are not equal. This test statistic is given by:

$$t = \frac{\beta - \lambda}{\sqrt{\mathrm{var}(\beta) + \mathrm{var}(\lambda) - 2\,\mathrm{cov}(\beta, \lambda)}}. \qquad (7.7)$$

In equation 7.7, the terms 'var' and 'cov' stand for the variance and the covariance of the coefficients, respectively. If this t-statistic is greater than the two-tailed $t$ critical value at the 5% level of confidence, the hypothesis that those coefficients are equal is rejected.

The likelihood ratio test statistic can be used to assess if the overall specification (model NEQ) is statistically superior when the quiet coefficient is assumed to be equal (model EQ), i.e. when a one unit improvement in quiet is valued equally as one unit level degradation. This test statistic is:

*-2 (Log likelihood of model EQ – Log likelihood of model NEQ)*

This test statistic is $\chi^2$ distributed with $k$ degrees of freedom equal to the number of restrictions made to coefficients (Ben-Akiva and Lerman 1997). The hypothesis that the coefficients β and λ are equal is rejected if the value of the test exceeds the $\chi^2$ critical value for the usual 5% level of confidence, and degrees of freedom equal one (in this example).

During the model development process, it was felt the need to test other alternative specific variables for modelling householders' differences in preferences for apartments 1 and 2. This was the case of the cost variable (housing service charge), where payment changes relative to current monthly payment are assessed (losses and gains in money).

#### 7.3.2.3 Size of changes and sign in the levels of quiet (relative to the base level experienced in the current apartment)

The effect of size of quiet changes relative to base level QBAS was modelled through the specification of a quadratic form of the changes in quiet relative to base:

$$V_{i1} = \beta \cdot QUIET_{i1} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot HSCH_{i1} + \alpha \cdot (QBAS_{i} - QUIET_{i1})^2, \qquad (7.8)$$

$$V_{i2} = \beta \cdot QUIET_{i2} + \eta \cdot VIEW_{i2} + \chi \cdot SUNL_{i2} + \gamma \cdot HSCH_{i2} + \alpha \cdot (QUIET_{i2} - QBAS_i)^2 \quad (7.9)$$

Taking the derivative of the conditional utility function with respect to quiet, yields:

$$\partial V_{i1} / \partial(QUIET_{i1}) = \beta + 2\alpha \cdot (QBAS_i - QUIET_{i1}), \quad \textbf{(7.10)}$$

$$\partial V_{i2} / \partial(QUIET_{i2}) = \beta + 2\alpha \cdot (QUIET_{i2} - QBAS_i). \quad \textbf{(7.11)}$$

As the terms in brackets are always positive, the α coefficient is expected to be negative. If the reference-dependent theory of Tversky and Kahneman (1991) is considered (see also chapter 4), the marginal value of both gains and losses in quiet are expected to decrease (equations 7.10 and 7.11). Adding this quadratic term considerably improved the log likelihood of the base model based on perceptions. Therefore size effects are important on the marginal utility of quiet. This finding seems also to indicate the presence of non-linear effects between QUIET and QBAS (best functional form to be further tested). Taking this finding, the best functional form for the interaction of QUIET and QBAS is searched for, results to follow in section 7.3.2.5 a). Making the quadratic term in equations 7.8 and 7.9 as alternative specific tested the effect of both size and sign.

#### 7.3.2.4 Size of changes and sign in the levels of the monthly housing service charge payments (relatively to the base HSCH)

In the SP design the money payment used was the housing service charge (HSCH). It varies by type of building, area of flat, existence of garage and other facilities in the lot (e.g. green space). Apartments located in more expensive buildings (with higher prices for apartments) have in general higher housing service charges, reflecting also higher maintenance costs. The effect of size of payments changes relative to the base payment was tested through a quadratic functional form for this term, following the same procedures as in section 7.3.2.3. The strength of the effect can then be directly assessed by the magnitude of the coefficient. By specifying different power coefficients (besides the power 2), the optimal power coefficient that conducts to the best model fit was searched for (criteria: maximum log likelihood). The log likelihood ratio test was used to assess the statistical significance of model improvements from the base model.

The joint effect of size and sign of money changes was tested by setting alternative specific coefficients for the quadratic terms representing the size effect. This model specification did not represent a statistical improvement relative to the base model (when coefficients are equal). The effect of sign of money payments (housing service charge decreases or increases) was initially tested by setting alternative specific coefficients for this variable in the base model, following the same procedures explained in sub-section 7.3.2.2. The t-statistics showed that the coefficients $\gamma$ and $\varphi$ for cost (housing service charge) that represented losses and gains in the monthly payments respectively were not statistically different from each other, at the 5% level of confidence.

#### 7.3.2.5 Additional variables involving continuous variables

The number of possible functional forms between the quiet (noise) variable and other continuous variables is large. An important point considered is whether there existed any evidence towards the expected form of the relationship (strength, sign, etc.). It is a common procedure to start with simpler interaction functional forms such as classic product terms (example: HSCH*HBAS, where HBAS represents the current monthly payment and HSCH the increased or decreased housing service charge). It might be the case that these functional forms are statistical significant and contribute to significant improvements in the log likelihood of the base model.

**a) Interaction of size of change in the levels of quiet with the absolute quiet/noise level in the preferred flat option**

In the noise studies reviewed no direct evidence was found on the best functional form for the interaction of size of change in the levels of quiet with the absolute quiet (noise) levels in the preferred flat option. From economic theory it is expected that this functional form can verify the property of decreasing marginal utility with size of changes in the good (i.e. as it becomes quieter). From reference dependent choice theory (Tversky and Kaheman 1991) it is expected a decreasing marginal utility of quiet for increasing size of improvements and deteriorations.

Several functional forms were to be tested for this purpose, starting with the simplest one: interaction of a quadratic term for the effect of size of change in the levels of quiet (see section 7.3.2.3) with the absolute levels of quiet. Note that this search for the best functional form reflected *a priori* expectations from economic theory. In section 7.3.2.3 it was found that the quadratic term $(QBAS\text{-}QUIET1)^2$ in equation 7.8 and $(QUIET2\text{-}QBAS)^2$ in equation 7.9 which represented the effects of change in the levels of quiet, respectively for losses and gains in quiet, was statistically significant. Moreover, the inclusion of these terms in the base model represented a significant improvement in the model fit. When modelling the interaction between size of changes in the levels of quiet (relative to the base noise level), and the absolute levels of quiet in the preferred flat option, it was found that the best fit was provided by a non-linear relationship as represented by the conditional indirect utility functions in equations 7.12 and 7.13.

$$V_{i1} = \beta QUIET_{i1} + \eta VIEW_{i1} + \chi SUNL_{i1} + \gamma HSCH_{i1} + \delta QUIET_{i1}(QBAS_i - QUIET_{i1})^2 , \quad \textbf{(7.12)}$$

$$V_{i2} = \beta QUIET_{i2} + \eta VIEW_{i2} + \chi SUNL_{i2} + \gamma HSCH_{i2} + \delta QUIET_{i2}(QUIET_{i2} - QBAS_i)^2 .$$

**(7.13)**

The previous models in 7.3.2.2 can be considered a special case of this one. In equation 7.12, QBAS (base level of quiet) is greater than QUIET (following deteriorations in the levels of quiet as perceived), whereas in equation 7.13 the QBAS level is less than QUIET (following improvements in the levels of quiet as perceived). Therefore, considering the first derivative of the conditional indirect utility functions with respect to QUIET1, some properties of this functional form can be shown (subscript *i* is omitted):

$$\frac{\partial V}{\partial (QUIET_1)} = \beta + \delta \cdot (QBAS - QUIET_1)^2 - 2 \cdot \delta \cdot QUIET_1 \cdot (QBAS - QUIET_1) =$$
$$= \beta + \delta \cdot (QBAS - QUIET_1) \cdot (QBAS - 3QUIET).$$

**(7.14)**

$$\frac{\partial V}{\partial (QUIET_2)} = \beta + \delta \cdot (QUIET_2 - QBAS)^2 + 2 \cdot \delta \cdot QUIET_2 \cdot (QUIET_2 - QBAS) =$$
$$= \beta + \delta \cdot (QUIET_2 - QBAS) \cdot (3QUIET_2 - QBAS).$$

**(7.15)**

As the terms between brackets such as (QBAS-QUIET1) and (QUIET2 – QBAS) are always positive due to the Quiet/Noise scale used in the computer survey (QBAS>QUIET1 and QBAS<QUIET2 because they represent situations of losses and gains in quiet levels respectively), this makes it easy to understand the marginal utility of quiet function properties above (equations 7.14 and 7.15):

- As the β coefficient is positive, the coefficient δ is expected to be negative in the reference-dependent model because the marginal utility of quiet is expected to decrease with the size of change. It shall be noted that economic theory says that the marginal utility of quiet will increase with size of good (that is quiet and not noise), but at a decreasing rate (diminishing marginal utility). Considering findings from previous work towards a reference-dependent choice theory (Tversky and Kahneman 1991), it is expected a "diminishing sensitivity" of the marginal value of quiet for both gains and losses in quiet with their size. The functional form obtained for the interaction of size of the changes in quiet with levels of quiet satisfies these properties as illustrated in Figure 7.1 and 7.2 (coefficients estimated that refer to the best fit model based on perceptions are used), which represent respectively losses and gains in quiet relative to the base level of quiet.

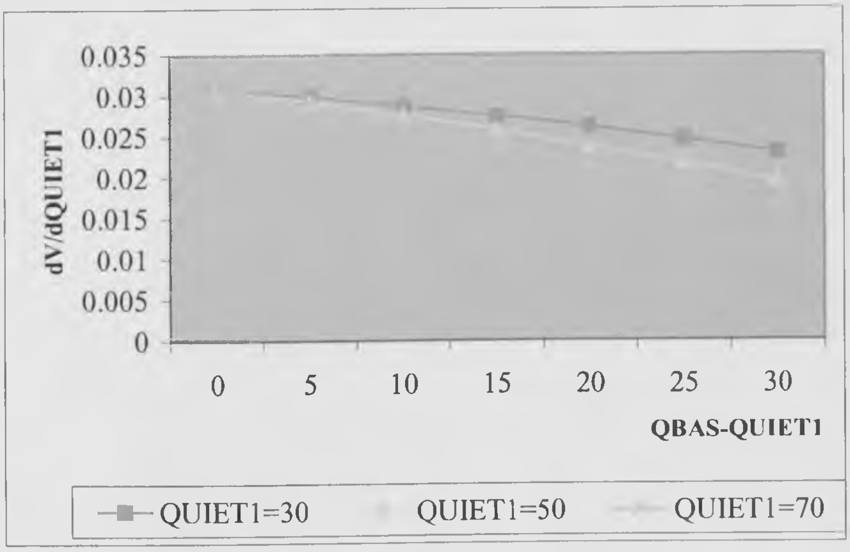


**Figure 7.1: Marginal utility of quiet as a function of (QBAS-QUIET1) which is the size of quiet changes (losses), using different levels of QUIET1 as specified.**

From Figure 7.1 it is shown that for the same change in the levels of quiet (QBAS-QUIET1) the marginal utility of quiet decreases more rapidly for those householders who live in quieter positions (QBAS is higher). This behaviour is consistent with *a priori* expectations.

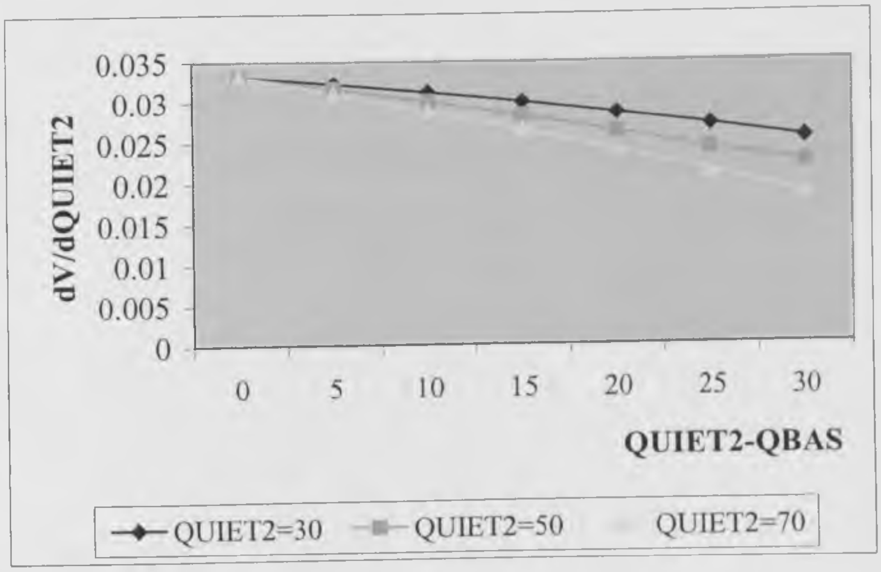


**Figure 7.2: Marginal utility of quiet as a function of (QUIET2-QBAS) which is the size of quiet changes (gains), using different levels of QUIET2 as specified.**

From Figure 7.2, it is shown that the marginal utility of quiet decreases with size of change (gains in quiet), and for the same change it decreases more rapidly when the base level (QBAS) is quieter. This behaviour (domain of gains) is consistent with *a priori* expectations both from economic theory and the reference-dependent choice theory.

On the other side, if one considers the same absolute change in the levels of quiet and compare the marginal utility of quiet for both losses and gains (Figures 7.1 and 7.2), it can be seen that the marginal utility function decreases more for the case of deteriorations (losses) in quiet than for improvements. This behaviour can be explained by prospect theory, as the disutility of one unit loss has a greater impact than the same unit as a gain. This model specification was statistically superior to the special case referred to earlier in sub-section 7.3.2.3.

**b) Interaction of quiet with the absolute level of quiet in householder's apartment**

Possible "reference effects" on household's choices/ preferences for quiet were explored. As noted by Chang *et al.* (1999) the idea that individuals use "reference prices"[3] against which they compare the actual prices of market goods is supported by various psychological theories. In this research, the hypothesis that householders might evaluate quiet (noise) levels between two apartments alternatives not in absolute terms but as "deviations" from each reference level (i.e. levels of quiet/noise in each household's apartment) is explored. Considering the literature review, reference effects have not yet been explored for the case of qualitative attributes such as levels of quiet (noise) indoors. In examining the nature and extent of possible reference effects, the effect of the *status quo* (base level of quiet experienced indoors) was assessed through the following model specifications:

$$V_{i1} = \beta \cdot QUIET_{i1} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot HSCH_{i1} + \phi \cdot (QBAS_i \cdot QUIET_{i1}), \quad \textbf{(7.16)}$$

$$V_{i2} = \beta \cdot QUIET_{i2} + \eta \cdot VIEW_{i2} + \chi \cdot SUNL_{i2} + \gamma \cdot HSCH_{i2} + \phi \cdot (QUIET_{i2} \cdot QBAS_i). \quad \textbf{(7.17)}$$

This is a special case of the previous model specification in 7.3.3.5 a) with both the base and size effects.

Equation 7.16 represents deteriorations in quiet levels relative to the status quo, noting that $QBAS_i > QUIET_{i1}$. Equation 7.17 represents improvements, with $QBAS_i < QUIET_{i2}$. Taking the derivative of the conditional utility function with respect to quiet, yields (subscripts are omitted for simplification):

$$\partial V / \partial(QUIET) = \beta + \phi \cdot QBAS. \quad \textbf{(7.18)}$$

From economic theory one can expect the $\phi$ coefficient to be negative: this is because as QBAS increases (it becomes quieter) the marginal utility of quiet is expected to fall. The sign of reference effects is modeled by setting an alternative specific coefficient for the respective term in equations 7.16 and 7.17, and proceed with the t-tests for assessing the hypothesis of inequality of coefficients (and statistical significance). This specification did not represent a statistical improvement relative to the base model with equal coefficients.

[3] For models based on current prices, see for example Hardie et al. (1993), where the reference price is the one observed on a previous purchase of the good.

**c) Interaction of housing service charge (of chosen flat option) with the base housing service charge payment**

The test of possible reference effects in householders' choices concerning the money payments were explored following the same procedures as outlined in b). The additional interaction term is instead the HSCB (Base Housing service charge payment) times the HSCH (Housing service charge of the chosen flat). This model specification represented a significant improvement from the base model.

Possible deviations from constant marginal utility of money (money gains versus money losses) were also tested. Alternative specific coefficients for the cost variable term were introduced. The modelling procedure and tests were already explained in section 7.3.2.2. This specification did not represent any statistical improvement in the base model. Other functional forms were used alternatively to test if the marginal utility of money was constant or not, by specifying the housing service charge as a power form. Other reference effects' models had been tested as differences of alternative payments relative to the current housing service charge (HSCH-HSCB). However, the functional forms did not represent any statistical improvement from the base model.

### 7.3.2.6 Additional variables involving dummy variables

Dummy variables were used to model the interaction of discrete variables that might interact with either quiet, such as gender, number of hours home (several dummy categories were tested), flat exposure, habit of having window open, etc. or with the cost variable (housing service charge) such as income (several categories). A dummy variable has the value of unity whenever the discrete event it represents is true, and zero otherwise. In many cases, a continuous variable (e.g. household income) was modeled by a set of dummy variables that represented several categories. As an example, let's consider the number of hours that each household usually spends home during the day[4] (NH). Several categories of incremental effects relative to base can be tested (example, equations 7.19 and 7.20).

$$V_{i1} = \beta \cdot QUIET_{i1} + \alpha \cdot DUM\,1 \cdot QUIET_{i1} + \mu \cdot DUM\,2 \cdot QUIET_{i1} + \\ + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot HSCH_{i1}. \tag{7.19}$$

[4] The definition of day period followed the Portuguese Noise legislation: 7am-10pm.

$$V_{i2} = \beta \cdot QUIET_{i2} + \alpha \cdot DUM\,1 \cdot QUIET_{i2} + \mu \cdot DUM\,2 \cdot QUIET_{i2} + \\ + \eta \cdot VIEW_{i2} + \chi \cdot SUNL_{i2} + \gamma \cdot HSCH_{i2}. \tag{7.20}$$

Several dummy incremental effects were specified such as in the example above: DUM1 =1 if $2<NH \leq 5$; 0 otherwise, and DUM2 =1 if $NH>5$; 0 otherwise. Coefficients need to be interpreted relative to the base or omitted category (in this example $0<NH\leq 2$). This approach was used to test for a monotonic relationship between the number of hours spent home (dummy variable) and the value of quiet. Following this specification, and assuming that the incremental dummy effects are statistically significant, the value of quiet (VoQ) for each of the three categories is by order of variables:

$$VoQ_{Base} = \frac{\beta}{\gamma}, \qquad VoQ_1 = \frac{\beta+\alpha}{\gamma}, \qquad VoQ_2 = \frac{\beta+\mu}{\gamma}. \tag{7.21}$$

Various categories of dummy variables were explored, bearing in mind the variability of the test variable in the sample (chapter 6). Considering that no monotonic relationship was found, the number of hours spent home may be correlated with other variables.

#### 7.3.2.7 Income effects

By income effects it is meant the income elasticity of the marginal value of quiet (MVQ). Following Flores and Carson (1997), the income elasticity of environmental values is the appropriate concept for understanding the distributional impacts of policies. This is because this measure holds the quantity of the environmental variable fixed as desired. In the environmental economics literature this measure is often designated as income flexibility, price flexibility of income or income elasticity of the virtual price (Garrod and Willis 1999; Randall and Stoll 1980; Haneman 1991). In this research, the terms income elasticity of MVQ or income flexibility are used to designate the same measure. Carson et al. (2001) have demonstrated that a good with income elasticity of demand greater than one (i.e. a luxury good) may have a WTP income elasticity that is less than zero but other values are also possible (i.e. greater than one or between zero and one). In the analysis conducted by Kristöm and Riera (1996), mostly containing evidence from contingent valuation studies in Europe, the income elasticity of environmental improvements is found to be less than one for the specific goods (water quality, wetlands, forests, parks). Some contradictory evidence from past studies is criticized, namely the hedonic pricing study on aircraft noise conducted by Walters (1975), where an income elasticity much greater than one was found. The mentioned authors justified this finding on the basis that the quality of the data used by

Walters (1975) was poor and assumptions made were not valid[5]. With regards to quiet, further research on the income elasticity of MVQ is needed.

In order to test the interaction of household's income with the cost variable (Housing service charge), several functional forms were specified:

**a)** Dummy income categories (incremental effects relative to base) – these involved the consideration of all income categories. These dummy variables were affected to the cost variable. Following economic theory, it is expected that household's willingness-to-pay for quiet will increase as income increases, but at a decreasing rate. Therefore, the cost coefficient is expected to fall as income increases.

**b)** Housing Service Charge deflated by Household Income: Considering the disaggregate income bands (see Chapter 6), the middle point of each band was used to compute the equivalent household monthly income ($Y_m$) correspondent to each income category.

$$V_{i1} = \beta \cdot QUIET_{i1} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot \frac{HSCH_{i1}}{Ym_i}. \tag{7.22}$$

$$V_{i2} = \beta \cdot QUIET_{i2} + \eta \cdot VIEW_{i2} + \chi \cdot SUNL_{i2} + \gamma \cdot \frac{HSCH_{i2}}{Ym_i}. \tag{7.23}$$

Considering the first derivative of the conditional indirect utility function with respect to the cost variable (general description without subscripts is used for simplification):

$$\frac{\partial V}{\partial (HSCH)} = \gamma \cdot \frac{1}{Ym}. \tag{7.24}$$

From economic theory, the coefficient $\gamma$ is expected to be negative. In this case the marginal utility of money is a decreasing function of income. The value of quiet (noise) is:

$$VoQ = \frac{\beta}{\gamma} \cdot Ym. \tag{7.25}$$

In this case, the income elasticity of the marginal value of quiet is:

$$\frac{\partial (VoQ)}{\partial Ym} \cdot \frac{Ym}{VoQ} = \frac{\beta}{\gamma} \cdot \frac{Ym}{VoQ} = 1. \tag{7.26}$$

**c)** Housing Service Charge deflated by adjusted household income (YADJ)- The adjusted household income per person was obtained by dividing the computed monthly household income in b) by an equivalence scale factor. Considering the "equivalisation" procedures of the British Department of Social Security (1998), the effects of type of household

[5] "Walters (1975) assumes that house prices are a proxy for permanent income, which, as Pearce (1980) explains, is a reasonable assumption only if income-elasticity of housing is unity".

member (e.g. couple, lone parent, disabled in household, etc.) and number of people in the household and age of each dependent are taken into account. Following this procedure, an household of two members without children has an equivalence factor of 1, whereas if they have two children the factor is 1.56. It is assumed that these equivalence factors will not differ in a great extent from the Portuguese social system. Therefore, it is expected that when the cost variable is deflated by this "improved income measure", those models will perform better than those using household total income (without any adjustment to number and type of members).

**d)** Housing Service Charge deflated by adjusted household income to the power n - several $n$ (n>0) parameters were successively tested. The best $n$ is the one that maximizes the value of the log likelihood function. The conditional indirect utility function for alternative 1 is represented for illustration:

$$V_{i1} = \beta \cdot QUIET_{i1} + \eta \cdot VIEW_{i1} + \chi \cdot SUNL_{i1} + \gamma \cdot \frac{HSCH_{i1}}{YADJ^{n}_{i}} . \quad \textbf{(7.27)}$$

Considering the first derivative of the conditional indirect utility function with respect to the cost variable (general description without subscripts is used for simplification):

$$\frac{\partial V}{\partial (HSCH)} = \gamma \cdot \frac{1}{YADJ^{n}} . \quad \textbf{(7.28)}$$

The marginal value of quiet (MVQ) income elasticity is in this case equal to the exponent $n$:

$$\frac{\partial VoQ}{\partial (YADJ)} \cdot \frac{YADJ}{VoQ} = n \cdot \frac{\beta}{\gamma} \cdot YADJ^{n-1} \cdot \frac{YADJ}{VoQ} = n . \quad \textbf{(7.29)}$$

In this study, the income elasticity of value of quiet was found to be 0.5, the value of the exponent in equation 7.29 that led to the best model fit (criteria: maximum likelihood). This finding seems to point out the fact that income elasticity of marginal value of quiet is far from being greater than one, as believed by many economists in the past. Other valuation studies for non-marketed goods found income elasticity values of similar magnitude, the case of value of time in the UK (Wardman 2002). Other evidence on other non-market goods such as recreational activities such as fishing in USA (Morey *et al.* 1993) and environmental services in Sweden (Hökby and Söderqvist 2001) seems to point out that income elasticity of WTP is greater than zero and less than one, but that this measure may be sensitive to the type of valuation function/estimation method used. Further research on this issue needs to be conducted for the case of quiet (noise) as shown in chapter 3.

## 7.4 MNL MODELS WITH ADDITIONAL VARIABLES BASED ON PERCEPTIONS INCLUDING THE EFFECT OF REPEATED OBSERVATIONS

Considering the housing environment (when individuals are indoors), several influential variables can interact between the noise pollution source (road traffic) and the residents living nearby roads. These influential variables may affect perceptions of quiet (noise) and preferences for the value placed on improvements (and reductions) in the levels of quiet. Considering the data collected during the main survey, the modelling work conducted for this section aimed to answer the following research question:

- *How (and why) the marginal values of quiet (noise) can be expected to vary across different householders' categories considering their perceptions of the indoor noise levels in the situations presented (and rated) ?*

The main observed influential variables on the marginal values of quiet are to be known by following the general principles described in section 7.3. All MNL-INT models estimated included the correct treatment for the twelve repeated choices made by each household. This was done with GAUSS. All explanatory variables, including the additional variables, were set to have fixed parameters (equivalent to standard MNL-INT with no random components). Therefore, parameter estimates are the same as those that are obtained from standard MNL-INT estimation (i.e. treating each choice observation as independent), with one difference: now the t-statistics of the parameter estimates are much lower, reflecting the increased "random variation" due to repeated choices.

### 7.4.1 Unsegmented Base Model

The parameters $\beta$, $\eta$, $\chi$ and $\gamma$ in Equations 7.1 and 7.2 are estimated with GAUSS adapting the code for panel data made by Kenneth Train. The effect of allowing for repeated observations was to reduce the t-statistics by around 40% (e.g. t-stats of the cost variable (HSCH) was –5.0, if the effect of repeated observations would not have been considered, and –2.956 after correction). From Table 7.1, it can be seen that all the estimated parameters have the correct sign and are statistically significant at the usual 5% level of confidence.

**Table 7.1: MNL Base Model.**

| **Variables** (parameters) | **Parameter Estimates (t-stats)** | |
|---|---|---|
| | With treatment for repeated observations | Without considering the effect of repeated observations |
| **VIEW** (η) | 0.02437 (9.39) | 0.02437 (13.8) |
| **QUIET** (β) | 0.03107 (8.40) | 0.03107 (15.2) |
| **HSCH** (γ) | -0.00007932 (-2.96) | -0.00007932 (-4.8) |
| **SUNL** (χ) | 0.01782 (6.24) | 0.01782 (10.2) |
| *Summary statistics*: Final Likelihood: -2915.257 ; $\rho^2$ w.r.t. zero: 0.149 ; $\rho^2$ w.r.t. constants: 0.088 | | |

Monetary variable is 1999 Escudos (1 Euro=200,482 Escudos).

The marginal monetary value of the quiet attribute is the ratio of two partial derivatives of the conditional indirect utility function. In this case of linear additive utility functions, and for this base model, it is simply the ratio of the quiet coefficient (β) and the cost variable one (γ). The mean value of quiet obtained is 392 (1999 Escudos per household per month per unit of perceived quiet). This value is higher than the marginal value of view (307 Escudos per household per month per unit of perceived view) and sunlight (225 Escudos per household per month per unit of perceived sunlight). Sunlight has a lower relative value. This result is somehow expected as some sampled householders seemed to consider it as a bad during the SP interview, probably due to excessive temperature indoors in the absence of air conditioning.

### 7.4.2 Random Utility Models with Additional variables

#### 7.4.2.1 Incremental impacts of the individual variables on marginal values of quiet

In this section the simple model is extended to include the wide range of variables collected during the main survey, in order to identify the main influential variables on the marginal values of quiet. The effect of each variable was individually tested, following the principles of econometric research described in section 7.3.

The factors that might affect individual response to road traffic noise were earlier investigated in chapter 4. It was noted that the SP-choice context of this study was novel, and that there is no established theory that can reveal with certainty the impact of each individual factor on each person's marginal utility. Expectations from community noise studies can be used with caution, bearing in mind the different situational factors and other variables. The studies that have considered the indoor traffic noise levels were only a few. As noted by

Tang and Au (1999), most studies used the noise measurements outdoors as an implicit proxy of the conditions indoors, ignoring the transmission of traffic noise through the buildings' facades and other internal factors. If one's aim is to value quiet (noise) indoors this may not be acceptable because noise levels indoors do not correlate necessarily with the levels of noise outdoors. On the other side, the cause and effect relationship between the level of noise (as measured) and individual's response is know for long to be confounded by personal and situational variables as demonstrated in chapter 4, section 4.3.2. Therefore expectations from the physical perspective (e.g. sound propagation) have limited impacts at the micro level (household indoors).

Table 7.2 presents a summary of the influential interactions with quiet, considering:

- the expected sign of the coefficient following economic theory or *a priori* expectations from existing noise studies and the statistical significance of each effect at the 5% (or 10%) significance level;
- the statistical improvement of the model relative to the base model presented in Table 7.2.

The effects were all tested together and the model including all statistically significant ones can be seen in Appendix 6 (Outputs from estimation using GAUSS). Considering the individual models estimated for each variable in Table 7.2, a summary of the results is next presented (note that outputs are available as separate technical reports):

***1. Age of the Household representative***

The marginal utility of quiet may vary according to age. Older individuals might be less sensitive to noise if their hearing system performance decreases. In the affirmative case, the expected sign of the age coefficients (incremental effect) would be negative, and the marginal utility of quiet will decrease with age. However, age might be positively correlated with other confounding factors such as health care and living style. Consequently, the random variation might be significant across the various categories.

The best model specification considered seven age segments (one was for missing information on age). Results showed that the impacts on quiet (coefficients) had a positive sign, but they were only slightly statistically significantly different from the base age group (15-24 band) for the 25-34 age group (t-stats=2.2) and to the older 60-69 segment (t- stats=2.1). The marginal value of quiet was found to be twice as high for the age group 60-69 (around 671 Escudos per month per household) than the one obtained for the base age group.

**Table 7.2: Individual Impacts (Incremental) on the Marginal Values of Quiet for the Range of Variables Tested.**

| Variable / Description of the Interaction Effect | | Expected Sign (+) or (-) | Incremental Effect is Statistically Significant | Model represents a Statistical Improvement |
|---|---|---|---|---|
| 1.AGY | Age of the respondent | ✓+ OR - | × | × |
| 2.AVB | Averting noise behaviour | ✓+ | × | × |
| 3.BLOT | Less familiar SP (lot) | ✓ (-) | ✓ | ✓ |
| 4.FE | Flat exposure to main road | ✓ (+ Back) | ✓ | ✓ |
| 5.FN | Floor Number (Dummy variable for upper floors) | ✓ (+) | ✓ | ✓ |
| 6.GD | Gender, Dummy variable for Females | ✓ (+) | ✓ | ✓ |
| 7.HINC | Household Income and Composition | ✓ (-) | ✓ | ✓ |
| 8.FCH | Households with children (Female respondents' effect) | ✓+ | ✓ | ✓ |
| 9.KHI | Awareness of the negative impacts of noise on health | × | ✓ | ✓ |
| 10.LAD | Level of Annoyance during the day | ✓ + | ✓× | ✓ |
| 11.LAN | Level of Annoyance during the night | ✓ + | ✓ × | ✓ |
| 12.NH | Number of hours normally spent at home | ✓+ | × | × |
| 13.NBAR | Presence of Noise Barriers in the Lot | ✓+ | ✓ | ✓ |
| 14.PB | Position of Respondents' bedroom to main road | ✓ (+ Back) | × | ✓ |
| 15.PS | Position of Respondents' sitting room to main road | ✓ (+ Back) | × | ✓ |
| 16.QBAS | Base Level of Quiet | ✓ | ✓ | ✓ |
| 17.LY | Level of Education | ✓ (+) | ✓× | ✓ |
| 18.RTYP | Type of main road (type of traffic and levels) | ✓+ - | ✓× | ✓ |
| 19.WLC | Habit of spending weekends normally at home working | ✓+ | × | × |
| 20.WOP | Habit of having window open in Spring/Summer | ✓ (+) | × | × |
| 21.YL | Number of years living in the apartment | ✓ (-) | ✓ | ✓ |

The marginal value of quiet for the age group 25-34 was 1.4 times higher than the one found for the base age group. Findings suggest that older householders have much higher preferences for quiet indoors, and this might be explained by the fact that they may have a greater affective attachment to their homes and also tend to spend more time home.

***2. Averting Noise Behaviour Indoors***

The marginal value of quiet may be higher for those householders who have conducted averting noise behaviour measures indoors (double glazing, etc.) as these measures reveal a preference for quiet indoors. As shown in chapter 6, noise averting behaviour is correlated with flat exposure to main road (68.3 % of the noise averting householders were located fronting the main road). This influential variable was modeled as a dummy variable (incremental effect from base, that was considered as those householders with no averting noise measures). Results from estimation showed that the two coefficients were not statistically different at the usual level of significance (t-stats=1.0).

***3. Less Familiar SP choice context (apartment choices within the same lot)***

Two SP context choices within a) lot and b) block were used, the lot was used when the block did not offer sufficient variation in the levels (for example, a different apartment with façade at the back does not exist in the same block of the respondent, and the apartment exposed at the back façade in the same lot is used). It is expected that respondents will have high familiarity in both SP context choices, but it is consistent to expect that in case b) respondent's familiarity is higher as they are choosing between apartment options of much closer neighbours than in a). This fact might also increase the random variation across the interaction effect in case a), but it is consistent to postulate that if householders are less familiar with the SP choice situation they are likely to be more attached to the *status quo*.
Therefore, the marginal value of quiet is expected to be lower in the case where apartment choices were within the same lot, in comparison to the SP situation where choices were within the same building. This may be a direct result of less familiarity to the choice context (apartment in different buildings) and possible higher random variation. Results show that this coefficient had the negative expected sign and it was statistically significant at the usual 5% level of confidence.

***4. Flat Exposure to Main Road***

Flat exposure relates to the exposition of respondent's bedroom and sitting room. Householders located at the back (quieter façade) are expected to have an higher preference for quiet, in comparison to those located fronting the main road. Therefore, the marginal value of quiet is expected to be higher for apartments exposed to the back/quieter façade. Results showed that the quiet coefficient for householders located at the back was around two times higher in comparison to those households fronting (or lateral) the main road (the coefficient was highly statistically significant at the 5% significance level). This finding points out the importance of a quieter façade.

***5. Floor Number***

The marginal utility of quiet is expected to be sensitive to floor number variation from lower to upper floors. From the physical point of view, i.e. if one considers the sound propagation from the noise source to the receiver, it is expected that noise levels (outside apartments' windows) will decrease from lower to upper floors, but only in the absence of obstacles (terrain elevations, etc), reflections from adjacent buildings or sound absorption from noise barriers. It was shown in chapter 6 (see Table 6.14) that households in lower floors perceive upper floors as noisier (i.e. lower floors were on average rated higher in the quiet variable). From prospect theory, the marginal utility of quiet is expected to decrease with size of good (bad), and then the expected sign for this coefficient is positive. On the other side, the floor number is a proxy for the distance to the traffic noise source, and higher floors are more distant from it, meaning a higher value of quiet.

Several model specifications were tried for the interaction of floor number with quiet, such as a dummy variable specification (using the middle floor and floor number greater equal to four), and a power interaction term. The functional form that conducted to the best model fit was a dummy variable specification. Results from estimation showed that the quiet coefficient for upper floors (defined as $FN \geq 4$) was always statistically significantly higher at the 5% level of confidence in all cases.

***6. Gender***

In chapter 6 (Table 6.10) it was shown that on average females spend more time home than males. Therefore the degree of association between gender and time spent home is significant. It is expected that the marginal utility of quiet would be higher for females than males as a result of this. Considering a dummy variable specification for females, this coefficient had the expected positive but it was only statistically significant at the 10% level of confidence.

***7. Household Income and Composition***

Income effects were already addressed in section 7.3.2.7. Economic theory says that the marginal utility of income will decrease with higher values of income (diminishing marginal utility), and the marginal value of quiet is expected to be an increasing function of income. Following the principles outlined previously underlying the econometric research for the effect of household income (and composition), the best model fit was found when cost (housing service charge) was divided by adjusted household income per person to the power 0.5. The cost (HSCH) coefficient was statistically significant at the 5% significance level.

***8. Household representatives with children***

The effect of this variable is expected to be positive. If households have children, and if they are attending school and need to stay home for studying, the marginal utility of quiet is expected to be higher. Considering the analysis in chapter 6, most households said they usually work/study home during weekends, mainly because of their children. Results showed that the coefficient had a positive sign and it was statistically significant at the 95% level of confidence only when it was specified as interacting with gender for female respondents, indicating that females with children do have a higher marginal value of quiet.

***9. Awareness of the negative impacts of noise on health***

Individuals who are aware of the negative impacts of noise on health may have a higher marginal utility of quiet in comparison to those who are not aware of the possible effects. As shown in chapter 6, only 31.6% of the sampled households are aware of these impacts. Estimation results show an unexpected sign (negative) for this coefficient, which contradicted our previous expectations. Therefore, other confounding factors may be present.

***10. Level of Annoyance during the day***

Increasing levels of annoyance during the day (7am-10pm) are expected to be associated with increasing marginal utilities of quiet. A household who is "very much annoyed" by traffic noise is expected to have a higher marginal utility of quiet in comparison to an household that is only a "little annoyed", for example. This variable was specified as incremental effects from base (households who are not annoyed). Results show that the marginal effects are only statistically different from base in the case of moderate levels of annoyance during the day.

***11. Level of Annoyance during the night***

As shown in chapter 6 (Table 6.24) there is no statistically significant difference in the mean households' annoyance for the day and night periods. Therefore, as before (variable 10), increasing levels of annoyance during the night (10pm – 7am) are expected to be associated with increasing marginal utilities of quiet. The positive sign for the marginal effect of this variable for increasing levels of annoyance was confirmed. This coefficient was significantly different from base (0.0294) for those householders who are moderately and very much annoyed (increasing magnitude of the coefficient was found, respectively 0.009644 and 0.01844). Householders who said they were a little annoyed during the night did not have a statistically different marginal utility of quiet in comparison with those who are not at all annoyed.

***12. Number of Hours normally spent home***

As shown in chapter 6, this variable is correlated with gender. However, the number of hours spent at home tends to be relatively similar, e.g. across females. The best specification for the effect of this variable on quiet was a powered function form (with power equal to 0.5). Although the coefficient had the right expected sign (positive), it not statistically significant at an acceptable confidence level.

***13. Presence of Noise Barriers in the Lot***

The presence of noise barriers in the vicinity of some buildings/lot may indicate that exposed householders are more sensitive to quiet. The noise barrier implemented along a segment in main road 1 (Figure 5.1, Chapter 5) was a result of previous complaints. Results from estimation show that householders located in lots with noise barriers do have a higher marginal value of quiet (993 Escudos per household per month, i.e. 63% higher than the base situation without noise barriers), statistically significant at the 95% level of confidence.

***14. Position of respondent's bedroom position to main road***

Individuals with bedrooms facing the quieter façade (back) may have a higher marginal utility of quiet. In chapter 6, it was shown that during the day period (7am-10pm) 71% of the households reported spending their time in the sitting room. Therefore the impact of position of bedroom is limited. Results showed that households with bedrooms fronting the main road had the same marginal utility of quiet to those in other situations, and this is consistent with the analysis in chapter 6.

***15. Position of respondent's sitting room to main road***

As explained before, a positive sign can be expected for the effect of this variable as householders spend a considerable percentage of their time home in this room. Results showed that the effect of this variable had a positive sign but it was not statistically significant at the 5% level of confidence. This finding together with that on bedroom exposure reinforces the use of variable 4 (flat exposure to main road) as a measure of exposure to traffic noise.

***16. Base Level of Quiet or Reference Level (Status Quo)***

It is expected that the marginal utility of quiet will be higher for those householders with quieter base levels. Results showed the expected sign and a highly statistically significant effect for this variable at the 95 % level of confidence. Therefore, the base level of quiet experienced by the household is a major influential factor on the marginal values of quiet.

***17. Level of Education***

Higher education levels might be associated with a higher marginal utility of quiet, as higher levels of education are in general correlated with increased needs for silence due to studying activities. Considering as base level those households with basic levels of instruction (1- Primary School; 2- Secondary School and 3- Technical Formation), the incremental effect of a higher level of education coefficient was statistically significant from base at the 5% level of confidence only for those respondents in group 6 (post-graduate study or Master level). These respondents have a higher preference for quiet (magnitude of the coefficient was around 68% higher than the base).

***18. Type of Main Road (Continuous or Intermittent Traffic; Traffic Levels)***

Considering the literature on noise studies, annoyance from traffic noise can be higher for intermittent traffic (main road 3) in comparison to continuous traffic situations (main road 1 and 2). Therefore, households nearby main road 3 might have a higher marginal utility of quiet. On the other hand, as traffic levels in main road 1 are much higher than in main road 2, it can be expected a lower marginal utility of quiet in the second case (less traffic noise). Considering as base, main road 1, the effect of intermittent traffic had the expected positive sign but it was not statistically significantly different from base at the 95% level of confidence. The effect of less traffic (main road 2) had the negative expected sign on the marginal utility of quiet and it was statistically significant at the usual significance level (coefficient for main road 2 represented a 25% reduction from base traffic level).

***19. Habit of spending weekends normally at home working/studying***

Households who spend weekends normally at home working may have a higher marginal utility of quiet, as they said they conduct study related activities. However, the effect of this variable was not statistically significant at the 95% level of confidence.

***20. Habit of having window open during Spring/Summer***

In warmer countries such as Portugal the bad ventilation conditions of some residential buildings normally imply that during spring/summer households will need to have windows open. Therefore, this behaviour will influence noise levels indoors (become noisier). Results showed that this effect was not statistically significant at the 5% level of confidence. This might be due to the fact that the majority of households had this behaviour in the study area.

***21. Number of Years living in the apartment***

Households who have lived in the apartments for a longer time might have a lower marginal utility of quiet, because of possible habituation effects to the context. However, the noise literature is not conclusive with this respect. Therefore, several functional form were tested for modelling the effect of this variable (quiet deflated by number of years to the power n, dummy variable for number of years greater or equal a specified value). The best model specification was found when the number of years was specified as a dummy variable, for number of years greater than or equal to five. The effect of number of years coefficient had the negative sign and it was statistically significant at the 5% level of confidence.

Besides the main variables tested presented in Table 7.2, other additional factors were explored such as the disposition of block façade to main road (parallel or perpendicular), influence of having stated quiet as a location factor, health problems in the household, household activities such as studying, and the number of motorised vehicles per household. Each effect was expected to have an impact on the marginal utility of quiet. However, these additional variables did not represent any statistically significant improvement in the model. This result adds to some variables presented in Table 7.2 whose effects were found of being of the wrong expected sign and or not statistically significant at an acceptable level of confidence. Several causes might explain each case such as: (i) lack of variability in the sample (number of hours normally spent home tends to be relatively homogeneous across categories of householders (females and males); habit of having the window open during Spring/Summer proved to be also a normal behaviour of the household), (ii) small number of respondents in that *strata* (householders who have conducted noise averting measures were small in comparison to others), (iii) possible presence of more complex interaction relationships (not just single interaction with quiet but with other variables) that was not captured by using the tested functional forms.

As a result from Table 7.2, the variables that are expected to have a greater impact on the marginal values of quiet can be identified and are represented in shadowed rows there. These are the variables that confirmed economic theory or *a priori* expectations and represented a statistically significant improvement in the explanatory power of the base model.

#### 7.4.2.2. Final multinomial logit model with additional variables, considering the effect of repeated choices

As a result of the step-by-step methodology described in section 7.2, the final MNL-INT model is represented in Table 7.3. This model has higher goodness-of-fit measures, explanatory ability (considering that all incremental effects of the individual additional variables represented added a statistical improvement to the base model) and theoretical plausibility. It was estimated using GAUSS, and t-stats of the coefficients are corrected to allow for repeated choices made by each household.

The results of Table 7.3 are discussed now in more detail:

**1 and 2:** Deterioration versus Improvements in the levels of quiet - The asymptotic t-test revealed that the model is superior in the case of alternative specific coefficients. Considering all other variables equal, the marginal value to avoid a one unit deterioration in the levels of quiet (as perceived) is around 8.8% higher than the money value to improve one unit of quiet. This finding seems to point to the existence of an asymmetric value function (gains versus losses) relative to the current perceived *status quo* of the household. All coefficients had the right sign and are statistically significant at the 5% level of confidence.

**3:** Interaction of quiet with general flat exposure (dummy variable for apartment exposure to back/quieter façade, incremental effect relative to base)- householders located at the quieter façade (general flat exposure is "Back") have a much higher marginal value of quiet in comparison to those fronting the main road. This marginal value in around 70% to 76% higher for householders located at the back, respectively facing a loss or a gain in quiet in comparison to those fronting the main road, *ceteris paribus*.

**Table 7.3: Final MNL-INT Model Based on Perceptions, Considering the Effect of Repeated Apartment Choices.**

| Text ID | Variable Description | Parameter estimates (t-stats) |
|---|---|---|
| 1 | QDET: Deteriorations in quiet levels (base) | 0.036075 (4.37) |
| 2 | QIMP: Improvements in quiet levels (base) | 0.033158 (4.19) |
| 3 | QBAC: Interaction of quiet with general flat exposure (dummy variable for back) | 0.025292 (3.41) |
| 4 | QNYL: Interaction of quiet with number of years living at the site (dummy var NYL $\geq$ 5) | -0.01799 (-2.55) |
| 5 | QCHC: Interaction of quiet with less familiarity to choice context (lot) | -0.00957 (-1.37)** |
| 6 | QFEM: Interaction of quiet with gender | 0.009662 (1.56)** |
| 7 | QSQCH: Interaction of quiet with size of quiet changes relative to the base level of quiet(/1000)♣ | -0.00288 (-2.44) |
| 8 | QFNU: Interaction of quiet with dummy for floor number $\geq$ 4 | 0.011999 (1.87)*** |
| 9 | BASH: Interaction of Housing Service Charge Levels with Current Payment (/$10^6$) | 0.002997 (1.54)** |
| 10 | HSCY: Housing Service Charge deflated by Household Income per person ♣♣ | -0.01937 (-2.47) |
| 11 | HSCM: Interaction of Housing Service Charge with missing information on income | -0.00013 (-2.38) |
| 12 | VIEW: View | 0.026664 (9.86) |
| 13 | SUNL: Sun Exposure | 0.020228 (6.90) |
| *Summary Statistics*<br>Final Likelihood: - 2834.890<br>$\rho^2$ w.r.t. zero: 0.1728<br>$\rho^2$ w.r.t. constants: 0.1132 | | |

Units: Housing Service Charge in 1999 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"); **(**)** Although the variables are not statistically significant at the 10% level of confidence, they were kept due to its right expected sign and magnitude of the effect is plausible (individual variables represented a statistically significant improvement when added to the base model); **(***)** The parameters are statistically significant at the 90% level of confidence; ♣ Functional form (see Equations 7.12 and 7.13); ♣♣ Functional form (see Equation 7.27): Housing Service Charge/ Household Income per person $^{0.5}$.

4: Interaction of quiet with number of years living at the site – the research hypothesis is that the value of quiet will decrease after overcoming a "certain threshold" represented by the number of years living (NYL) at the site (and being exposed to the adverse impacts of noise). The best fit was found for the following dummy variable specification: Dummy variable =1 if NYL $\geq$ 5; 0 otherwise. This coefficient has the right expected sign. Therefore, the period of five years seems to be a threshold for habituation effects to noise.

5: Interaction of quiet with less familiar choice context (dummy variable if household faced an SP choice within the lot) – during the SP experiment respondents were offered flat choices within the same block or lot. Although respondents' familiarity to flat options are taken into account in both situations, it can be expected that the random variation $\sigma$ (e.g. due to less precise ideas or perceptions of the internal noise levels indoors) is higher when choices are within the same lot of the respondent than when choices involve the same building and thus closer neighbours. Considering the scale of the logit model ($\pi/(\sqrt{6}*\sigma)$, as the random variation is higher, the coefficient associated to a less familiar context is expected to be lower. This coefficient (incremental effect) had the negative expected sign. Although it was only statistically significant at the 10% level of significance, the inclusion of this interaction term proved to increase the explanatory power of the base model (following the likelihood ratio test, as presented in section 7.2).

**6:** Interaction of quiet with gender (dummy variable for females)- in Lisbon females tend to spend more time at home than males, due to their professions and childcare related activities. It was postulated that this fact affects the way levels of quiet are perceived indoors in terms of its relative importance. Results show lower marginal values of quiet for males than females, ceteris paribus. The coefficient had the right expected sign, and it is statistically significant at the 10% level of confidence.

7: Interaction of quiet with size of quiet changes relative to the base level of quiet (/1000) - the properties of this functional form was explained in detail in section 7.3.2.5a). The coefficient had the negative expected sign and it is statistically significant at the 95% level of confidence. Results seem to point to the existence of a non-linear interaction effect between size of change and the preferred level of quiet. The functional form that conducted to the best model fit could be explained by the reference-dependent choice theory (Tversky and Kahneman 1991). It conducts to a decreasing marginal utility of quiet as size of gains and losses in quiet increase. Considering the same change, the marginal utility of quiet decreases more for losses than for gains (one unit degradation in the levels of quiet has a greater impact than the same unit as an improvement), meaning that households are loss averse.

**8:** Interaction of quiet with dummy for floor number, FN (dummy variable for FN≥ 4) – The analysis in chapter 6 showed that upper floors are perceived as noisier than lower floors. Therefore, the marginal utility of quiet is expected to increase from lower to upper floors (loss in quiet), following the reference-dependence theory. After testing several specifications for the dummy variable, the best fit was confirmed for floor number greater equal than four. This coefficient had the positive expected sign and it is statistically significant at the 10% level of confidence.

**9:** Interaction of Housing Service Charge Levels with Current Payment ($/10^6$) – this coefficient had the positive expected sign. In the Lisbon housing market the housing service charge is a function of flat area, existence of garage, green space in the lot, building quality, etc. Considering the sampled buildings, the housing service charge is often equal for the same floor number (e.g. 4F and 4B, one fronting the main road and one at the back/quieter façade both in floor 4). The variation in monthly payments is only significant between extreme floors, i.e. the lower and upper floors. Upper floors are in general more expensive (and have higher housing service charges), and are occupied by higher income households who are less sensitive to cost.

**10:** Interaction of Housing Service Charge with adjusted income per person (considering household composition): the best fit was found when the cost variable was divided by adjusted income to the power 0.5. It was shown in section 7.3.5 that this power can be interpreted as householders' "income flexibility" or income elasticity of (marginal) value of quiet. It indicates the percentage increase in the (marginal) value of quiet that would follow a percentage increase in adjusted income.

The expected negative sign was obtained for this coefficient with a statistical significance at the usual 5% level of confidence.

**11:** Interaction of Housing Service Charge with missing information on income – as some information was missing with respect to households income group, a dummy variable was specified to consider the value of quiet for these households with unspecified income. An earlier analysis of the income effects that had considered all income groups specified as dummy variables (incremental effects from a base considered as income groups 1-3) showed that the magnitude of the incremental effect of the missing income coefficient was similar to the incremental effect of income group 6 (middle income householders). This coefficient had the negative expected sign and it was statistically significant at the usual 5% level of confidence.

**12:** View - the coefficient for view was highly statistically significant and had the positive expected sign, indicating that householders always prefer more of "view" (units of view as perceived) than less.

**13:** Sun Exposure - the coefficient for sun exposure was highly statistically significant at the 5% level of confidence, but lower in magnitude in comparison to the view coefficient. It can be postulated as a result of the field survey (comments from householders) that some householders do consider more of sun exposure (units of perceived sun exposure) as a bad (and not a good).

Considering the linear conditional indirect utility functions, the value of quiet for each household type can be computed as the ratio of two partial derivatives, with respect to the quiet and the cost variable (housing service charge).

In order to illustrate the range of values of quiet that can be obtained, a scenarios' approach is adopted. The base is a male respondent who has lived for less than 5 years in a lower apartment floor (< 4) whose base housing service charge is 7500 (1999 Escudos per month). Two levels of income per person are considered and two conditions of flat exposure (back and front). It is assumed that the household faced apartment choices within the same building during the SP experiment. The correspondent marginal values of quiet are represented in Table 7.4 for the case of an improvement in the levels of quiet.

**Table 7.4: Marginal Values of Quiet per Unit of Perceived Improvement.**

| 1999 Escudos per household per month | | | **Marginal Values of Quiet** | | |
|---|---|---|---|---|---|
| **Adjusted Income per person per household** | **Experienced Noise Level (QBAS)** | **Quiet Level ($QUIET_2$)** | **Improvement Size** | **Flat exp. Fronting main road** | **Flat exp. quieter façade (back)** |
| 30000 | 60 | 70 | 10 | 322.7 | 605.8 |
| | 60 | 80 | 20 | 255.1 | 538.1 |
| | 40 | 50 | 10 | 335.6 | 618.7 |
| | 40 | 60 | 20 | 280.8 | 563.9 |
| 60000 | 60 | 70 | 10 | 509.5 | 956.4 |
| | 60 | 80 | 20 | 402.6 | 849.5 |
| | 40 | 50 | 10 | 529.9 | 976.7 |
| | 40 | 60 | 20 | 443.4 | 890.2 |

Results show that the values of quiet for householders located at the "back" are around two times higher than those fronting the main road. The marginal value of quiet decreases with size of improvement and, for the same size of change, it is lower if the base level experienced by the respondent in his/her current apartment is quieter. The interaction effect of housing service charge with the base monthly payment in the *status quo* accounts for around 40% in the variation of the marginal values of quiet.

Table 7.5 illustrates the situation when the household faces a loss (deterioration) in the levels of quiet (as perceived), considering the same respondent type as before.

**Table 7.5: Marginal Values of Quiet per Unit of Perceived Deterioration.**

| 1999 Escudos per household per month | | | | **Marginal Values of Quiet** | |
|---|---|---|---|---|---|
| **Adjusted Income per person per household** | **Experienced Noise Level (QBAS)** | **Quiet Level ($QUIET_1$)** | **Deterioration Size** | **Flat exp. Fronting main road** | **Flat exp. quieter façade (back)** |
| 30000 | 60 | 50 | 10 | 432.7 | 715.8 |
| | 60 | 40 | 20 | 442.4 | 725.5 |
| | 40 | 30 | 10 | 419.8 | 702.9 |
| | 40 | 20 | 20 | 416.6 | 699.7 |
| 60000 | 60 | 50 | 10 | 683.2 | 1130.0 |
| | 60 | 40 | 20 | 698.4 | 1145.3 |
| | 40 | 30 | 10 | 662.8 | 1109.7 |
| | 40 | 20 | 20 | 657.7 | 1104.6 |

Table 7.6 shows the ratio of the marginal values of quiet for deteriorations over the marginal values of quiet for improvements, using the values in Table 7.4 and 7.5 (same type of household as described)

**Table 7.6: Ratio of Marginal Values of Quiet (Loss/Gain).**

| **Ratio of Marginal Values of Quiet (Deteriorations/Improvements)** | | | | |
|---|---|---|---|---|
| **QBAS** | **YADJ** | **Change** | **Flat exp. Fronting main road** | **Flat exp. at the Back** |
| 60 | 30000 | 10 | 1.3 | 1.2 |
| 60 | | 20 | 1.7 | 1.3 |
| 40 | | 10 | 1.3 | 1.1 |
| 40 | | 20 | 1.5 | 1.2 |
| 60 | 60000 | 10 | 1.3 | 1.2 |
| 60 | | 20 | 1.7 | 1.3 |
| 40 | | 10 | 1.3 | 1.1 |
| 40 | | 20 | 1.5 | 1.2 |

It is shown that the value of quiet function is not symmetric (deteriorations in quiet are valued higher than improvements). This function is steeper if the household is fronting the main road than if it is at the back/quieter façade. This finding seems to indicate that households who are fronting the main road are more averse to losses than those located at the back.

## 7.5 MNL MODELS WITH ADDITIONAL VARIABLES BASED ON PHYSICAL NOISE MEASURES INDOORS INCLUDING THE EFFECT OF REPEATED OBSERVATIONS

The main objectives of the modelling work reported in this section were to answer the following research questions:

a) *If householder's perceptions of the internal noise levels indoors are replaced by the equivalent physical noise measures taken indoors in Leq dB(A), how the marginal values of quiet are expected to vary across different householders' categories ?*
b) *Are these models based on physical noise measures statistically superior to the models based on perceptions (section 7.4)?*

Whenever the physical noise measure was missing for that specific apartment, the nearest neighbor measure was used. The noise data collection methodology described in chapter 4 ensured that a noise measure always exists within a maximum of 2 floors difference from the current flat.

The physical noise measures in Leq dB(A) levels[6] are in a logarithmic scale. It is important to remember that the decibel is not an absolute measure, but it is a ratio of two quantities (equation 7.30). Therefore, the decibels cannot simply be added arithmetically. Following the definition of the weighted sound pressure level in dB(A):

$$dB(A) = 20 \cdot \log\left(\frac{p_A}{p_0}\right) \qquad \textbf{(7.30)}$$

it can be seen that the decibel measure (A-weighted) is a ratio between two sound pressure levels, $p_A$ the weighted sound pressure level, and $p_0$ the reference sound pressure level. The reference value is taken as $2x10^{-5}$ Pascal, the threshold of audible sound. From equation 7.30 it follows that the difference of two noise levels in dB(A) are not a direct arithmetic operation.

In this thesis, and for estimation purposes the A-weighted sound pressure level is used giving levels in microPascal, after converting each dB(A) measure into this linear scale.

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[6] The definition of physical level indicates that the specific quantity is measured as a ratio to a specific reference magnitude.

### 7.5.1 Unsegmented Base Model

As in section 7.4.1, the main variables presented in the SP experiment are considered in the specification of the deterministic component of the conditional indirect utility function. The quiet variable is now designated as "NOISE", and is expressed using the equivalent physical noise measures in A-weighted microPascal.

In Table 7.7 the results of the simplest base bivariate logit model (model 1) and an alternative base model where the noise variable is made alternative specific (model 2), considering the effect of repeated observations are reported. All variables had the right expected sign, the noise coefficient is now negative considering the scale used. In model 1, the cost coefficient was not statistically significant even at the 10% level of confidence.
The cost variable will become statistically significant later as other non-acoustical variables are included. It is shown in Table 7.7 that once the model is segmented according to the general flat exposure (base model 2), the cost variable increased its significance (although it is still not statistically significant at the usual 95% level of confidence). The qualitative variables, view and sunlight are statistically significant at the 5% level of significance in all base models.

**Table 7.7: MNL Base Model Using Noise in A-Weighted MicroPascal.**

| Variables | Parameter Estimates (t-stats) | |
|---|---|---|
| | Base Model 1 | Base Model 2 |
| VIEW | 0.02575 (10.684) | 0.025905 (10.100) |
| NOISE-Deterioration | -0.000354 (-6.636) | -0.000304 (-5.677) |
| NOISE-Improvement | | -0.000168 (-1.73)* |
| HSCH | -0.0000221 (-0.951)* | -0.0000424 (-1.694)* |
| SUNL | 0.016286 (6.052) | 0.016836 (6.211) |
| Log Likelihood | -3000.4043 | -2999.2397 |
| $\rho^2$ w.r.t. zero: | 0.1233 | 0.1248 |
| $\rho^2$ w.r.t. constants: | 0.0601 | 0.0617 |

(*) The variable is not statistically significant at the 5% level of significance.

Considering model 2, the mean value of noise can be computed per unit of A-weighted sound pressure level. Using equation 7.30, these values can be converted again to dB(A). The value of noise is around 161 Escudos per dB(A) for a situation of deterioration in noise, and 89 Escudos per dB(A) improvement in the levels (noise reduction). Therefore, householders value on average a dB(A) deterioration in noise about twice as much as an improvement, pointing out the existence of an asymmetric value of quiet (noise) function. However, this is a preliminary result based on a lower significance level on the cost and noise variable. Considering the other qualitative attributes, it can be said that the mean value of view and sun exposure are respectively 611 and 397 (1999 Escudos per perceived unit). Therefore, the value of view is around 1.5 times higher than the value of sunlight. These relative values are in line with previous results based on perceptions (Table 7.1), but now the goodness-of-fit measures are lower.

### 7.5.2 Final Multinomial Logit Model with Additional variables, Considering the Effect of Repeated Observations

The same step-by-step methodology and econometric principles as in section 7.4 is followed. Again, it was one of the objectives to detect the main influential variables that interact with the noise variable when perceptions of the respondents are replaced by the real physical noise measures. The final MNL-INT model with additional variables is presented in Table 7.8. This model was the one with higher goodness-of-fit measures, explanatory ability and theoretical plausibility. It was estimated using GAUSS, such that the t-stats of the coefficient estimates are corrected for repeated SP choices made by each household. All the coefficient estimates represented in Table 7.8 had the right expected sign. Two parameters (variables 7 and 10) are statistically significant at the 10% level of confidence (but their inclusion in the model represents a statistical improvement relative to the base model without them, following a likelihood ratio test; their influential effect is also in line with *a priori* expectations). The other remaining variables are all statistically significant at the 5% level of significance.

The results in Table 7.8 show that the main influential variables on noise are:

**1 and 2**: Deteriorations versus Improvements in noise levels (base) – as in the results of section 7.4.2.2 the value of noise function is not symmetric in the domain of losses versus gains. Considering the magnitude of the coefficients involved, it can be seen that the marginal value of noise in the case of an increase in noise (degradation in quiet) is 1.32 times higher than the marginal value when a reduction in the levels is supposed to occur (improvement in quiet). This result should be regarded with caution as the SP design was set for generic attributes, noting however that the correlation between losses and gains was low.

**Table 7.8: Final MNL-INT Model Based on A-Weighted Sound Pressure, Considering the Effect of Repeated Apartment Choices.**

| Text ID | Variable Description | Parameter estimates (t-stats) |
|---|---|---|
| 1 | NDET: Deteriorations in noise levels (base) | -0.000526 (-3.994) |
| 2 | NIMP: Improvements in noise levels (base) | -0.000396 (-2.523) |
| 3 | NBAC: Interaction of noise levels with general flat exposure (dummy var for back) | -0.000339 (-3.114) |
| 4 | NNYL: Interaction of noise with number of years living at the site (dummy var NYL $\geq$ 5) | 0.0004225 (3.34) |
| 5 | NCHC: Interaction of noise with less familiarity to choice context (lot) | 0.0003706 (2.859) |
| 6 | NSIZ: Interaction of noise with size of change relative to base noise level ♣ | -0.0000543 (-2.477) |
| 7 | NFNU: Interaction of noise with dummy for floor number $\geq$ 5 | -0.00166 (-1.578)** |
| 8 | HSCY: Housing Service Charge deflated by Household Income per person ♣♣ | -0.01735 (-2.383) |
| 9 | HSCM: Interaction of Housing Service Charge with missing information on income | -0.0001 (-2.04) |
| 10 | BASH: Interaction of Housing Service Charge Levels with Current Payment ($/10^6$) | 0.003621 (1.793)*** |
| 11 | VIEW: View | 0.027455 (10.3) |
| 12 | SUNL: Sun Exposure | 0.018607 (6.72) |

*Summary Statistics*
Final Likelihood: - 2937.242
$\rho^2$ w.r.t. zero: 0.1418
$\rho^2$ w.r.t. constants: 0.081

Units: Housing Service Charge in 1999 Escudos; Income per person is in 1999 Thousand Escudos. Sun Exposure and View (as perceived): 0 –100; Noise in A-weighted sound pressure level (μPa); ** Although this variable was not statistically significant at either the 5% or 10% level of significance it was kept in the model due to its correct sign and expected magnitude (variable when added to the base model improvement its explanatory power, considering the likelihood ratio test statistic); *** Statistically significant at the 10% level of significance; ♣ Functional Form (that conducted to a best fit): (Noise – Base Noise Level) $^{0.7}$ ; ♣♣ Functional form: Housing Service Charge/Income per person $^{0.5}$.

**3**: Interaction of quiet with general flat exposure (dummy variable for apartment exposure to back/quieter façade, incremental effect relative to base) – the marginal utility of noise for an household exposed to back/quieter façade is around twice more than the same type of household (same observed characteristics) exposed to fronting the main road.

**4**: Interaction of noise with number of years living at the site – the functional form that has provided the best fit with the data was found for a dummy specification for number of years greater than or equal to five. This finding confirms previous functional form when noise was expressed using householders' perceptions (as rated) of the internal noise levels. This may indicate that households become used to noise after a specific living experience.

**5**: Interaction of noise levels with less familiarity with choice context (dummy variable if household faced an SP choice within the lot) –if the household is supposed to face an apartment choice within the lot, it can be expected that the corresponding real physical noise measures will deviate much more from the perceptions of those levels, than in the case where respondents would have reasoned considering perceptions of noise levels in the same building. This coefficient had the positive expected sign and it is statistically significant at the usual 5% level of significance. Considering the magnitude of this coefficient, it can be seen that the marginal utility of quiet will decrease substantially as a result of less familiarity with the choice context.

**6:** Interaction of noise with size of change relative to base noise level (reference effects) – The functional form that has provided the best fit is illustrated in equations 7.31 (deterioration in noise) and 7.32 (improvement in noise) using the respective components of the conditional indirect utility functions:

$$V_{i1}^{effect6} = \varphi \cdot (NL_{i1} - NLBAS_i)^{0.7} \qquad \textbf{(7.31)}$$

$$V_{i2}^{effect6} = \varphi \cdot (NLBAS_i - NL_{i2})^{0.7} \qquad \textbf{(7.32)}$$

where NL represents the noise level in the chosen apartment , and NLBAS the base noise level in the household's current apartment. Following the noise physical scale: $NL_{i1} \geq NLBAS_i$ (equation 7.31) and $NLBAS_i \geq NL_{i2}$ (equation 7.32). The power 0.7 was obtained after successive runs where different power coefficients were tested (maximum likelihood criteria). This functional form confirms a decreasing marginal utility of noise with size of noise changes relative to base, as expected from the reference dependence theory (Tversky and Kahneman 1991). In order to derive the impact of this interaction term on the marginal utility of quiet, the partial derivative of the conditional indirect utility function is taken, as represented in equation 7.33 and 7.34:

$$\frac{\partial V_{i1}}{\partial(NL_{i1})} = 0.7 \cdot \varphi \cdot (NL_{i1} - NLBAS_i)^{-0.3} \quad \textbf{(7.33)}$$

$$\frac{\partial V_{i2}}{\partial(NL_{i2})} = -0.7 \cdot \varphi \cdot (NLBAS_i - NL_{i2})^{-0.3} \quad \textbf{(7.34)}$$

It can be seen that considering the magnitude of φ coefficient (-0.0000543), and that noise changes are to the power (-0.3), that the impact of this term on the marginal values of noise is small. This functional form is in line with previous expectations than non-acoustical factors are more relevant than the physical noise levels *per se*. The inclusion of this interaction term proved to add a significant statistical improvement to the final model, indicating the presence of reference effects of small magnitude.

**7:** Interaction of noise with dummy variable for floor number ≥ 5: the best specification was found when the dummy variable for floor number was greater than or equal to 5. Considering the analysis in chapter 6, upper floors are on average noisier in terms of physical noise measures than lower floors, and this considers the range of factors interaction between the source and at the reception sites (indoors). The coefficient for this interaction term had the right expected sign, but it is only statistically significant at the 10% confidence level. The inclusion of this term in the final model proved to represent a statistical improvement, following the likelihood ratio test statistic.

**8:** Housing Service Charge deflated by Household Income per person: this term represents the interaction of the SP cost variable with the adjusted income per person (considering household composition). The parameter estimate associated with this interaction term had the expected negative sign and statistical significance. As in section 7.4.2.2, the best fit was found when the cost variable was deflated by income to the power 0.5. This power coefficient can be interpreted as householders' income flexibility, as earlier explained. The income effect explains why the cost coefficient is statistically significant, in comparison to the base models in Table 7.7.

**9:** Interaction of Housing Service Charge with missing information on income: results confirm explanation for variable 11, section 7.4.2.2.

**10:** Interaction of Housing Service Charge Levels with Current Payment ($/10^6$): results confirm findings for variable 9, section 7.4.2.2.

**11 and 12:** View and Sunlight: these coefficient estimates are highly statistically significant at the 5% level of confidence, and had the right expected sign. Their order of magnitude is similar to those obtained previously (Table 7.3).

Tables 7.9 and 7.10 illustrate the range of values of noise that can be obtained, respectively, in a situation of improvement and deterioration in the noise levels. The ratio of the first order partial derivative of the conditional indirect utility function with respect to quiet over the partial derivative with respect to the cost variable (housing service charge), for the same type of respondent as selected in section 7.4 for consistency purposes, is computed. It is obtained a value of noise per A-weighted sound pressure level. This value is then transformed to the equivalent value per dB(A) using equation 7.30.

**Table 7.9: Marginal Values of Noise per dB(A) decrease.**

(1999 Escudos per dB(A) decrease).

| Adjusted Income per person per household | Noise Change (NLBAS –$NL_2$) μPa | Equivalent Noise Change in dB(A) | Flat exp. Fronting main road | Flat exp. quieter façade (back) |
|---|---|---|---|---|
| 30000 | 28.250 | 3 | 117.4 | 221.0 |
| | 39.905 | 6 | 117.8 | 222.0 |
| | 63.245 | 10 | 118.3 | 222.5 |
| 60000 | 28.250 | 3 | 196.3 | 370.5 |
| | 39.905 | 6 | 197.0 | 371.2 |
| | 63.245 | 10 | 197.8 | 372.0 |

Note: 1 dB(A) change is equivalent to 22.44 A-weighted μPa.

**Table 7.10: Marginal Values of Noise per dB(A) increase.**

(1999 Escudos per dB(A) increase).

| Adjusted Income per person per household | Noise Change (NLBAS –$NL_2$) μPa | Equivalent Noise Change in dB(A) | Flat exp. Fronting main road | Flat exp. quieter façade (back) |
|---|---|---|---|---|
| 30000 | 28.250 | 3 | 166.0 | 270.1 |
| | 39.905 | 6 | 165.5 | 269.7 |
| | 63.245 | 10 | 165.0 | 269.2 |
| 60000 | 28.250 | 3 | 277.4 | 451.6 |
| | 39.905 | 6 | 276.7 | 450.9 |
| | 63.245 | 10 | 275.9 | 450.1 |

The small variation in the marginal values of noise with the size of the physical change confirms previous expectations from noise studies that individuals' response to noise levels is mainly influenced by non-acoustic factors (household income, location at the quieter façade, etc). The marginal values of noise are sensitive to the adjusted household income, as expected from economic theory.

Results from Table 7.9 and 7.10 show that the value of noise function is asymmetric and steep if the household is fronting the main road. The marginal value of quiet is between 1.6 and 1.8 times higher for a household located at the back than the same household (other observed characteristics equal) located fronting the main road and facing a situation of improvement and deterioration in the noise levels, respectively. This is also a consequence of having modelled additive effects by linear-in-parameters utility functions.

## 7.6 MNL MODELS WITH ADDITIONAL VARIABLES BASED ON PHYSICAL NOISE MEASURES OUTDOORS INCLUDING THE EFFECT OF REPEATED OBSERVATIONS

In this section the noise variable is expressed with the equivalent physical noise measures taken outdoors. Considering the noise data collection methodology earlier described in this thesis, it shall be noted that two contiguous rooms fronting the same facade were used to take the noise measurements in each apartment, such that a noise measurement indoors and outdoors is collected. The advantages of this methodology were described in detail in chapter 5.

The main objectives of the modelling work reported in this section were to test if the equivalent physical noise measures outdoors at each floor facade can serve as a proxy for valuing noise in similar contexts to the one used in this research study. The use of these noise measurements would make easier (and less costly) the noise data collection. Therefore, it is of interest to test if marginal values of noise per dB(A) outdoors will converge to those values estimated in section 7.5, where levels of noise were expressed as the equivalent physical noise measures indoors. For estimation purposes the A-weighted sound pressure levels in microPascal are again used.

The models based on physical noise measures outdoors had a much poorer performance in comparison to the models based on physical noise measures indoors, as expected. Therefore, the unsegmented and best fit models estimated are not reported in this thesis due to space constraints. Nevertheless, for comparison purposes the respective goodness-of-fit measures are used whenever needed.

## 7.7. COMPARISON OF MODELS

### 7.7.1 Goodness-of-fit Measures

Table 7.11 provides a summary of the goodness of fit measures of the base MNL models estimated in sections 7.4 (perceptions), 7.5 (physical noise measures indoors) and 7.6 (physical noise measures outdoors), considering that they have the same number of variables and observations.

**Table 7.11: Unsegmented MNL models.**

| Variables (Parameters) | Perceptions | Indoor noise | Outdoor noise |
|---|---|---|---|
| VIEW ($\eta$) | 0.02437 (9.39) | 0.02575 (10.684) | 0.028381 (10.953) |
| QUIET ($\beta$) | 0.03107 (8.40) | -0.000354(-6.636) | -0.00101 (-5.058) |
| HSCH ($\gamma$) | -0.00007932 (-2.96) | -0.0000221(-0.951) ** | -0.00092 (-0.379)** |
| SUNL ($\chi$) | 0.01782 (6.24) | 0.016286 (6.052) | 0.01555 (5.69) |
| *Summary statistics*: | | | |
| Final Likelihood: | -2915.257 | - 3000.404 | -3030.824 |
| $\rho^2$ w.r.t. zero: | 0.149 | 0.1233 | 0.1156 |
| $\rho^2$ w.r.t. constants: | 0.088 | 0.0601 | 0.0518 |

** Variable is not statistically significant at the 5% level of confidence.

The model based on perceptions outperformed both of the other two. This result was expected considering that respondents used their perceptions to evaluate the situations presented to them during the SP experiment, and also because from noise studies non acoustical factors are believed to be more important than the physical noise measures alone to explain householders' preferences for quiet. Noise ratings also reflect householders' attitudes in some extent. Therefore, a model with physical noise measures (and without interaction factors of another nature) is expected to be a poor model.

Table 7.12 compares the final MNL-INT models for repeated observations presented in sections 7.4, 7.5 and 7.6 respectively and compared in this section. The respective goodness-of-fit measures estimated are summarized.

**Table 7.12: Comparison of MNL-INT Models: Goodness-of-fit Measures.**

| Goodness-of-fit measures | Perceptions (as rated) | Leq dB(A) ndoors | Leq dB(A) outdoors |
|---|---|---|---|
| Log likelihood | -2834.890 | -2937.242 | -3000.4424 |
| $\rho^2$ w.r.t. zero | 0.1728 | 0.1418 | 0.1244 |
| $\rho^2$ w.r.t. constants | 0.1132 | 0.0818 | 0.0613 |
| Number of Params. | 13(*) | 12 (*) | 8 |
| NOBS | 4944 | 4944 | 4944 |

(*) These models were estimated with one additional term for missing information on number of years living at the apartment. As this term was not statistically significant, it was not represented in the previous Tables containing estimating results.

It can be seen that the model that performed best was the model presented in section 7.4, when the quiet (noise) variable was expressed with the respondents' ratings. It can be seen that the adjusted likelihood ratio index for model 7.6 based on physical measures outdoors ($\rho^2$ with respect to constants) is around half of the correspondent index for model 7.4 based on perceptions.

The model reported in section 7.5 based on physical noise measures indoors had an inferior performance to the model based on perceptions. However it was statistically superior to the one based on physical noise measures outdoors in section 7.6, but not in a great extent considering the magnitude of their adjusted likelihood ratio indexes. The poor performance of the model based on physical noise outdoors can be explained by the analysis conducted in chapter 6: noise variations along the same façade is often close to zero, and noise levels indoors can be very different from those outdoors considering the range of factors that can differ (type of windows, area covered by windows in each façade, buildings materials, layout, etc.).

Findings confirm the research hypothesis set in this study that models based on perceptions can perform better than those based on physical noise measures. This hypothesis was set considering earlier valuation studies for other non-marketed goods that have used respondents' perceptions, and findings from marketing studies that people tend to respond to what they perceive.

### 7.7.2 Interaction Effects with Quiet (Noise)

The model based on perceptions was the one that was able to capture more interaction effects (range of influential variables tested) with the levels of quiet (as rated), as presented in Table 7.3. Therefore, the marginal values of quiet as perceived are expected to provide a better representation of householders' implicit valuations during the SP experiment.

Considering specification of the model based on perceptions as base (higher goodness-of-fit measures), it is summarized in Table 7.13 the effects that were captured in the other two models based on physical noise measures indoors (model 7.5) and outdoors (model 7.6). The statistically significant effects are marked with a tick.

**Table 7:13: Comparison of MNL-INT Models Considering the Interaction Effects Represented.**

| **Model based on Perceptions (7.4)** | **7.5** | **7.6** |
|---|---|---|
| Deteriorations in quiet levels (base) | ✓ | ** |
| Improvements in quiet levels (base) | ✓ | ** |
| Interaction of quiet with general flat exposure (dummy var for back) | ✓ | ✓ |
| Interaction of quiet with number of years living at the site (dummy var NYL $\geq$ 5) | ✓ | - |
| Interaction of quiet with less familiarity to choice context (lot) | ✓ | - |
| Interaction of quiet with gender | - | - |
| Interaction of quiet with size of quiet changes relative to the base level of quiet | (∇) | - |
| Interaction of quiet with dummy for floor number | ✓ | ✓ |
| Interaction of Housing Service Charge Levels with Current Payment | ✓ | - |
| Housing Service Charge deflated by Household Income per person | ✓ | ✓* |
| Interaction of Housing Service Charge with missing information on income | ✓ | ** |

(∇) Interaction effect found only captured the size of noise change.
(*) Only statistically significant at the 10% level of confidence;
(**) Not statistically significant.

It is shown that the model based on physical noise measures (model 7.5) has captured the major interaction effects with the quiet (noise) variable, excluding the effects of gender and the noise level in the current situation. Therefore, the models based on perceptions and the physical noise measures had similar performances in detecting the main influential variables in the valuation context. The model based on physical noise measures outdoors (7.6) had a very low performance with respect to this issue.

### 7.7.3 Comparison of Marginal Values of Quiet (Noise) for Different Apartment Situations

In this section different apartment situations are used to assess the values of quiet for real noise changes (as rated and measured). The final MNL-INT models in section 7.4 and 7.5 are considered on the basis that these models had a much higher performance in comparison to the model based on the outdoor noise measures. The mean change in ratings and indoor physical noise measures across the different situations is computed from the SP sample.

Table 7.14 represents the marginal values of quiet obtained for several situations, considering an adjusted household income level of 60 (Thousand Escudos per month) and base housing service charge of 7500 (1999 Escudos per month). A loss (deterioration) or gain (improvement) in the levels is considered following the analysis in chapter 6 (upper floors are on average noisier than lower floors). Because the model based on perceptions is sensitive to the base noise level experienced (QBAS) in the current apartment, average rating for the sample in each situation is used in the computation of values.

The mean change in noise levels in dB(A) from one apartment to other situations as represented in Table 7.14 is relatively similar, and therefore it was expected that the model based on physical noise measures would give similar marginal values of noise per dB(A). In Table 7.14, dividing the marginal value of quiet per unit of perceived loss (rating) by the respective marginal value obtained per dB(A), it can be found that this ratio ranges from 2.4 to 3.0 (mean value is 2.7). Dividing the marginal value of quiet per unit of perceived gain (ratings) by the correspondent marginal value per dB(A), a range from 2-3.7 (mean value is 2.9) can be found. These findings seem plausible as they correspond to an average equivalence between one unit of perceived change (as rated) and the physical noise measures.

**Table 7.14: Comparison of Marginal Values of Quiet (as perceived and measured) for a Typical Household.**

| | Mean change in ratings | Mean change in dB(A) | VoQ Unit ratings | VoQ dB(A) |
|---|---|---|---|---|
| **Current apartment: UF- Upper Front , QBAS = 45** | | | | |
| **UF-LF (Gain)** | 11.8 | 4.4 | 727 | 197 |
| **UF-LB (Gain)** | 22.2 | 6.8 | 630 | 197 |
| **UF-UB (Gain)** | 20.2 | 6.1 | 651 | 197 |
| **Current apartment: LB- Lower Back, QBAS = 60** | | | | |
| **LB-LF (Loss)** | 21.2 | 5.7 | 1145 | 451 |
| **LB-UB (Loss)** | 11.9 | 3.7 | 1135 | 451 |
| **LB-UF (Loss)** | 20.6 | 6.2 | 1145 | 451 |
| **Current apartment: UB- Upper Back, QBAS = 53** | | | | |
| **UB-UF (Loss)** | 15.1 | 6.3 | 1343 | 451 |
| **UB-LB (Gain)** | 22.0 | 4.4 | 1052 | 370 |
| **UB-LF (Loss)** | 21.7 | 5.9 | 1341 | 451 |
| **Current apartment: LF- Lower Front, QBAS = 41** | | | | |
| **LF-LB (Gain)** | 20.5 | 5.8 | 428 | 197 |
| **LF-UF (Loss)** | 12.4 | 4.2 | 671 | 277 |
| **LF-UB (Gain)** | 22.7 | 6.4 | 403 | 197 |

Units: VoQ is 1999 Escudos per month per household.

Next, in Table 7.15 it is considered the ratio of values correspondent to each pair involving a change in the noise levels (example: UF-UB divided by UB-UF, i.e. losses divided by gains in quiet involving changes in the upper floor between front and back façade exposure), and a further examination is conducted.

**Table 7.15: Ratio of Marginal Values of Quiet (Losses/Gains).**

| Changes in the levels | Loss/Gain | |
|---|---|---|
| | Ratings | dB(A) |
| **Back - Front façade** | | |
| **(UB-UF)/(UF-UB)** | 2.1 | 2.3 |
| **(LB-LF)/(LF-LB)** | 2.6 | 2.3 |
| **Lower - Upper Floors along the same façade** | | |
| **(LB-UB)/(UB-LB)** | 1.08 | 1.3 |
| **(LF-UF)/(UF-LF)** | 0.92 | 1.4 |
| **Lower-Upper Floors in opposite façades** | | |
| **(UB-LF)/(LF-UB)** | 3.3 | 2.3 |
| **(LB-UF)/(UF-LB)** | 1.8 | 2.3 |

Table 7.15 shows that losses in quiet (as perceived) from an upper back apartment to a lower apartment are valued around 3.3 times higher than the correspondent gains. On the other side, losses and gains along the same façade tend to converge to the same value (ratio is

close to one). The mean change in ratings along the mean same façade is around two times smaller than the one involving opposite facades, and mean difference of the absolute levels (experienced) are closer. Therefore, following expectations from the reference-dependence theory, a ratio close to one was expected. On the other hand, a loss in the levels equivalent with a change from the back to front façade in the same floor is valued between 2.1 (upper floors) and 2.6 (lower floors) times higher than the correspondent gains (as perceived). This finding indicates the importance of a quieter façade in high-rise buildings.

The ratios obtained from the model based on physical noise measures converge to previous findings.

## 7.8 COMBINING THE MNL-INT MODEL BASED ON RATINGS WITH RANDOM PARAMETERS LOGIT SPECIFICATIONS

### 7.8.1 Introduction

In this section, the MNL logit model with additional variables that performed best is considered for further analysis. This MNL-INT model is the one based on ratings.

The objective of the modelling work conducted for this section is to test whether improvements in the explanatory power of the model can be achieved if a Mixed Logit type specification (ML) that takes into account the random variation across observed (and unobserved) heterogeneity is followed. The designation of random parameters logit is used which is interchangeable with the previous Mixed Logit term.

The MNL-INT models derived in the previous sections have considered the deterministic (or observed) heterogeneity in householders' preferences for quiet (noise) by including several additional variables of the various influential variables on quiet (noise). The "observed heterogeneity" is therefore treated as fixed for each group of respondents (with the same observed characteristics).

In this section, the mentioned observed heterogeneity is allowed to vary randomly over each household. The ML specifications tested in this section allow random (unobserved) heterogeneity over the already treated deterministic (observed) heterogeneity. The research hypothesis is that this ML specification might improve our understanding on the way householders' preferences for qualitative variables such as quiet vary in the presence of observed attributes (and its interactions with influential factors in the context), and other unobserved influences (including its interactions with already observed effects).

The models are estimated by simulated maximum likelihood using GAUSS and the mixed logit code for panel data earlier referred.

### 7.8.2 Mixed Logit Modelling Methodology

The final MNL-INT model presented in section 7.4 is considered as the base model. It is termed here as the 'fixed effects' model', bearing in mind that the effects are fixed for the same household categories (same observed characteristics). The specification of the conditional utility functions for the deterministic component referring to two pairs of apartment choices at a time is represented (see Table 7.3 for notation):

$$V_{i1} = \alpha \cdot QDET_{i1} + \beta \cdot QIMP_{i1} + \chi \cdot QBAC_{i1} + \delta \cdot QNYL_{i1} + \varepsilon \cdot QCHC_{i1} + \phi \cdot QFEM_{i1}$$
$$+ \varphi \cdot QSCQCH_{i1} + \gamma \cdot \cdot QFNU_{i1} + \eta \cdot BASH_{i1} + \mu \cdot HSCY_{i1} + \theta \cdot HSCM_{i1}$$
$$+ \xi \cdot VIEW_{i1} + \psi \cdot SUNL_{i1}. \qquad \textbf{(7.35)}$$

$$V_{i2} = \alpha \cdot QDET_{i2} + \beta \cdot QIMP_{i2} + \chi \cdot QBAC_{i2} + \delta \cdot QNYL_{i2} + \varepsilon \cdot QCHC_{i2} + \phi \cdot QFEM_{i2}$$
$$+ \varphi \cdot QSCQCH_{i2} + \gamma \cdot \cdot QFNU_{i2} + \eta \cdot BASH_{i2} + \mu \cdot HSCY_{i2} + \theta \cdot HSCM_{i2}$$
$$+ \xi \cdot VIEW_{i2} + \psi \cdot SUNL_{i2}. \qquad \textbf{(7.36)}$$

The first eight parameters in equations 7.35 and 7.36 refer to interaction of several influential variables on quiet (noise), whereas the parameters η, μ, and θ refer to cost reference and income effects. These parameters represent a "mean value" for each group of households with the same observed characteristics over repeated choices.

For ML modelling, a step-by-step methodology is followed:

**1.** Each "fixed" parameter (in equations 7.35 and 7.36) is allowed to vary randomly over householders (one parameter at a time), such that the ML specification is (other terms as in previous equations are omitted for simplification):

$$V_{i1} = (\alpha + \zeta_i) \cdot QDET_{i1} + \cdots \tag{7.37}$$

$$V_{i2} = (\alpha + \zeta_i) \cdot QDET_{i2} + \cdots \tag{7.38}$$

The parameter $\zeta$ in equations 7.37 and 7.38 is allowed to vary for each household (i=1,2,...,412) over repeated choices (note that subscripts that refer to the choice occasion are omitted, t=1,2,...,12). This parameter represents the random variation for each interaction term, and it can be interpreted as the stochastic deviation relative to the mean value ($\alpha$, in this example) for that specific group of householders. This random variation is intrinsic to each householders' own tastes, and it is correlated over several repeated choices.

**2.** The best distribution for the random coefficient is tested, starting with distributions that derive from *a priori* expectations, e.g. normal distributions (if tastes are assumed to be normally distributed across the sampled householders, taste variation follows the standard deviation relative to mean value), triangular distribution (if tastes follows a range of values with mean *m* with spread s, whose density function is zero below m-se and m+ s ) and log-normal (if tastes are always of one specific sign, e.g. positive). The best distribution assumption for each random parameter is a major ongoing research area, as mentioned by Hensher (2001a). In this research several functional forms for the random parameters explored such as normal and lognormal. The log likelihood at convergence of the model was assessed at a time.

**3**. Improvements in the base model (Fixed effects) as a result of each random parameter logit specification were assessed by means of the likelihood ratio test, introduced in section 7.3.2.2.

4. Using GAUSS, the final ML model is found using the simulated maximum likelihood criteria at convergence; the simulation was based on 125 random draws (Halton draws).

Following Revelt and Train (1999) a number of 100 Halton draws is recommended for the estimation of the RPL model. Bhat (2001) showed that for higher integral dimensions involving distributions of 4-5 unknown random parameters, the quasi-Monte Carlos simulation method (Halton sequence method) using 100 draws conducted to an equivalent accuracy to using 2000 pseudo-random draws using the standard Monte Carlo method, and 125 draws provided a better accuracy in one-tenth of the time in comparison. Nevertheless, the final ML models estimated have required much more computation time in comparison to the previous standard MNL-INT model.

### 7.8.3 Final Mixed Logit Model

Table 7.16 shows the final ML model that was achieved following the step-by step methodology described in the previous section. Each variable was added at a time, and it was kept if the distribution of the random coefficients as tested improved the likelihood of the base model.

It is found that the mixed logit model performs better in explaining preferences for quiet, considering the significance of the random coefficients pointing out for individuals' intrinsic tastes across the already modelled groups based on observed attributes. Also, the log likelihood at convergence of the mixed logit is -2448.513 in comparison to the value of – 2834.390 for the MNL-INT model, and following a likelihood ratio test this represented a significant improvement considering for the additional 7 degrees of freedom.

Following the ML specification reported in Table 7.16, it is possible to retrieve more information on the factors that influence the variation of householders' tastes:

**1 and 2** – Deteriorations versus Improvements in the levels of quiet: the best specification for the coefficient for deteriorations was a fixed one. The standard deviation of the random component for all distributions was not statistically significant. It had the expected sign but it was lower than the corresponding coefficient for improvements (base). However, the best specification for the coefficient for improvements was a random parameters one, when a normal distribution was assumed. The standard deviation of the random coefficient was highly significant (8.61). This finding seems to indicate quite rigid behaviour of individuals when concerning losses in quiet in comparison to improvements in quiet (loss aversion). The proportion of individuals with wrong sign is 2%.

**3** - Interaction of quiet with general flat exposure: householders located at the quieter façade (back) have a higher marginal value of quiet in comparison to those fronting the main road. Considering the normally distributed coefficient, it can be seen that the standard deviation of this coefficient is highly significant (6.47) due to householders' heterogeneity. The proportion of individuals with wrong sign is 11%.

**Table 7.16: Combined MNL-INT Models with Random Parameters.**

| Text ID | Variable Description | Mean (t-stats) | Standard Deviation (t-stats) |
|---|---|---|---|
| 1 | QDET: Deteriorations in quiet levels (base) | 0.0473 (2.54) | - |
| 2 | QIMP: Improvements in quiet levels (base) ♦ | 0.0439 (2.49) | 0.0206 (8.61) |
| 3 | QBAC: Interaction of quiet with general flat exposure (dummy var for back) ♦ | 0.0673 (5.93) | 0.0548 (6.47) |
| 4 | QNYL: Interaction of quiet with number of years living at the site (dummy var NYL ≥ 5) ♦ | -0.02346 (-2.19) | 0.0214 (2.66) |
| 5 | QCHC: Interaction of quiet with less familiarity to choice context (lot) ♦ | -0.01143 (-0.83) | 0.0531 (5.56) |
| 6 | QFEM: Interaction of quiet with gender ♦ | 0.02698 (2.977) | 0.0472 (4.07) |
| 7 | QSQCH: Interaction of quiet with size of quiet changes relative to the base level of quiet(/1000)♣ | -0.00352 (-2.281) | - |
| 8 | QFNU: Interaction of quiet with dummy for floor number ≥ 4 | 0.01518 (1.414) | - |
| 9 | BASH: Interaction of Housing Service Charge Levels with Current Payment ($/10^6$) | 0.00596 (3.12) | - |
| 10 | HSCY: Housing Service Charge deflated by Household Income per person ♣♣ | -0.03281 (-3.26) | - |
| 11 | HSCM: Interaction of Housing Service Charge with missing information on income | -0.00022 (-3.28) | - |
| 12 | VIEW: View ♦♦ | -3.527 (-24.9) | 0.911 (5.749) |
| 13 | SUNL: Sun Exposure ♦ | 0.0391 (7.181) | 0.0544 (6.415) |
| Log likelihood at convergence | | -2448.513 | |

**Units**: Housing Service Charge in 1999 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).

**4** – Interaction of quiet with number of years living at the site (dummy variable for number of years ≥ 5): the best specification was found when this coefficient was allowed to vary across individuals following a normal distribution. The standard deviation of this coefficient is statistically significant at the usual 5% level of confidence. The proportion of individuals with wrong sign is 14%.

**5** – Interaction of quiet with familiarity to the SP choice context (lot): The best specification for this coefficient was found when it was allowed to vary across individuals following a normal distribution. The standard deviation of this coefficient (5.56) confirms the importance of random variation across observed heterogeneity. The mean value was not statistically significant at the 5% level of confidence, and this fact indicates that tastes tend to balance out with respect to the effect of familiarity of choice context on the marginal values of quiet.

**6** – Interaction of quiet with gender (dummy variable for females): The best specification for the interaction of this dummy coefficient with quiet was when it was allowed to vary across individuals following a normal distribution. The standard deviation of the mean coefficient is highly statistically significant (4.07), reflecting the importance of unobserved random variation intrinsic to each individual (female) case. All individuals had the right sign for this parameter.

**7** – Interaction of quiet with size of quiet changes relative to the base: the coefficient in Table 7.19 is rescaled (/1000) in order to get elements of the Hessian of the same order of magnitude. The best specification for this coefficient was a fixed one. In this case, considering the functional form for this interaction term, it can be said that it has a fixed (same) effect on each household type (i.e. with same base level of quiet and facing same size of changes in levels). The proportion of individuals with wrong sign for this parameter is 1%.

**8** - Interaction of quiet with dummy for floor number greater equal than four: the best specification was a fixed effects one, and it shall be noted that this coefficient is only statistically significant at a low level of significance, below 5%. The proportion of individuals with wrong sign for this parameter is 8%.

**9** – Interaction of housing service charge with current payment ($/10^6$): the presence of reference effects with respect to the base payment (housing service charge) follows a fixed effect specification. This specification is imposed in order to obtain marginal values of quiet. This is because the distribution of the ratio coefficient that involves the computation of the marginal value of quiet (ratio of two partial derivatives in the conditional indirect utility function) is not easy tractable in all cases, depending on the distribution of the random parameters in the numerator (quiet) and denominator (cost). All individuals had the right sign for this parameter.

**10** – Interaction of housing service charge with adjusted income per person (considering household composition): This cost coefficient is kept fixed, as in 9 in order to be able to derive tractable marginal values of quiet. It shall be noted that the ratio of two random coefficients e.g. normally distributed over log-normal (this would be the case if this cost variable would have been specified following a log-normal distribution, as it can be expected that it is always negative for all householders), is not as easy to treat because the resultant density distribution of the coefficient ratio (marginal value of quiet) will have a non closed form. All individuals had the right sign for this parameter.

**11** – Interaction of housing service charge with missing income: for the same reasons as in 9 and 10, this cost coefficient is kept fixed. All individuals had the right sign for this parameter.

**12** – View: the best distribution for this coefficient was log-normal, and its mean and standard deviation are highly statistically significant. It shall be noted that GAUSS gives the log (view coefficient estimate), and this justifies the negative sign of the mean of the log (view coefficient). Following the log-normal distribution, the mean and standard deviation of the view coefficient have to be calculated. It shall be noted that GAUSS gives as output the logarithm of the view coefficient. Therefore the mean of the view and standard deviation of the view coefficient need to be computed as: mean is $exp\ (m+s^2/2)$ and its standard deviation is equal to: $exp\ (m+s^2/2)*sqrt\ (exp\ (s^2-1))$, being $m$ and $s$ respectively the mean and standard deviation of the logarithm of the view coefficient. Following the log-normal distribution by definition, all individuals had the right sign for this parameter.

**13** – Sun Exposure: the best specification for this coefficient was when it was allowed to vary following a normal distribution. It can be seen that the mean and standard deviation of this coefficient has an high statistical significance, as in 12 confirming the importance of dealing with the issue of householders' taste variation for qualitative variables. The proportion of individuals with wrong sign for this parameter was 24%, and this higher value is consistent with the fact that for some individuals more sunlight is considered as a bad, whilst for others is a good.

### 7.8.4 Marginal Values of Quiet

The range of values of noise (mean values) that can be obtained by the mixed logit specification are shown in Tables 7.17 and 7.18, for a deterioration (loss) and improvement (gain) in quiet respectively. The previous values obtained with the standard MNL-INT model are indicated in brackets for easy of comparison.

For consistency purposes within this chapter, the same type of household is considered: a male respondent who has lived for less than 5 years in a lower floor flat (<4), paying a base housing service of 7500 Escudos per month. The objective is to compare how the mean values of quiet varied as a result of the mixed logit in comparison to the values of quiet reported earlier for the same type of individual (Tables 7.4 and 7.5). Therefore, the resulting difference is due to unobserved taste variation intrinsic to individuals' tastes in different groups of same observed characteristics.

The interest of this exercise resides on findings from other studies such as Algers et al. (1998) who found a lower value of time when the when the time coefficient was allowed to vary in the population following a normal distribution (and cost was fixed). Overall, these authors found that the estimated value of time was a function of the model specification, and that the standard logit model estimates of value of time (coefficients are treated as fixed in the population) were always higher. Considering the literature reviewed, this is the first study where the effect of mixed logit specifications is tested for the case of value of quiet (noise).

**Table 7.17: Marginal Value of Quiet per Unit of Perceived Improvement.**

| 1999 Escudos per household per month | | | | Marginal Values of Quiet | |
|---|---|---|---|---|---|
| **Adjusted Income per person per household** | **Experienced Noise Level (QBAS)** | **Quiet Level** | **Improvement Size** | **Flat exp. Fronting main road** | **Flat exp. quieter façade (back)** |
| 30000 | 60 | 70 | 10 | 266.8 (322.7) | 731.8 (605.8) |
| | 60 | 80 | 20 | 215.8 (255.1) | 680.8 (538.1) |
| | 40 | 50 | 10 | 276.6 (335.6) | 741.6 (618.7) |
| | 40 | 60 | 20 | 235.3 (280.8) | 700.2 (563.9) |
| 60000 | 60 | 70 | 10 | 432.7 (509.5) | 1186.8 (956.4) |
| | 60 | 80 | 20 | 349.9 (402.6) | 1104.0 (849.5) |
| | 40 | 50 | 10 | 448.5 (529.9) | 1202.6 (976.7) |
| | 40 | 60 | 20 | 381.5 (443.4) | 1135.6 (890.2) |

**Table 7.18: Marginal Value of Quiet per Unit of perceived Deterioration**

| 1999 Escudos per household per month | | | | **Marginal Values of Quiet** | |
|---|---|---|---|---|---|
| **Adjusted Income per person per household** | **Experienced Noise Level (QBAS)** | **Quiet Level ($QUIET_1$)** | **Loss Size** | **Flat exp. Fronting main road** | **Flat exp. quieter façade (back)** |
| 30000 | 60 | 50 | 10 | 348.7 (432.7) | 790.2 (715.8) |
| | 60 | 40 | 20 | 356.0 (442.4) | 797.5 (725.5) |
| | 40 | 30 | 10 | 339.0 (419.8) | 780.5 (702.9) |
| | 40 | 20 | 20 | 336.6 (416.6) | 778.1 (699.7) |
| 60000 | 60 | 50 | 10 | 565.5 (683.2) | 1281.5 (1130.0) |
| | 60 | 40 | 20 | 577.3 (698.4) | 1293.3 (1145.3) |
| | 40 | 30 | 10 | 549.7 (662.8) | 1265.7 (1109.7 |
| | 40 | 20 | 20 | 545.8 (657.7) | 1261.8 (1104.6) |

Comparing the ML mean values with the standard MNL-INT ones (in brackets), it can be seen that the former model gives mean values of quiet of around 17% or 24% lower for a situation involving a gain (Table 7.17) or a loss (Table 7.18) respectively if a household is fronting the main road. However, if a household is located at the back/quieter façade, the mean value of quiet in the mixed logit specification is higher than in the MNL-INT specification. It shall be noted that this is because there is a statistically significant large taste variation around the mean dummy coefficient representing the interaction with flat exposure at the back (quieter) facade. When taste variation is not allowed for around the observed influential variable (MNL-INT model), the researcher does not know the impact of the random variation (unobserved) intrinsic to each household due to this variable since a "fixed effect" is estimated for that group of households (e.g. located at the back facade). Therefore, the ML specification brings some additional information to the process of understanding the causes (observed or not) on householders' preferences for quiet. Moreover, the magnitude of unobserved taste variation can be assessed. In this study, the problem of bias in the mean values of quiet derived from the MNL-INT model is not a systemmatic problem since the values derived from the ML specification are higher in some circumstances and lower in others. Overall, the discrepancy in values' estimates can be considered of small magnitude.

### 7.8.5 Confidence Intervals for the Marginal Values of Quiet

The derivation of confidence intervals of the marginal values of quiet (point estimates) is an ongoing research area. Considering the environmental and stated preference literature reviewed, appropriate formulae for setting confidence intervals was already derived to bound the value of time (Armstrong et al. 2001). In this study, the quiet and cost variable interacts with other segmenting variables (additional variables), and for this reason the proposed methods by Armstrong et al. (2001) cannot be applied. As suggested (Ettema et al. 1997; Armstrong et al. 2001) the confidence intervals can be derived alternatively by using multivariate normal simulation.

The methodology followed in the present research to set the confidence intervals for the marginal values estimated was conducted using simulation of multivariate normal variates, i.e. the parameters of the best fit model estimated (mixed logit) were computed from a multivariate normal distribution. To this hand, the GAUSS code used to estimate the final mixed logit model had to be adapted to allow as output the covariance matrix of the parameters estimated (Table 7.16), and then used to build the Cholesky matrix. A large number of draws were used (60000) and the 95% confidence intervals were set considering the mean and variance estimates of the generated sample, by computing the 2.5% and 97.5% percentiles.

Tables 7.19 to 7.22 represent the results of the simulations for setting the confidence intervals for the marginal values of quiet presented earlier (Tables 7.17 and 7.18) considering the model with higher fit with the data estimated.

**Table 7.19: Confidence Intervals for a Situation of Improvement (Gain) in Quiet (Flat Exposure Fronting the Main Road).**

| Adjusted Income per person per household | Marginal Value of Quiet point estimate | Simulation Mean | Lower Limit | Upper Limit | Interval Size |
|---|---|---|---|---|---|
| 30000 | 266.8 | 240.9 | 29 | 588 | 559.0 |
| 30000 | 215.8 | 187.8 | -3.2 | 504.4 | 507.6 |
| 30000 | 276.6 | 249.3 | 36.6 | 605.8 | 569.2 |
| 30000 | 235.3 | 203.7 | 10.6 | 532.6 | 522.0 |
| 60000 | 432.7 | 334.8 | 44.6 | 847.2 | 802.6 |
| 60000 | 349.9 | 271.9 | 5.6 | 724.8 | 719.2 |
| 60000 | 448.5 | 351.8 | 52.8 | 864.6 | 811.8 |
| 60000 | 381.5 | 294.1 | 14.8 | 778.2 | 763.4 |

Unit values are in 1999 Escudos (1 Euro= 200,482 Escudos).

**Table 7.20: Confidence Intervals for a Situation of Improvement (Gain) in Quiet (Flat Exposure at the Back).**

| Adjusted Income per person per household | Marginal Value of Quiet point estimate | Simulation Mean | Lower Limit | Upper Limit | Interval Size |
|---|---|---|---|---|---|
| 30000 | 731.8 | 590.6 | 374.0 | 912.8 | 538.8.8 |
| 30000 | 680.8 | 548.8 | 347.8 | 847.8 | 500.0 |
| 30000 | 741.6 | 597.8 | 378.4 | 915.0 | 536.6 |
| 30000 | 700.2 | 565.0 | 359 | 871.2 | 512.2 |
| 60000 | 1186.8 | 843.9 | 515.0 | 1322.0 | 807.0 |
| 60000 | 1104.0 | 785.1 | 461.6 | 1252.4 | 790.8 |
| 60000 | 1202.6 | 853.0 | 521.4 | 1327.0 | 805.6 |
| 60000 | 1135.6 | 806.5 | 480.2 | 1281.8 | 801.6 |

Unit values in 1999 Escudos (1 Euro= 200,482 Escudos).

**Table 7.21: Confidence Intervals for a Situation of Deterioration (Loss) in Quiet (Flat Exposure Fronting the Main Road).**

| Adjusted Income per person per household | Marginal Value of Quiet point estimate | Simulation Mean | Lower Limit | Upper Limit | Interval Size |
|---|---|---|---|---|---|
| 30000 | 348.7 | 251.6 | 47.8 | 643.2 | 595.4 |
| 30000 | 356.0 | 208.9 | 14.8 | 572.8 | 558.0 |
| 30000 | 339.0 | 267.2 | 53.3 | 662.0 | 608.4 |
| 30000 | 336.6 | 234.3 | 29.6 | 587.4 | 557.8 |
| 60000 | 565.5 | 365.1 | 68.2 | 919.8 | 851.6 |
| 60000 | 577.3 | 305.1 | 21.6 | 806.2 | 784.6 |
| 60000 | 549.7 | 375.4 | 75.2 | 941.6 | 866.4 |
| 60000 | 545.8 | 326.4 | 37.8 | 855.0 | 817.2 |

Unit values are in 1999 Escudos (1 Euro= 200,482 Escudos).

**Table 7.22: Confidence Intervals for a Situation of Deterioration (Loss) in Quiet (Flat Exposure at the Back).**

| Adjusted Income per person per household | Marginal Value of Quiet point estimate | Simulation Mean | Lower Limit | Upper Limit | Interval Size |
|---|---|---|---|---|---|
| 30000 | 790.2 | 609.6 | 363.0 | 967.4 | 604.4 |
| 30000 | 797.5 | 569.0 | 328.2 | 915.0 | 586.8 |
| 30000 | 780.5 | 617.1 | 368.6 | 977.0 | 608.4 |
| 30000 | 778.1 | 585.2 | 341.4 | 935.4 | 594.0 |
| 60000 | 1281.5 | 869.2 | 518.2 | 1370.0 | 851.8 |
| 60000 | 1293.3 | 811.2 | 465.8 | 1297.6 | 831.8 |
| 60000 | 1265.7 | 880.6 | 528.2 | 1386.0 | 857.8 |
| 60000 | 1261.8 | 833.4 | 486.8 | 1326.0 | 839.2 |

Unit values in 1999 Escudos (1 Euro= 200,482 Escudos).

## 7.9 CONCLUSIONS

The modelling work conducted is novel in considering householders' heterogeneity (nature and extent) of preferences on the marginal valuations of traffic noise externalities in the home. A range of variables (situational, socio-economic, behavioural, attitudinal) was collected by means of the SP CAPI surveys. Because the SP-choice context used in this research is also novel, the range of community noise studies reviewed were not conclusive with respect to the expected impacts of most variables. Therefore, the econometric research allowed a certain degree of flexibility by testing several alternative functional forms for the explanatory variables in each case.

The stated preference-choice data was driven by respondents' perceptions of the internal noise levels indoors and other qualitative attributes intrinsic to apartments and blocks they were familiar with. A range of other variables collected during the main survey (noise levels inside apartments and outside; socio-economic variables related to each respondent, etc) served to build a range of multinomial logit models with additional variables of the main influential variables on quiet (noise). Three types of MNL-INT models were developed following a common step-by-step methodology and econometric principles, considering the quiet (noise) variables expressed as perceived levels (as rated), as the equivalent Leq dB(A) measures taken indoors and as the equivalent Leq dB(A) measures outdoors, taken from each apartment window. The model that performed best was identified, considering the respective goodness-of-fit measures, ability to capture the main influential variables (interaction effects with quiet/noise) and plausibility of marginal values of quiet (noise).

Findings showed that the model based on perceptions was statistically superior to both the models based on physical noise measures. Overall, the models based on perceptions and the physical noise measures indoors have captured the most influential effects on the marginal values of quiet (noise). This finding pointed out the importance of non-acoustical factors besides the physical noise measures in explaining preferences for quiet. Using realistic noise changes' situations, the marginal values of noise per unit of rating converged to those as measured, in the sense that losses were on average much higher valued than gains in the same apartment situations, and almost equally valued as gains in similar situations involving a noise change along the same facade.

The implication of this finding for future noise valuation studies in a similar SP choice context is that whenever data on respondents' perceptions do not exist, then the physical noise measures indoors have necessarily to be used to get plausible marginal values of noise. If the physical noise measures indoors cannot be taken (or are too costly), then the noise measures indoors need to be computed by mixed engineering and acoustics approaches, e.g. taking the predicted noise levels outdoors (in each exposed floor) and correcting those for the planned insulation conditions (façade characteristic such as materials and window types, area of windows per façade, etc).

The marginal value function is asymmetric for the models based on perceptions of quiet and the equivalent Leq dB(A) measures indoors. Marginal improvements in quiet (noise) are less valued than deteriorations. This finding is in line with recent studies of marketing science and psychology. From these studies it was expected that losses have a greater impact on individuals' utility than gains, but for other types of goods. To my knowledge this is the first study where an asymmetric marginal value function is tested for the case of noise in the residential context, confirming in a large extent the reference-dependence theory.

The finding that the value of quiet function is asymmetric has a direct implication in terms of transport planning and environmental impact assessment: if two transport projects (e.g. construction of alternative road versus public transport) are supposed to have the same absolute impact in terms of the noise levels (e.g a 10 dB(A) deterioration in the noise levels from the *status quo* and a 10 dB(A) improvement in the noise levels, respectively), it can be said that if the former project is chosen it will produce a much greater change in utility to the exposed householders in comparison to the other option.

The standard multinomial logit models with additional variables have represented the observed heterogeneity on the marginal values of quiet (noise), considering the main influential variables tested. The inclusion of these additional variables significantly increased the explanatory power of the base model in all cases. The key explanatory variables were the general flat exposure to main road, base level of noise experienced, size of noise changes, adjusted household income per person and floor number, number of years living at the apartment, gender and base monthly payment as housing service charge. The income elasticity of marginal values of quiet was found to be less than one (0.5). Considering realistic mean noise changes, a one unit of perceived loss (gain) in quiet was marginally valued in the range 671 (403) to 1145 (1052) Escudos per month per household (1999 prices). One dB(A) increase (decrease) was valued between 277 (197) to 451 (370) Escudos per month per household. One unit of perceived gain and loss (as rated) was found equivalent on average to 2.9 and 2.7 dB(A) respectively.

The MNL-INT specification was compared with a ML specification. In the ML models tested, random (unobserved) heterogeneity over the deterministic (observed) heterogeneity was allowed. The issue of taste variation across the sampled individuals could be understood in a more comprehensive way, following a step-by-step methodology for finding the best distribution for each random coefficient.

It was found that 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 (additional variables of the influential variables of the standard MNL-INT). The omission of random parameters (standard MNL-INT) was shown to conduct to higher value of quiet estimates in some situations and to lower values in others. Overall, the bias could be considered of small magnitude. Considering estimated distributions of the random parameters, it was shown that the respective standard deviations were highly significant. This indicated that there exists a significant heterogeneity at the individual level across households with the same observed influential characteristics.

# CHAPTER 8:
# ALTERNATIVE APPROACHES FOR VALUING QUIET/ NOISE: REVEALED PREFERENCE TECHNIQUES

## 8.1 INTRODUCTION

This chapter presents an alternative modelling approach for valuing quiet/noise indoors. The Revealed Preference (RP) valuation approach uses data on housing characteristics related to the observed apartment purchases of 412 householders (RP- current choice). These data are used to establish a surrogate market for the non-market good indoors (quiet). The RP models estimated used data on flat characteristics, including prices from the same sample of households that have responded to the SP-choice experiment. Later, in chapter 10, a comparison of the values of quiet estimated from these two models (RP and SP) is made, and the convergent validity of these techniques for the purpose of valuing traffic noise externalities in the home can be discussed.

One interesting point of the analysis conducted in this chapter is the investigation of householders' preferences towards quiet indoors in two different situations that are designated as:

1. RP-Current choice (RP-CC): this represents the actual apartment choice of the household (observed at the moment the survey was conducted). It shall be noted that this choice was subject to the specific local market conditions, including the allocation process by the developer and availability constraints, whilst most apartment choices were made some time ago (see chapter 6). Therefore, the current apartment choice is also termed as an *ex ante* RP choice situation. At the moment the apartment purchase decision was taken, qualitative variables such as quiet (noise) indoors would not have been fully experienced;
2. Attitudinal RP *ex post* choice: This represents the preferred flat choice of the household "now" (i.e. at the moment the survey was administered), assuming that all apartments evaluated in the SP exercise would be available. RP usually refers to models based on the observed (actual) behaviour of the individuals. Therefore, the situation described is not a RP choice. Therefore, the term "Attitudinal RP" (abbreviated to A-RP) is adopted.

In the *ex post* situation, qualitative variables such as quiet/noise have been experienced in the current apartment context.

The remainder of this chapter is organized as follows. Section 8.2 firstly describes the housing market segment surveyed and the allocation process (8.2.1), the data set and theoretical framework (8.2.2). The succeeding three sub-sections comprise the estimation of standard multinomial logit models (MNL) of householders' choices where the quiet/noise variable is expressed by three different metrics: 8.2.3- Householders' perceptions of the internal noise levels (ratings); 8.2.4- Equivalent physical noise measures indoors (Leq dB(A) converted to A-weighted sound pressure levels); 8.2.5- Equivalent physical noise measures outdoors, at each apartment floor. These models are subsequently examined and compared (8.2.6). Section 8.3 follows the same type of analysis as in section 8.2, but apartment choices are now the Attitudinal -RP *ex post* choices. Standard MNL and Mixed logit models are estimated, using the perceived levels of quiet/noise and the physical noise measures. Section 8.4 provides a comparison of the aggregate models estimated and segmentation using main variables (exposure to main road, household income) is conducted for the best fit model, bearing in mind that the objective is to follow the same econometric principles in the research analysis set out in chapter 7. The main section conclusions are summarized in 8.5.

## 8.2 REVEALED PREFERENCE MODELS BASED ON OBSERVED APARTMENT CHOICES

### 8.2.1 The Housing Market Segment and Allocation Process

In order to understand the RP-CC models estimated, the specific housing market segment needs first to be considered. The housing segment mainly comprises privately-owned apartments in high-rise buildings in Lisbon, whose characteristics were earlier described in chapter 6. The EPUL ("Empresa Publica de Urbanizacao de Lisboa") is the dominant developer (public/private capital) in the study area whose aim it is to provide shelter for all social groups, a target that is reflected by the wide range of flat prices and characteristics available in the area. This developer follows a known set of market rules:

- The residential development is undertaken under several construction phases, usually by lot. Each lot contains several buildings of the same external layout. These are publicly announced (and advertised) by a local marketing office;

- Each potential buyer is given a full brochure of the development phase (lot) that contains detailed information of the apartment and its internal characteristics. The apartments in the brochure are usually identified using an acronym based on the number of bedrooms (e.g. T0 - studio; T1-1 bedroom; etc.) and floor (e.g. 1A, 7A, etc.). Other detailed characteristics such as the internal layout, construction materials used indoors, existence of garage, etc. are also specified. The developers' minimum price for selling each flat type is referred in the brochure and application form;
- If the household is interested in buying a specific flat, a form has to be filled in. Each householder has to state in this form a bid price for the wanted flat type.
- The developer usually allocates the flat to the household who offered the highest bid.

Therefore, when householders state their preferred choice they do it in the presence of full information of the housing attributes. However, it is interesting to note that whereas quantitative attributes such as price and number of bedrooms are readily understood, other qualitative variables (e.g. sun exposure, quietness) might require some experience *in situ* to be perceived as determinant location factors within a block or lot.

As the demand for a specific flat type can be greater than its supply, and because each flat is allocated to the individual who stated the highest bid, an alternative flat within the block (e.g. other floor) is usually offered as an alternative purchase to those who lose out. Due to this flats' availability constraint, the RP actual choice data set integrates a great percentage of householders who have accepted a flat (usually the attributes that are similar to both this alternative flat and the preferred one is the number of bedrooms, which is highly correlated with price). Some apartment choices will not truly reflect householders' preferences, because the preferred alternative was not available *ex ante*. However, the error term in the discrete choice modelling framework can handle this fact, i.e. choices that wouldn't always be made.

### 8.2.2 The RP Data Set and the Theoretical Framework

The RP data set refers to flats of householders located in the same residential area in Lisbon (Telheiras). Therefore, location factors such as accessibility by private/public transport to workplace and neighbourhood attributes are controlled for (these can be considered the same for all flat choices). Apartment choices are considered at the level of a block /lot (micro behaviour analysis).

In our survey, the RP data refers to four flat alternatives that were shown to respondents for them to rate the respective attributes (these were later presented again in the SP-choice experiment). The RP data set of 412 observations integrates a wide range of flat options (and actual choices) as shown in chapter 6.

For modelling purposes, taking into account the large number of possible flat alternatives (choices), these flat options were placed into one of the following four segments (one is the observed flat choice):

1. UF (Upper front floors), if floor number is greater than the intermediate[1] floor and is located at the façade fronting the main road;
2. UB (Upper back floors), if floor number is greater than the intermediate floor and is located at the façade at the back;
3. LF (Lower front floors), if floor number is less than or equal to the intermediate floor and is located at the façade fronting the main road;
4. LB (Lower back floors), if floor number is less than or equal to the intermediate floor and is located at the façade at the back.

Flats located laterally to the main road were considered in the group of those located at the back of the building, due to its small number (twelve observations). The above segmentation is also in line with the SP experimental design, such that the issue of convergent validity of estimates of quiet/noise can be addressed.

Considering the random utility framework, multinomial logit models of four apartment alternatives are estimated using linear-in-parameters utility functions. Householder's deterministic utility is conditional on choice of a certain apartment, considering the set of feasible choices and observed attributes. The error term is hypothesized to follow an independent and identically distributed extreme value distribution (McFadden 1974). This assumption might be too restrictive in certain contexts of residential choice, as it implies that the odds (ratio of the probabilities) of one household to choose flat 1 relative to flat 2, for example, are independent of the attributes of other flat alternatives in the choice set. Considering the choice set in the present study, the models refer to the behavior of households in the same block or lot (micro level), and not within different residential zones. The cross elasticities among all pairs of flat alternatives (e.g. UF and LF; UF and LB, etc.) is expected to be similar. For defining the deterministic component of the utility, the following observed attributes in each apartment choice are considered:

- VIEW: View as perceived (rated) by the householder;

[1] An intermediate floor is the middle floor, computed as MN/2 (MN is the maximum number of floors in the specific block).

- QUIET (or NOISE) levels indoors: Quiet as perceived (rated) or Noise as measured (Leq dB(A)), respectively;
- SUNL: Sunlight as perceived (rated) by the householder.
- HSCH: Housing Service Charge (1999 Escudos);
- PRICE: Price of flat (Million of 1999 Escudos);
- NBED: Number of Bedrooms;
- PARK: Number of Parking spaces in the garage;
- FN Floor number;
- FE: Exposure to Back, Front, Lateral.

These RP data were gathered in our computer survey. However, some respondents had forgotten the prices of the other flat alternatives (although they said they knew them at the moment they had purchased the flat). Therefore, for consistency purposes the housing market prices data given by the EPUL and APEMI (1999 prices) was used in around 36% of cases.

The next section presents the standard Multinomial Logit models estimated using the RP data for the current apartment choice, and the other housing attributes as presented above. The variable quiet/noise is expressed as perceived levels (ratings).

### 8.2.3 Revealed Preference Models Based on Household's Perceptions (Ratings)

These models consider householders' perceptions of qualitative variables (view, noise, sunlight) for the four flat options, and the other three attributes as described in the previous section. As already explained, the levels of qualitative attributes were rated in a continuous scale from 0 to 100, where 0 represents the worse level of the variable (e.g. very noisy) and 100 the best (e.g. very quiet). The random utility framework as presented in chapter 7 is used, but now the dependent variables correspond to a choice within four possible alternatives.

As described in section 8.2.2, the RP choice context is at the level of a block or lot. Therefore, changes in traffic noise between the *ex ante* and *ex post* situations are expected to affect the flat alternatives in a similar proportion. This is true only if the "relative noise context" can be considered equivalent in both situations. The context includes all influential factors that might affect noise levels indoors in one flat option without affecting the other flat options in the same proportion (flats in the same block/lot). Therefore, a further examination of the blocks surveyed had to be conducted.

It was found out that in the study area seven high rise blocks were occupied before the main road (North-South Ring road) had been built. There are 112 householders in this situation. As shown in Chapter 6, the householders interviewed nearby had considered this road the main cause of noise nuisance at home. During the survey data collection, photos were given by an household showing a green area around the blocks *ex ante*. Looking at the then situation, these blocks were not exposed to traffic noise (as the main road 2 was not built). It seems more plausible to assume that noise levels in all apartment locations for those households were the same, as the type of block construction and external (internal) layout follow the same type of standards (research hypothesis). To test this hypothesis, a sensitivity analysis is conducted by estimating three types of MNL base models:

1- B-Model: Base MNL model with the full sample of 412 householders;

2-C-Model: Corrected MNL model, after excluding the mentioned seven blocks from the analysis (112 observations);

3-S-Model: Base MNL model for the entire sample, but where the quiet/noise attribute is hypothesised to be the same in the seven mentioned blocks (all other rated attributes in the *ex post* situation remain). This scenario is equivalent to say that all floors in the seven blocks were equivalent in what concerns "noise levels from road traffic" (in reality this corresponds to have relative values equal to zero for all situations).

The estimation results showed the following:

- In the B-model, the quiet coefficient had the wrong expected sign. This reflected some "noise" in the data, as explained. Alternative specific constants that could pick up any floor façade or effect did not represent any statistical improvement. Once the mentioned 112 observations were excluded (C-model), the quiet coefficient had the positive expected sign. Including all the observations and assuming for those observations equal levels of quiet in the *ex ante* situation (S-model), the quiet coefficient estimate had the positive expected sign.
- The quiet coefficient is not statistically significant in the C and S models. This confirms previous expectations. As shown in Chapter 6, in the *ex ante* situation only a small percentage of the respondents considered "quiet" as a primary location factor (around 4% of the householders stated quiet as the most important location factor, and 9% as the second most important). The "quiet" factor was presented to householders as "less noise from road traffic" (each factor was within a list of eleven factors that were found to be representative in explaining householders' choices). The fact that only a small

percentage of householders stated quiet as a primary factor in explaining the *ex ante* flat choice is understandable, considering the market allocation process, and because levels of quiet indoors (as a result of traffic noise) need first to be experienced before they can be attributed a value (research hypothesis). To a certain extent this argument also applies to view and sunlight, but some differences can be established *a priori* considering the housing market information. Local estate agents usually classify view under several categories such as "view to green area", "view to open space", "sea view", etc. and each flat is classified as being exposed to North or South orientation. The attribute "noise levels indoors" is not specified, which seems to indicate that this is an *ex post* attribute in the sense that it may need to be first experienced before it can be considered as an important location factor. Therefore, it is consistent to expect the quiet coefficient not to be statistically significant in the *ex ante* situation (no experience). As the random utility framework uses implicitly relative perceptions of quiet (apartment situations in the same block/lot) the quiet coefficient is expected to be positive (right sign).

Therefore, although the B-model is slightly better statistically, the S-model is preferred on the theoretical ground. On the other side, the ex ante situation is compatible with both base models (C and S). The final models presented in Table 8.1 were achieved by departing from these C and S base models, and by adding successively one additional explanatory variable at a time. The likelihood ratio test statistic, as earlier described in chapter 7 was used to assess if the addition of one extra variable increased the explanatory power of the base model.

**Table 8.1: MNL Models Based on Perceptions (Ratings), *Ex Ante* RP-Choice.**

| **Variables** | **Parameter Estimates (t-ratio)** | |
|---|---|---|
| | **Model C** | **Model S** |
| **VIEW** | 0.1487E-01 (3.6) | 0.1127E-01(3.2) |
| **QUIET** | 0.2561E-02 (0.6) | 0.2148E-02(0.5) |
| **PARK** | 0.556 (2.2) | 0.5002 (2.2) |
| **HSCH** | -0.2101E-0.3 (-5.7) | -0.1769E-03 (-5.5) |
| **SUNL** | 0.1496E-01 (2.7) | 0.2184E-01 (4.9) |
| Summary Statistics: | | |
| Number of Observations | 300 | 412 |
| Final value of Likelihood | -380.4368 | -524.3755 |
| "Rho-Squared" w.r.t. zero | 0.0842 | 0.0819 |
| "Rho-Squared" w.r.t. constants | 0.0586 | 0.0569 |

Considering the housing market data, the flat price is highly correlated with number of bedrooms. The fact that neither attributes (flat price or number of bedrooms) added any statistically significant improvement in the explanatory power of the respective base models can be *a priori* surprising. Considering the housing market conditions described earlier, each flat choice reveals the price each household is willing to pay for it. Considering the data used for the four flat types described, 66.5% of the householders faced similar flat prices by floor, and 16% had similar prices for the current flat choice and upper floors. Since the price of flat does not vary much, this does not help to obtain a statistically significant coefficient. On the other side, the housing price data used might be subject to measurement errors and also to some misperceptions of the householders. Indeed, even in recent flat purchases, the householder might have stated a perceived flat price in the opposite floor for example, and in reality this might diverge substantially (or not) from the real price. Also, published flat prices used to fulfill missing data are average figures, and might not be representative of the householders' real purchases at the micro level.

In order to assess the plausibility of the values derived from the final models, the market price (1999) is verified in terms of the housing service charge for an additional parking space in garage. The value obtained from the final model C and S estimated is, respectively, 2646 and 2828 (1999 Escudos per month per household). These marginal estimates are of similar order of magnitude to the average real monthly money payment for one additional parking space in garage. Usually, the amount of housing service charge in a monthly payment depends on the flat area, number of parking spaces in garage, and existence of other facilities to maintain (e.g. lifts, interior garden, etc.).

### 8.2.4 RP Models Based on the Leq dB(A) Measures Indoors

In this section the same modelling framework as before is followed, now expressing the quiet (noise) variable in terms of the physical noise measure $L_{eq}$ dB(A) taken indoors. As explained in chapter 7, this variable is converted to A-weighted micropascal for estimating the models. The base models designated as B, C and S are consistently estimated as previously, for the reasons already explained. These are represented in Table 8.2.

**Table 8.2: MNL Models Based on Physical Noise Measures Indoors,**

***Ex Ante* RP Choice.**

| Variables | Parameter Estimates (t-ratio) | | |
|---|---|---|---|
| | Sensitivity Analysis | | |
| | B -Model | C-Model | S-Model |
| **VIEW** | 0.9963E-02(2.8) | 0.1323E-01(3.1) | 0.1008E-01(2.9) |
| **NOISE** | 0.466E-01(3.7) | 0.4456E-01(3.0) | 0.4282E-01(2.9) |
| **HSCH** | -0.1743E-03(-5.5) | -0.2059E-03(-5.7) | -0.1745E-03(-5.5) |
| **SUNL** | 0.2073E-01(4.7) | 0.1557E-01(2.8) | 0.2217E-01(5.0) |
| *Summary statistics:* | | | |
| N. Observations | 412 | 300 | 412 |
| Final Likelihood | -519.8701 | -378.8631 | -522.5301 |
| "Rho-Squared" w.r.t. Zero | .0898 | .0890 | .0851 |
| "Rho-Squared" w.r.t. Constants | .0650 | .06535 | .0602 |

Unit: Noise in A-μPa.

All the variables in the base models were statistically significant but the quiet/noise coefficient had the wrong sign, indicating that people were valuing noisier places to live! Whereas the actual flat choice might not be the true preference of the householder, during our survey several householders commented that they did not know it was so noisy there when they purchased the flat. Therefore, the actual choice may be indeed noisier than other alternatives considering the true physical noise measured. One comment was that "*traffic noise only became important after we started living here everyday*...". It is important to note that noise measurements indoors have been taken in the *ex post* situation. The assumption that relative noise measurements were stable over the two situations (*ex ante* and *ex post*) cannot be guaranteed. This is because some householders might have modified the insulation of their flats through noise-averting measures, namely those fronting the main road which can be transformed into quieter places (thus altering the sign of the relative noise differences in terms of Leq dB(A)). In our sample, considering the statistical analysis in chapter 6, 25% of the householders were in these conditions. Nevertheless, comparing the goodness-of-fit measures of the models estimated (Table 8.1 and 8.2), the models based on the true physical noise measures are slightly better statistically.

The final MNL model of the *ex ante* apartment choices with higher fit with the data is represented in Table 8.3, using the total number of observations. As in the previous section, the final MNL model includes all statistically significant variables with expected sign that contributed for statistical improvements in the base model.

**Table 8.3: Final MNL Models, *Ex Ante* RP Choice.**

| Variables | Parameter Estimates (t-ratio) |
|---|---|
| | **Final Model S** |
| **VIEW** | 0.1127E-01(3.2) |
| **PARK** | 0.4964(2.2) |
| **HSCH** | -0.1766E-03(-5.5) |
| **SUNL** | 0.2196E-01(5.0) |
| Summary statistics: | |
| Number of observations | 412 |
| Final value of Likelihood | -524.4948 |
| "Rho-Squared" w.r.t. Zero | .0817 |
| "Rho-Squared" w.r.t. Constants | .0566 |

The noise variable (as measured) is not included due to the reasons explained, noting that the measurements had taken place in a different moment (*ex post*). The explanatory variables such as flat price in the RP data may not have enough variation in order for its effect to become statistically significant. On the other hand price of flat is highly correlated with number of bedrooms. Results in Table 8.3 show also that the ratio of the sunlight coefficient over the view one is around 2. This means that householders' marginal utility for sunlight in an *ex ante* situation is much higher. This confirms previous expectations that sun exposure, as indicated in the local estate agents is a major location factor considered by households. However, once it is experienced indoors preferences might change.

### 8.2.5 RP Models Based on the Leq dB(A) Measures Outdoors

The same modelling framework and procedures as in the previous section were followed, using now as quiet/noise variable the $L_{eq}$ dB(A) noise physical measures taken outdoors, at each apartment floor. MNL models were estimated, where noise was converted to A-weighted micropascal, following a procedure described in chapter 7. Estimation results showed that the quiet/noise coefficient had the wrong expected sign (as in the previous sub-section). This is indicative that householders in the *ex ante* situation did not consider the physical noise measures outdoors taken in an *ex post* situation.

### 8.2.6 Comparison of Models

The objective of this section is to compare the final RP models estimated to represent the *ex ante* householders' flat choice. More important than the goodness-of-fit measures is the theoretical plausibility of the RP models estimated, and moreover if these confirm (or not) previous expectations motivated by other data collected.

As shown in the analysis conducted in chapter 6, quiet was not expected to be a statistically significant variable in the *ex ante* situation, considering the small percentage of households who pointed out quiet as a significant location factor within the building or lot. However, the quiet coefficient had the right expected sign, and this converges to the plausibility of the model. Overall, the RP models based on perceptions had a much better performance than the ones based on physical noise measures following this criteria. When quiet/noise was expressed using the physical noise measures, the coefficient had the wrong expected sign. This suggests that since the *ex ante* situation to the present various influential factors caused the relative noise measures indoors to diverge (e.g. averting behaviour, traffic conditions, etc). For consistency purposes, the quiet/noise variable when expressed in terms of the physical noise measures was removed from the utility maximizing framework used. This is so because noise measurements indoors were taken in an *ex post* situation, and these data is used to model choice flat behaviour *ex ante*. On the other side, correction of the sample would have been difficult without information on the diverging factors in the two situations. Considering the full sample, the RP model based on perceptions had a higher likelihood ratio index (0.0569), but this was only slightly higher (0.0566) than for models where noise (as measured) was excluded from householders' utility function. This indicates that in the ex ante RP choice situation, the levels of noise (as measured now) were not relevant in choice decisions (or that measurement errors due to assuming the same relative physical noise measures are large).
This result points out to the importance of having information on the true factors that were underlying the real choices of the householders at the micro level (complementary data collected using the SP noise computer survey). This is an important issue for validating the theoretical plausibility of the values' estimates.

## 8.3 ATTITUDINAL RP MODELS OF HOUSEHOLDS' APARTMENT CHOICES IN AN *EX POST* SITUATION

In this section the Attitudinal RP *ex post* apartment choices are considered, i.e. the apartment choices the households said they would buy "now". As in section 8.2, MNL models are estimated using the perceived levels of quiet/noise and the true physical noise measures.

These A-RP models were introduced in section 8.1 and they were based on an attitudinal response (apartment choice if now, same RP opportunity choice set). They focus on an *ex post* situation, after householders had experienced living in the respective flat. This situation is time consistent with the expressed perceptions of view, noise and sunlight (ratings) and noise physical measurements that were collected during the experiment. Therefore we will use the full data set referring to 412 householders.

During the survey householders were told to consider that the same apartment choices (that led to the current observed apartment choice) were available to purchase, and for them to reveal the true choice now (i.e. if apartment choice were to happen at the moment the survey was conducted). Because they have already experienced qualitative variables indoors (view, quiet, sunlight), a change of preferences might occur between the *ex ante* and *ex post* choice situations. Table 8.4 represents the *ex ante* flat choice and the number of householders who shifted their position to other flat alternatives in the *ex post* situation (% of the totals per each line are reported, computed as the absolute value in the cell divided by the number of households in that location in the *ex ante* situation). Table 8.4 uses as cut-off point for an upper floor a floor number greater than the maximum number of floor in the building/2.

**Table 8.4: Apartment Choices in the *Ex Ante* and *Ex Post* Situations.**

| *Ex post*→<br><br>*Ex ante* | **Upper Front**<br><br>**UF** | **Upper Back**<br><br>**UB** | **Lower Front**<br><br>**LF** | **Lower Back**<br><br>**LB** | **Total of shifts to other locations (%)** |
|---|---|---|---|---|---|
| **UF: 98** | 67<br>68.37%) | 26<br>(26.53%) | 3<br>(3.06%) | 2<br>(2.04%) | 31<br>(31.6%) |
| **UB: 65** | 1<br>(1.54%) | 58<br>(89.23%) | 3<br>(4.62%) | 3<br>(4.62%) | 7<br>(10.7%) |
| **LF: 143** | 25<br>(14.48%) | 13<br>(9.09%) | 88<br>(61.54%) | 17<br>(11.89%) | 55<br>(38.5%) |
| **LB: 106** | 4<br>(3.77%) | 23<br>(21.7%) | 5<br>(4.72%) | 74<br>(69.81%) | 32<br>(30.2%) |

The analysis of Table 8.4 and findings from chapter 6 allow the following conclusions:
UF: the majority of movers located in the upper floors prefer in the *ex post* situation an upper floor at the back (26.5%), whereas the majority (68.4%) stays in the same situation. As the layout of upper floors is the same in most blocks, the householders who would move to the back façade reveal a preference for quiet now; on the other side the higher number of householders who do not move can be justified by those who had already taken averting

noise measures and have a preference for bigger flats (lower flats are in general of smaller area).

- UB: As expected the majority of households stay in the quieter façade;
- LF: The households who would move were 38.5% of the initial number in the *ex ante* situation, and have a preference for upper floors not necessarily at the back (only 54.5% of the movers would locate now at the back). Again, the majority of the households (61.4%) would choose now the same apartment. This is also indicative of preference for other attributes (e.g. being in lower floors is preferred for some households due to price of flat, etc.).
- LB: Although the majority of households would choose now the same apartment as expected, the ones who would shift their positions would prefer an upper apartment in the same façade at the back.

Since the majority of households would choose the same apartment now (shaded cells in Table 8.4), apartment choices in the *ex post* situation reveal in general a moderate change of preference for other attributes different from the *ex ante* choice.

### 8.3.1 Attitudinal RP Models based on Perceptions

In the estimation of the MNL models, the RP data on perceptions (ratings) is used for all qualitative variables that enter in the utility function of the householder flat choice in the *ex post* situation: view, quiet/noise and sunlight, as well as the other quantitative attributes (price of flat, number of bedrooms and number of parking spaces). The models estimated are represented in Table 8.5, and some findings are outlined next:

**1:** View - this coefficient had the right expected sign and it is statistically significant at the 5% level of confidence. The ratio of the view coefficient over the quiet coefficient is around 2. Following the statistical analysis in chapter 6 and Table 8.4, this is a consequence of households to prefer higher floors (which are perceived on average as noisier than lower floors and have better view as rated).

**2:** Quiet - this coefficient had the right expected sign and it is "now" in the *ex post* choice situation statistically significant at the 5% level of confidence. This means that householders' preferences towards quiet are "now" much higher than in the *ex ante* RP choice. This finding seems to point out the important role of respondent's experience.

**3:** Price of Flat (perceived price)-This variable did not represent any statistically improvement to the base model, following the likelihood ratio test statistic. The price of flat (as perceived) is subject to respondent's misperceptions and error measurements inherent of having to use other sources of data to complement the missing information on some apartment prices (data based on the EPUL base prices). On the other side, at the level of this micro analysis (building and lot), the variation of housing prices is only significant between extreme floors (top and ground floor) as prices tend to be relatively similar for the same floors, in opposite facades.

**4:** Number of Bedrooms - this variable is a proxy for the area of the apartment, and follows the typology of the developer. The functional form that provided the best fit was for a dummy variable specification (NBED ≥ 4). This coefficient had the right expected sign and it was statistically significant at the 10% level of confidence. Results seem to indicate preferences for bigger flats "now" (these are in general the upper floors). This is plausible considering the changes in the household composition since the *ex ante* and *ex post* situation.

**5:** Number of parking spaces in garage- this coefficient had the positive expected sign and it was statistically significant at the 5% level of confidence. This reflects the high motorisation of the sampled area (see also chapter 6) and preferences for parking spaces in garage.

**6:** Housing Service Charge - this coefficient had the negative expected sign ant it was statistically significant at the 5% level of confidence.

7: Sun Exposure – this coefficient had the positive expected sign and it was statistically significant at the 5% level of confidence. The relative magnitude of this coefficient in comparison to the view one was expected. Some households prefer less sun exposure "now" than before (*ex ante*) and others more, reflecting perhaps different tastes.

**Table 8.5: Attitudinal RP-choice Models Based on Perceptions,**

***Ex Post* Apartment Choice.**

| Text ID | Variables | Parameters Estimates (t-ratio) | |
|---|---|---|---|
| | | **Base Model** | **Final Model** |
| 1 | **VIEW** | 0.229E-01 (6.2) | 0.2178E-01 (5.9) |
| 2 | **QUIET** | 0.1092E-01 (2.8) | 0.1152E-01 (3.0) |
| 3 | **PRICE** | - | - |
| 4 | **NBED** | - | 0.4466 (1.8) |
| 5 | **PARK** | - | 0.5868 (2.5) |
| 6 | **HSCH** | -0.7435E-04 (-2.6) | -0.9801E-04 (-3.2) |
| 7 | **SUNL** | 0.1932E-01 (4.3) | 0.1886E-01 (4.2) |
| *Summary statistics*: | | | |
| N. Observations | | 412 | 412 |
| Final value of Likelihood | | -513.9180 | -508.5802 |
| "Rho-Squared" w.r.t. Zero | | .1002 | .1096 |
| "Rho-Squared" w.r.t. Constants | | .0981 | .1067 |

Table 8.5 shows that the A-RP *ex post* choice model represents a much better fit with the data than the *ex ante* situation. The likelihood ratio index jumps from 0.0569 (*ex ante*) to 0.1067 (*ex post*).

### 8.3.2 Attitudinal RP Models Based on Physical Noise Measures Indoors and Outdoors

In this section, the physical noise measures taken indoors and outdoors are used. The MNL models are estimated using the same discrete choice framework as before.

In the previous section where quiet was expressed using householders' perceptions (ratings), this variable was found to be statistically significant. Therefore, in the *ex post* situation, internal noise levels are believed to enter the householders' utility functions in a consistent way. The noise variable expressed in Leq dB(A) is transformed into a new variable expressed by the equivalent linear scale in μPa/1000; such that all qualitative variables that enter the utility function are expressed in a linear rating scale (see equation 7.35, chapter 7).

The final MNL models estimated with higher goodness-of-fit measures are represented in Table 8.6.

**Table 8.6: Attitudinal RP-choice Models Based on Physical Noise Measures Indoors and Outdoors, *Ex Post* Apartment Choice.**

| Text ID | Variables | Parameters Estimates (t-ratio) | |
|---|---|---|---|
| | | **Indoor measures** | **Outdoor measures** |
| 1 | **VIEW** | 0.2449E-01 (6.5) | 0.2282E-01 (6.2) |
| 2 | **NOISE♦** | -0.1565E-01 (-3.1) | -0.1197E-04 (-1.5) |
| 3 | **PRICE** | - | - |
| 4 | **NBED ♣** | 0.4563 (1.9)* | 0.4629 (1.9)* |
| 5 | **PARK** | 0.5444 (2.0) | 0.5267 (2.0) |
| 6 | **HSCH** | -0.8472E-04 (-2.9) | -0.9040E-04 (-3.1) |
| 7 | **SUNL** | 0.1932E-01 (4.3) | 0.1802E-01 (4.0) |
| *Summary statistics*: | | | |
| N. Observations | | 412 | 412 |
| Final value of Likelihood | | -508.3944 | -513.9406 |
| "Rho-Squared" w.r.t. Zero | | .1099 | .1002 |
| "Rho-Squared" w.r.t. Constants | | .1070 | .0973 |

♦ A-weighted μPa/1000. *Statistically significant at the 10% level of confidence.
♣ Dummy variable specification (=1 if NBED≥ 4; 0 otherwise)

Estimation results show that the MNL models based on the physical noise measures indoors performed better than those based on the outdoor physical noise measures. This was somehow expected, and converges to findings achieved in chapter 7 when using the SP data.

Table 8.6 shows that for the MNL models based on physical noise measures indoors all the variables had the right expected sign and statistical significance at the 5% (one at 10%) level of confidence. The noise coefficient had the negative expected sign and it was statistically significant at the usual 5% significance level, and this is a change from the *ex ante* situation. This finding seems to be in line with the analysis in chapter 6, that on average there was an agreement in relative terms between householders' perceptions of noise indoors and the true physical noise measures indoors (e.g. upper floors were perceived on average as noisier than lower floors using respondents' ratings or the true physical noise measures). On the other side, in the MNL model based on the outdoor physical noise measures, the noise coefficient was not statistically significant at the 5 or 10% level of confidence. Following the analysis in chapter 6, this was somehow expected as the variation of noise levels outdoors along the same façade is smaller than between lower front and lower back floors in presence of noise barriers or terrain elevations. On the other side noise levels at the façade might not be the most adequate proxy for the noise levels as perceived indoors, considering the range of influential factors (type of windows, floor number, etc.). Therefore, the relative physical noise levels indoors differ in general from the ones at the exterior, considering the different apartment situations (LF, LB, UF, UB). This can be noticed by comparing the magnitude of the noise coefficient estimates in Table 8.6 (outdoor coefficients are much smaller reflecting a much lower variation across the situations).

### 8.3.3 Comparison of Models Based on Perceptions and Physical Noise Measures Indoors

Table 8.7 compares the A-RP ex post choice models based on perceptions and the physical noise measures indoors. It was shown in the previous sub-section that this last model outperformed the one based on the outdoor noise measures. Estimation results show that the model based on the physical noise measures indoors provides a slightly better fit with the data in comparison to the models based on perceptions (the likelihood ratio index is 0.107 and 0.1067 respectively). This is a very interesting finding in the sense that respondents' experience now (implicit in the ratings) is in line with the true physical noise measures.

**Table 8.7: Attitudinal RP-choice Models with Higher Fit with the Data.**

| Text ID | Variables | Parameters Estimates (t-ratio) | |
|---|---|---|---|
| | | Perceptions | Indoor measures |
| 1 | **VIEW** | 0.2178E-01 (5.9) | 0.2449E-01 (6.5) |
| 2 | **NOISE**♦ | 0.1152E-01 (3.0) | -0.1565E-01 (-3.1) |
| 3 | **PRICE** | - | - |
| 4 | **NBED** ♣ | 0.4466 (1.8) | 0.4563 (1.9)* |
| 5 | **PARK** | 0.5868 (2.5) | 0.5444 (2.0) |
| 6 | **HSCH** | -0.9801E-04 (-3.2) | -0.8472E-04 (-2.9) |
| 7 | **SUNL** | 0.1886E-01 (4.2) | 0.1932E-01 (4.3) |
| *Summary statistics*: | | | |
| N. Observations | | 412 | 412 |
| Final value of Likelihood | | -508.5802 | -508.3944 |
| "Rho-Squared" w.r.t. Zero | | .1096 | .1099 |
| "Rho-Squared" w.r.t. Constants | | .1067 | .1070 |

♦A-weighted μPa/1000. *Statistically significant at the 10% level of confidence.
♣ Dummy variable specification (=1 if NBED≥ 4; 0 otherwise)

Considering the MNL model estimates, it shall be pointed out that each coefficient estimated represents an average point estimate for all sampled householders.

### 8.3.4 Random Parameters Logit Specification

The effect of householders' heterogeneity of preferences towards qualitative variables such as quiet is worth to be explored by random parameters' logit specifications (RPL). Since the RP sample size is small (12 times smaller than the SP sample), the rationale is to have an idea about the extent of possible taste variation associated to qualitative variables. Although nothing can be said about the possible influential factors (nature of heterogeneity), householders' tastes may vary according to observed and unobserved variables, but due to the lack of variability in the data the same approach followed in chapter 7 to deal with respondents' heterogeneity of preferences cannot be followed. Therefore, RPL models can be of use in small sample sizes to assess the impact of taste variation on values' estimates (research hypothesis).

The estimation of the RPL models follows the same step-by-step methodology earlier described in chapter 7. The taste weights associated to each qualitative variable (view, quiet and sunlight) were treated as random parameters. Estimation results using GAUSS are presented in Table 8.8.

**Table 8.8: Final RPL Based on the *Ex-Post* A-RP Data.**

| Text ID | Variables | RPL based on A-RP data | |
|---|---|---|---|
| | | Mean coefficient (standard error) | Standard deviation (standard error) |
| 1 | **VIEW** | 0.02256 (0.00407) | 0.00493 (0.00359) |
| 2 | **QUIET♣** | -4.6892 (0.58028) | 0.5711(0.4517) |
| 4 | **NBED** | 0.4538 (0.2649) | - |
| 5 | **PARK** | 0.5607 (0.2506) | - |
| 6 | **HSCH*** | -0.00975 (0.00324) | - |
| 7 | **SUNL** | 0.02127 (0.00517) | 0.00947 (0.0043) |
| *Summary statistics*: | | | |
| N. Observations | | 412 | |
| Final value of Likelihood | | -504.2106 | |

♣ Outputs are mean of the ln (quiet coefficient) and the standard deviation of the logarithm of the quiet coefficient. The mean and its standard deviation would need to be computed as in chapter 7, and lead to a 0.0108 and 0.0077 value respectively.

* Variable was scaled: 1999 Escudos/100.

The RPL was statistically superior to the standard MNL model at the 5% significance level (log-likelihood at convergence was –504.2104, with three additional random parameters in comparison to the standard MNL models in Table 8.7; the likelihood ratio test statistic is 8.37 > critical $\chi 2$ value for 3 degrees of freedom, 7.81). In the RPL model with higher goodness-of-fit measures the view and sunlight coefficients followed a normal distribution whereas the quiet coefficient a log-normal distribution. The standard deviation of the quiet coefficient is not statistically significant (asymptotic t-stats is 1.26). The mean value is 0.0108 is highly statistically significant, and of similar magnitude as using the standard MNL. The fact that the standard deviation of the view coefficient was not statistically significant at the usual 5% significance level may indicate that the different tastes in the population cancel out, following a similar study analysis (Train 1998). The standard deviation of the sunlight coefficient was statistically significant at the usual 5% significance level. This indicates that there exists much more heterogeneity of preferences with respect to sunlight in comparison to the other two qualitative attributes (view and quiet).

The better fit with the data of the RPL model seems to indicate that random taste variation would have probably been significant to explain householders' *ex post* choices if we had a bigger RP sample. On the other side, the RPL specification in comparison to the standard MNL model conducts to similar mean values of quiet, as the magnitude of the ratio of the quiet coefficients (mean value in the RPL model) over the housing service charge is similar.

## 8.4 COMPARISON OF MODELS

This section provides a comparison of the RP choice models estimated, following two research directions:

1- Comparison of the RP-current choice (*ex ante*) and the A-RP *ex post* choice: the role of respondent's experience on valuing qualitative attributes such as quiet/noise indoors is addressed.

2- Estimate segmented A-RP models (best fit model based on perceptions), in order to compare values of quiet estimates with the SP data (chapter 10).

### 8.4.1 RP-current Choice versus A-RP *Ex-Post* Choices

The MNL models estimated in each situation described (*ex ante* and *ex post*) with higher fit with the data are summarized in Table 8.9. Although the model based on physical noise measures indoors slightly outperformed the one based on perceptions in the *ex post* situation, the MNL model based on perceptions is used for consistency with the *ex ante* situation. The analysis will be focusing on householders' preferences for qualitative attributes.

**Table 8.9: RP-current Choice (*Ex Ante*) and A-RP *Ex Post* Choice Models.**

| Text ID | Variables | Parameters Estimates (t-ratio) | |
|---|---|---|---|
| | | ***Ex ante* choice (RP)** | ***Ex post* choice (A-RP)** |
| 1 | **VIEW** | 0.1127E-01 (3.2) | 0.2178E-01 (5.9) |
| 2 | **QUIET** | 0.2148E-02 (0.5) | 0.1152E-01(3.0) |
| 3 | **NBED♣** | - | 0.4466 (1.8) |
| 4 | **PARK** | 0.5002 (2.2) | 0.5868 (2.5) |
| 5 | **HSCH** | -0.1769E-03 (-5.5) | -0.9801E-04 (-3.2) |
| 6 | **SUNL** | 0.2184E-01 (4.9) | 0.1886E-01 (4.2) |
| *Summary statistics*: | | | |
| N. Observations | | 412 | 412 |
| Final value of Likelihood | | -524.3755 | -508.5802 |
| "Rho-Squared" w.r.t. Zero | | .0819 | .1096 |
| "Rho-Squared" w.r.t. Constants | | .0567 | .1067 |

♣ Dummy variable specification (=1 if NBED≥ 4; 0 otherwise)

Table 8.9 shows that qualitative coefficients (view, quiet) differ more from the *ex ante* and *ex post* situation, whereas the Sunlight coefficient can be considered of similar magnitude. Interestingly, the ratio of the sunlight coefficient over the view one is close to 2 in the *ex ante* choice, indicating that householders do prefer more sunlight to a better view. However, in the *ex post* situation, the relative magnitude of both these two coefficients can be considered very close. A change of preference for these attributes occurred (indicator of some impact of respondents' experience). Those householders who shifted their positions (see also Table 8.4) to Upper floor apartments do have in general a preference for a bigger area (following variable 3 specification, Table 8.8), and this attribute is correlated with View which is usually perceived as better in Upper Flats than in Lower Flats. On the other side those who shifted to the opposite façade at the back (quieter) may be trading-off "less noise (more quiet)" with "less sunlight".

Factors that could modify householders' relative perceptions of the apartments in the same block (or lot) were analyzed and controlled for in the *ex ante* choice data. The research hypothesis was that householders' preference would change as experience of this attribute occurs. In the *ex ante* situation, the quiet coefficient is not statistically significant. This is consistent with the location factors that were referred by the householders to have explained their apartment choices (only 4% of the sampled householders have stated quiet as the most important factor, and 9% ranked it in the second place). As expected, in the *ex post* situation the quiet coefficient was statistically significant at the usual 5% significance level in the *ex post* situation.

Findings in this section converge to the idea that a minimum level of experience of the good (bad) to be valued needs to occur in order to derive consistent values' estimates.

Table 8.10 presents the marginal values of quiet and other qualitative attributes in the RP-current choice and A-RP *ex post* choices.

**Table 8.10: Marginal Values (1999 Escudos per month).**

| | Marginal Values | |
|---|---|---|
| | ***Ex ante* Choices** | ***Ex post* Choices** |
| **VIEW** | 63.7 | 222.02 |
| **QUIET** | 12.1* | 117.5 |
| **SUNL** | 123.5 | 192.4 |

* The Quiet coefficient estimate was not statistically significant.

### 8.4.2 Attitudinal RP Choice in the Ex Post Situation versus SP-Choice

As already explained throughout this chapter, the *ex post* flat choice situation that refers to the A-RP models estimated is closer to the SP-choice experiment. Both are conducted in the same moment, where most of the respondents had already experienced at the micro level (block, lot) qualitative variables such as the internal levels of quiet. Herein, experience is also associated with increased familiarity as households become acquainted with their direct neighbours.

This section aims to present a segmented A-RP choice model such that a comparison of the values of quiet derived by this model and the SP-choice (chapter 7) can be made. This will be central to chapter 10, when the issue of convergent validity of estimates of quiet/noise is discussed.

Although the comparison of A-RP *ex post* choice and SP-choice can be conducted at the level of the simplest base models (same number of variables), this would have been a very indicative comparison, as the value of quiet is considered as an average in the sample. It does not take into account the role of important segmenting variables such as income, householder composition, base noise level in the *status quo*, etc. that were found to exert a significant influence on values of quiet in the analysis conducted in chapter 7. This section considers the segmentation of the A-RP *ex post* choice model estimated based on perceptions considering main influential variables (Table 8.11). The number of significant effects is expected to be much smaller in comparison to the SP data, bearing in mind the much reduced sample size.

Because the RP data refers to the sample of householders that have answered the SP-choice experiment, it was expected in a certain extent that both A-RP and SP-choice models could be compared following similar variables' specifications. Therefore, the same econometric principles as described were followed. The interaction effects of several variables that were found statistically significant to influence quiet and the marginal utility of money (e.g. Housing Service Charge deflated by income) are tested, following a similar step-by-step methodology as in the SP-choice models. Each influential variable was added one at a time to the base A-RP model, and a likelihood ratio test indicates if the model with the additional variable was statistically superior. Although the same variables and alternative functional forms as in the SP-choice analysis were tested, and alternative functional forms, the number of those that conducted to statistical improvements in the base A-RP *ex post* choice model were much less. This is also a consequence of the small RP sample (412) in comparison to the SP (4944).
The A-RP model based on respondents' perceptions of quiet/noise is used for the segmentation purposes. The model estimated with higher fit with the data is represented in Table 8.11, and the base model is also included for comparison.

**Table 8.11: Segmentation of the A-RP *Ex Post* Choices.**

| Variables | | Parameters Estimates (t-ratio) | |
|---|---|---|---|
| | | **A-RP base model** | **A-RP best fit model** |
| 1 | **VIEW** | 0.2178E-01(5.9) | 0.2241E-01(6.0) |
| 2 | **QUIET** | 0.1152E-01(3.0) | n.a. |
| 3 | **NBED♦** | 0.4466(1.8) | 0.4839 (2.0) |
| 4 | **PARK** | 0.5868(2.5) | 0.5897 (2.5) |
| 5 | **HSCH** | -0.9801E-04 (-3.2) | n.a. |
| 6 | **SUNL** | 0.1886E-01 (4.2) | 0.1977E-01 (4.3) |
| 7 | *QUIET1* | - | 0.8172E-02 (1.9) |
| 8 | *QUIET2* | - | 0.1209E-01(3.1) |
| 9 | *HSCHY♣** | - | -1.044 (-3.7) |
| 10 | *HSCH-M*** | - | -0.1799E-03(-2.1) |
| *Summary statistics*: | | | |
| N. Observations | | 412 | 412 |
| Final Likelihood | | -508.5802 | - 504.0888 |
| $\rho^2$ w.r.t. Zero | | .1096 | 0.1174 |
| $\rho^2$ w.r.t. Constants | | .1067 | 0.1146 |

♣Functional Form: Housing Service Charge/Adjusted Income per person$^{n}$ .

* HSCHY units: x$10^3$ 1999 Escudos per month; n.a.: not applicable.

** HSCH-M unit: 1999 Escudos per month.

♦ Dummy variable (=1 if NBED ≥ 4; 0 otherwise); this coefficient is not statistically significant at the 5% or 10% level of confidence; it is kept due to its right expected sign and its importance in explaining the A-RP *ex post* choices.

Following estimation results in Table 8.11, further explanation is next added to the following segmenting variables:

**7:** QUIET1 - This variable represents the effect of an apartment being exposed at fronting the main road (Upper Front and Upper Front floors). This effect is set by an alternative specific variable in the indirect conditional utility functions. This variable had the expected sign and magnitude, revealing that those who locate fronting the main road have a lower marginal utility of quiet than those that locate at the back (quieter) façade. This coefficient estimate is statistically significant at the 10% level of confidence.

**8:** QUIET2 - This variable represents the effect of being exposed at the back (quieter) façade (alternative specific coefficient for Upper Back and Lower Back floors). Householders lateral to the main road were also considered as being exposed at the quieter façade. This coefficient had the positive expected sign and relative magnitude, and it is statistically significant at the 5% level of confidence.

9: HSCHY- This term represents the Interaction of Housing Service Charge with Household adjusted income per person, as in chapter 7 (units are Thousand of Escudos per month). The functional form that led to the best model fit was when the housing service charge was divided by the household adjusted income to the power 0.6. Following the analysis conducted in chapter 7 (see section 7.3.5) the exponent $n=0.6$ is the income elasticity of the marginal value of quiet. It is noted that the income elasticity is now a bit higher than in the SP-choice analysis (n=0.5), but these are convergent results (both are less than one and close estimates).

**10**: HSCH-M- this variable is the interaction of housing service charge with missing income. Its inclusion in model estimation is necessary in order to deal with missing data on previous variable 9.

In order to assess the plausibility of the estimates of quiet/noise derived from the segmented A-RP model estimated (Table 8.11), it is presented in Table 8.12 the values of quiet for different levels of adjusted household income per person.

**Table 8.12: Marginal Values of Quiet per Unit of Perceived Improvement.**

| | **Marginal Values of Quiet (MVQ)** | | |
|---|---|---|---|
| Adjusted Income per person per household | Flat at the façade Front (1) | Flat at the façade Back (2) | Ratio of MVQ (2/1) |
| 30000 | 43.0 | 63.4 | 1.5 |
| 60000 | 60.6 | 89.7 | 1.5 |
| 90000 | 74.3 | 109.9 | 1.5 |

Money unit: 1999 Escudos per month per household.

Results in Table 8.12 show that marginal values of quiet are sensitive to adjusted household income, confirming the sign of expectations from economic theory. Considering the general exposure of the household apartment, the marginal value of quiet for a household located at the quieter façade is around 2 times higher than for a household located fronting the main road. The marginal values seem plausible, and these will be compared with those obtained previously with the SP-choice data in chapter 10.

## 8.5 CONCLUSIONS

Considering the literature on housing decisions using discrete choice analysis, this modelling work was the former to derive marginal values of quiet using the RP data on observed apartment characteristics at the micro level, considering as the unit of analysis the same block (or lot) of the household.

Households' purchase decisions were taken in the presence of full information of the quantitative attributes (published brochures by the developer). However, it is interesting to note that whereas published quantitative attributes such as price and number of bedrooms and type of interior materials are readily understood, other qualitative variables (not referred to the mentioned brochure) such as levels of quiet indoors, view or sun exposure might require some experience *in situ* before they can be perceived as determinant location factors within a block/lot (research hypothesis). In the *ex post* situation (i.e. at the moment when the survey was conducted) qualitative attributes had already been fully experienced indoors.

Changes in traffic noise between the *ex ante* and *ex post* situations are expected to affect the flat alternatives in a similar proportion (levels as perceived). A further examination of the possible deviation factors was undertaken, but noise (as measured now) had to be taken from the householders' indirect utility function in the *ex ante* situation. The fact is that the error variance (of the error component in the random utility framework) can be much higher in the *ex ante* situation than in the *ex post*, and this would result that these models based on physical noise measures estimated in the two situations cannot be compared (because they would have had led to different scale factors).

After conducting a sensitivity analysis of the deviant effects on relative perceptions within a block/lot in the two situations described, it was concluded that the modelling of the *ex ante* RP-choice and A-RP *ex post* apartment choices' data would provide in some extent an indication of the impact of respondents' experience on valuing quiet indoors.
It shall be noted that the A-RP *ex post* situation is closer to the SP choice situation as both refer to choices "now" and are based on measures taken now. Therefore, variables are subject to much lower measurement errors then in the *ex ante* choice situation.

Considering the much smaller sample size (412) than in the SP-choice analysis (4944), multinomial logit models (without interaction effects) were fist estimated considering the observed apartment attributes in the two situations. The quiet/noise variable was again expressed by three different metrics, as in chapter 7 (perceived levels, physical noise levels indoors and outdoors), and the respective models compared. Considering the choice set in the present study, the models refer to the behaviour of households in the same block or lot (micro level).

Estimation results show that the coefficient for quiet/noise as perceived was not statistically significant in the *ex ante* situation. This was in line with the degree of importance of quiet stated by the sampled householders in comparison with other factors. 2.9% of the respondents stated quiet to have been the most important factor in explaining their housing purchases. However, in the *ex post* situation (after the respondent had lived in the apartment) the quiet coefficient was statistically significant at the 5% level of confidence. This finding seems to point out that levels of quiet (noise) indoors need to be experienced before they can enter as a fully consistent attribute in the conditional indirect utility function of householders' choices. The implication is that the issue of familiarity with the flat alternatives available needs to be correctly addressed in any housing choice experiment.

The RPL model had a higher fit with the data than the standard MNL in the *ex post* choice situation. Although the standard deviations of the random coefficients for quiet were not statistically significant at the 5% level of confidence in the *ex post* situation, the significantly higher likelihood at convergence of the RPL model, indicated that if the RP data had a bigger sample size, taste variation would have been an important issue to explain significantly the apartment purchase decisions. It shall be noted that the RPL models have assumed that the random components are uncorrelated. However, the random variation of the sunlight and quiet (noise) coefficients might be in a certain extent correlated due to the process of selectivity of apartments (apartments at the quieter façade have in general less sunlight), and even can be valued as a group relative to the other attributes. This can be subject of further research in the presence of a bigger sample size.

In order to be able to compare values of quiet (noise) estimates using the A-RP *ex post choice* and SP-choice data, further segmentation of the MNL model based on perceptions was conducted. Following the same econometric principles as outlined in chapter 7, the estimation results show that the major influential variables were household adjusted income per person and exposure to main traffic road. The income elasticity of value of quiet (noise) is 0.6, a slightly higher value than the one obtained previously using the SP data (0.5), but a convergent number.

The marginal value of quiet for a household located at the quieter façade is around 1.5 times higher than for a household located fronting the main road. Following economic theory expectations, the marginal value of quiet increases with household income. The marginal values of the qualitative attributes obtained seemed plausible, but these are to be compared with those obtained previously with the SP-choice data in chapter 10, considering the theoretical plausibility of values and the necessary assessment criteria.

# CHAPTER 9:
# ALTERNATIVE APPROACHES FOR VALUING QUIET/ NOISE: THE CONTINGENT VALUATION METHOD

## 9.1 INTRODUCTION

This chapter presents a complementary approach for valuing quiet/noise: the Contingent Valuation Method (CVM). As mentioned in chapter 2, the CVM is a special case of the Stated Preference approach, where a direct WTP question is posed referring to a sole alternative involving changes in the provision of a public good (bad). It uses a hypothetical scenario (or contingency) that is supposed to take place such as reductions (increases) in road traffic levels that lead to an “environment improvement” (reduction of noise levels indoors) or “deterioration” (increase in noise levels indoors).

The research reported in this chapter aimed to test the open-ended CV elicitation format for valuing quiet/noise indoors. The WTP questions were framed considering respondents' perceptions of the levels of quiet (noise) in the *status quo* (current apartment) and another apartment situation within the same block (or lot) of the respondent, having the same opportunity choice set as in the SP-choice experiment. The implicit physical noise measures taken in the two situations are also considered, such that a WTP per implicit dB(A) can be estimated. The CV framework generates continuous data: households' stated bids for the perceived differences in the noise levels. The split sample of deteriorations and improvements in the levels of quiet from each situation experienced (noise levels at the current apartment) is used.

The remainder of this chapter is organized as follows. Section 9.2 first provides a link between the CV literature and the development of the WTP questions in the main survey (9.2.1). The sub-section (9.2.2) presents the CV sample characteristics through the data screening and analysis. The estimation process of the WTP models is outlined as a result (9.2.3). The WTP models estimated considering households' perceptions (as rated) are presented in section 9.3, in situations of losses and gains in quiet. Section 9.4 presents the WTP models estimated based on the implicit physical noise measures. The models estimated in sections 9.3 and 9.4 are compared in section 9.5, where a critical analysis of the modelling work is made. Several scenarios of realistic noise changes are used in order to assess the plausibility of the values' estimates. Finally, section 9.6 presents the main findings of the chapter.

## 9.2 THE WTP QUESTIONS

### 9.2.1 The Design of the WTP Questions

The design of the WTP questions and their order (importance) within the main survey was earlier discussed is chapter 5. Bearing in mind that this research study was focusing on the use of SP-choice techniques for valuing quiet (noise), the choice of the WTP questions' elicitation format was fundamentally a compromise between the statistical efficiency of the implicit estimation method and survey implementation time, also related to households' acceptability. The open-ended elicitation format (OE) was chosen, and the ratings given for the noise levels indoors in the current apartment and the other three apartment situations that were presented during the SP-choice experiment are used as frame of reference (these ratings were implicit in the description of the apartments through their logos such as "7T", floor seven at the façade at the Back). Considering each household reference position, the following questions were asked for each case:

If the respondent rated his/her flat as the quietest flat amongst the four flat situations, question type 1 was asked. This took the form:

**1**. "*How much are you willing to pay per month to avoid your indoor noise levels being as bad as in apartment* NA ?" (NA is the logo for the apartment that was rated by the respondent as being the worst in terms of noise levels indoors);

If the respondent rated his/her apartment as the noisiest apartment amongst the four apartment situations rated, question type 2 was asked. This took the form:

**2.** "*How much are you willing to pay per month to improve your indoor noise levels to be as good as in flat* NI?" (NI is the logo for the flat that was rated by the respondent as being the quietest);

If the respondent lived neither in the noisiest flat nor the quietest, both questions of type 1 and 2 were presented. Households in this case answered both questions. The use of computers facilitated this task, as apartment logos appeared automatically. Respondents were told to consider that those possible improvements (or deteriorations) in quiet would result from traffic noise reductions (or increases) nearby.

### 9.2.2 The Open-ended Elicitation Format and Bias Minimisation

The framing of the WTP questions aimed to use respondents' experience and familiarity with the good (bad) being valued. This was expected to reduce the hypothetical bias. Cameron and Englin (1997) when modeling the relationship between respondents' experience, bid values and the conditional variance of the estimated WTP values, and concluded that more experienced individuals have smaller conditional variances leading to more precise WTP values.

During the main survey some respondents seemed to face an initial uncertainty with the WTP amounts to state. This might be due to the (deliberate) omission of the vehicle payment and also to the OE elicitation format itself. Bateman et al.'s study in 1995 showed that the level of uncertainty in answering open-ended questions could be a major concern. More recent work of Langford et al. in 1998 concluded that "useful information can still be obtained from smaller, open-ended (OE) studies". Several CV studies found much higher estimates of mean WTP when these are derived from other elicitation formats such as the dichotomous one (single referendum protocol) in comparison to the OE (McFadden 1994; Garrod and Willis 1995; Green et al. 1998). Other elicitation formats such as the dichotomous format would have required a much larger sample as suggested by the known NOAA[1] guidelines (Arrow *et al.* 1993). However, it can be complicated by potential biases such as anchoring or starting point bias, as the initial payment bid used may alter respondents' psychometric responses (Mitchell and Carson 1989). The OE elicitation format does not suffer from potential anchoring bias, but other drawbacks can be identified in the economic valuation literature (Garrod and Willis 1999; Pearce et al. 2002). Having said that, both the OE and other elicitation formats are subject to different advantages and drawbacks, and to common bias (e.g. strategic and hypothetical bias). The *pros* and *cons* of the various elicitation formats seem to converge to the fact that "there do not appear to be any simple design rules that a responsible CV practioner could use to guarantee reliable, reproductible results"(Green et al. 1998).

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[1] National Oceanic and Atmospheric Administration, USA.

### 9.2.3 The CV Sample and Descriptive Statistics

#### 9.2.3.1 Data screening

The survey area and characteristics of the sampled households were described in chapter 6. Of the 412 households who were given the SP-choices, only 334 (81% of the sample) answered the WTP questions. During the second phase of the data collection a less extensive version of the SP computer program was used which omitted the CV, as explained in chapter 5. Of these 334 households, 110 (33%) rated their current flat as neither the quietest nor the noisiest of the four apartment options, 123 (37%) rated their flat as the worst, 94 (28%) rated their flat as the quietest, and 7 (2%) households gave equal ratings to both their apartment and other apartment options. These seven respondents were excluded from the analysis, as the WTP questions were not relevant to them (the SP computer program was asking them the questions for validating the rating process). None of the seven respondents was willing to pay anything as expected as they experience no change. Of the initial sample size of 334 households, statistical outliers outside the economic means of the respondent, and protest votes were excluded. Table 9.1 provides a summary of the CV data screening.

**Table 9.1: CV data screening.**

| | WTP to avoid | WTP to improve |
|---|---|---|
| **Number of cases (cases WTP=0)** | 204 (9) | 233 (10) |
| **Protest votes** | 73 | 80 |
| **Outliers outside the economic means of the respondent *** | 1 | 2 |
| **Statistical Outliers ♦** | 4 | - |
| **Number of cases (valid)** | 126 | 151 |

* WTP > Adjusted Household Income per person per month ♦These were subsequently observed from the boxplot of the WTP values: cases with more than 3 box-lengths from the upper and lower edge ($25^{th}$ to $75^{th}$ percentile).

The criteria to consider an answer a protest was: a) respondents stated during the interview that the question is difficult or disliked it and did not answer; b) the household thinks nothing shall be paid because it's his/her right to live in a quiet environment and complained during the interview that the provision of quiet is felt to be government responsibility, etc. The impact of protest answers reduced the sample size for analysis by 37 % (WTP to avoid observations) and 34% (WTP to improve observations). The descriptive statistics of the sample, considering the stated amounts of WTP to avoid and to improve for specific noise changes are summarized in Table 9.2. These were obtained after removing outliers and inconsistent observations from the sample.

**Table 9.2: Descriptive Statistics of the CV sample: WTP for losses and gains in quiet.**

| | LOSSES IN QUIET | | | GAINS IN QUIET | | |
|---|---|---|---|---|---|---|
| | **WTP to avoid** | **Change in Levels (Ratings)** | **Change in Levels Leq dB(A)** | **WTP to improve** | **Change in Levels (Ratings)** | **Change in Levels Leq dB(A)** |
| **Mean (S.E.)** | 2203 (166.0) | 21.8 (1.5) | 6.0 (0.4) | 2198 (141.7) | 20.4 (1.4) | 6.6 (0.38) |
| **Median** | 2000 | 20 | 6.0 | 2000 | 15 | 6.2 |
| **Mode (*)** | 1000 | 20 | 8.8 | 1000 | 10 | 3.9 |
| **Minimum** | 0 | 1 | 0 | 0 | 80 | 0.3 |
| **Maximum** | 7000 | 81 | 15.3 | 5000 | 1 | 17.60 |
| **Observations for analysis** | 126 | 126 | 79 | 151 | 151 | 113 |

WTP Units: 1999 Escudos per month; S.E.: Standard Error; **(*)** Several modes exist.

Excluding the protest zeros[2], the WTP zero responses were a few (Table 9.2), around 4% of the total WTP responses for each situation (gains and losses). It shall be noted that a considerable number of positive bids were given as a second trial (response was not immediate), and many respondents said at first "*I have no idea of the amount*" or asked me if I wanted to state a number to them. In this case, the respondents had to be reminded of the WTP questions again and their budget constraints. The fact that most households gave a positive bid is wanted neither to be an act of "sympathy" or nor of "moral satisfaction" (see, for example, Kahneman and Knetsch 1992).

### 9.2.4 Estimation of the WTP Models

In general, the choice of the estimation method is dependent on the distribution of the WTP bids and quiet/noise levels and the form of the relationship between the dependent and explanatory variables, a result of some underlying theory or *a priori* expectations. The CV data was split in two groups: 1-WTP to avoid deteriorations (losses) in quiet and 2- WTP to obtain improvements (gains) in quiet. Figure 9.1 represents the scatterplots of the WTP values versus the changes in noise levels (Losses and Gains in quiet are defined as differences in the levels from the current level of quiet as rated at the respondent's apartment and the other level, respectively rated as better or worse). In this Figure (9.1, right), gains in quiet are negative values due to the rating scale used (100 is "very quiet" and 0 is "very noisy").

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[2] A protest zero does not mean necessarily a real zero payment in all circumstances (see for example the approach followed by Morrison et al. (2000) who used subsequent follow-up questions and recoded the protest zeros using this information.

Following Figure 9.1, the WTP bids appeared to be clustered at certain levels, around 500, 1000, 2000, 3000 and 5000 Escudos per month. These may be rounded values that households are most familiar with. On the other hand, this may be indicative of different regression equations with different slopes and intercepts according to various heterogeneous groups. It shall be noted that the clustering of responses had occurred in other studies (Mitchell and Carson 1989; Haltstead *et al.* 1991). These authors pointed out that respondents might be more familiar with some "prices" or money values, perhaps used frequently in buying some goods. In valuing quiet indoors, one can expect different bid amounts for the same environmental change as householders are heterogeneous, taking into account for example the different socio-economic variables, exposure to noise and living experiences that might affect preferences.

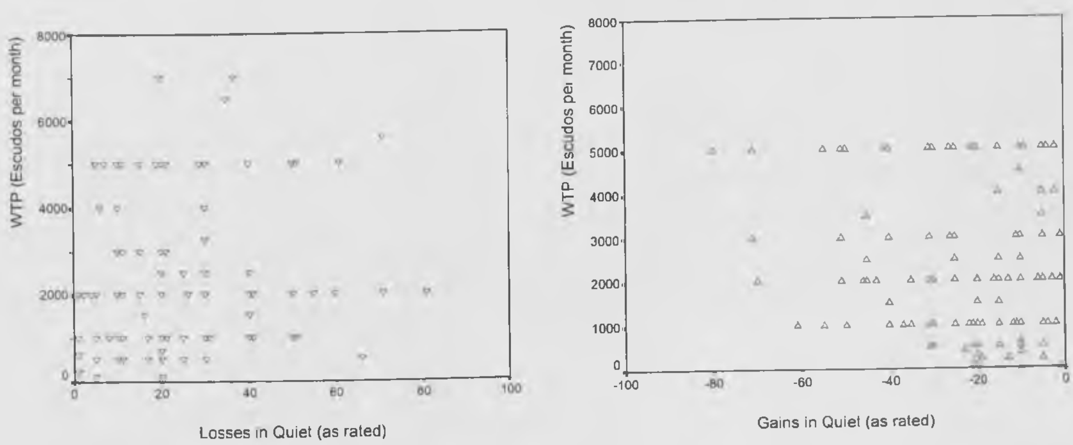


**Figure 9.1: Scatterplot of households' willingness-to-pay for changes in the noise levels as perceived (rated).**

Considering the range of influential variables, the CV data was tentatively grouped according to the different values of the variables (e.g. exposure to main road, household income, etc.) and several preliminary Ordinary Least Squares (OLS) regression models were used to assess the fit with the data. However, a large proportion of the variance of the WTP bids remained unexplained, even considering observations with common characteristics (flat exposure, household income, etc). The clustered pattern of the data seems to be associated to some random variation, and common round bid values may be linked to psychological behaviour of the respondent considering his/her familiarity with rounded payments of small magnitude. Future OE CV studies in the context can test further this research hypothesis by using follow-up questions.

In the preliminary analysis, OLS regression models were explored due to its common use in the CV literature. Using SPSS (Norusis 1999), the examination of the residuals and its scatterplots resultant from linear regression models are easily made to verify classic assumptions. For example, if the assumption of linearity between the dependent variable (WTP) and the independent variables (changes in the levels of quiet/noise) is not verified in reality, the OLS parameter estimates are biased and also without meaning (Kennedy 1998). Moreover, the OLS regression models assume that variance is constant within the sample, and if this is not the case[3] and if the differences in variability can be predicted from other variables, the weighted least squares estimation procedure is worth to be tried. The violation of the assumption of linearity was checked in SPSS by plotting the studentised residuals[4] against the predicted values, where a non-linear relationship was evident. On the other side the variance of the residuals was higher for higher values of the predicted dependent variable than for smaller values (plot of the studentised residuals against the predicted values).

Considering the underlying theory, e.g. the reference-dependence theory (Tversky and Kahneman 1991) the preferred functional form relating WTP and changes in quiet (as differences from the *status quo*) is aimed to verify diminishing sensitivity with size of gains and losses in quiet. Therefore, non-linear functional forms in parameters need to be explored. The Nonlinear Least Squares (NLLS) regression was selected for estimating the WTP bid functions, and considering the CV literature this is a novel application. The NLLS iterative procedures of SPSS were used. The sequential quadratic programming algorithm used, as its name indicates, a quadratic approximation in the minimization of the sum of square residuals procedures, considering a set of initial parameter estimates. The dependent variable is the WTP amounts and the independent variables are the changes in levels from the reference situation of the respondent (as perceived and using the implicit physical noise measures) and the set of additional explanatory variables (socio-economic and others), following non-linear in parameters model specifications.

## 9.3 WTP MODELS BASED ON PERCEPTIONS (Ratings)

In this section the WTP models based on householders' perceptions (ratings) estimated are presented. These comprise the WTP models for improvements (gains) and WTP to avoid deteriorations (losses) in the levels of quiet. Table 9.3 provides a summary of the parameter

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[3] This means the disturbances do not have the same variance or are heteroskedastic.

[4] Studentised residuals consider the WTP variability in each point: observed residuals divided by an estimate of the standard deviation of the residuals at each point.

estimates of the WTP models that provided the better fit with the data, following each model specification (see correspondent text ID).

**1a: Base WTP models**

The simplest model relates the WTP bids for improvements (or deteriorations) in quiet with the environmental change (gains or losses in quiet) through the following functional form:

$$WTPI = \beta \cdot QGAIN^{\lambda} \quad , \quad WTPA = \beta \cdot QLOSS^{\lambda}, \tag{9.1}$$

where QGAIN (QLOSS) is the absolute value of the difference between the level of quiet (noise) as rated in the current apartment (*status quo*) and the other situation rated as better (worse) (note that in the case of gains of quiet, the level in the *status quo* is a lower value than the other rated level due to the ratings scale used).

The model in equation 9.1 does not include any intercept term since one would expect a zero WTP if gains or losses indoors are zero. The parameter λ is expected to be between zero and one. Following economic theory, the WTP is expected to increase with size of good (gain in quiet) but at a decreasing rate. From the reference-dependence theory, it is expected to find a diminishing marginal sensitivity with size of good (or bad), i.e. for both gains and losses in quiet.

**1b: Sensitivity to absolute levels of quiet in the reference situation (Incremental effect)**

Several functional forms were explored to test the interaction of WTP bids with the absolute levels of quiet. This had included the use of various categories of dummy variables representing incremental effects from the base level experienced and the product interaction term (e.g. QGAIN*QBAS, being QBAS the level in the status quo).

The models with higher fit with the data and theoretical plausibility estimated in each situation were as follows:

$$WTPI = \beta \cdot QGAIN^{\lambda} + \delta \cdot DUMQBAS \cdot QGAIN^{\lambda},$$

$$WTPA = \beta \cdot QLOSS^{\lambda} + DUMExp \cdot QLOSS^{\lambda}, \tag{9.2}$$

where DUMQBAS =1 if QBAS (level in the *status quo*)< 65; 0 otherwise and DUMExp =1 if current apartment has exposure at the back; 0 otherwise). This last dummy variable was used since the WTP model (to avoid a loss in quiet) was not sensitive to the absolute levels in the *status quo*. From economic theory it is expected the marginal value of quiet will decrease with size of good (i.e. as QGAIN increases), but as QBAS increases (i.e. becomes quieter considering the scale used), the WTP is expected to decrease (in the equation that represents gains in quiet the δ coefficient is expected to be positive). For the equation that represents losses in quiet, if the hypothesis of diminishing marginal sensitivity will verify, the WTP is expected to decrease with size of bad (QLOSS), and if the situation experienced is related to being located at the back/quieter facade (the δ coefficient is expected to be positive).

**2a: Base WTP models, considering the household adjusted income per person**

Several functional forms were explored to model the effect of the household adjusted income per person (YADJ) on WTP. An additional explanatory variable was used in the NLLS regression model, as well as an interaction term (QGAIN*YADJD$^n$, using different powers $0<n<1$). The best fit with the data was found when n was close to 0.1, which was equivalent to the logarithm of YADJ, as follows:

$$WTPI = \beta \cdot QGAIN^{\lambda} \cdot \ln(YADJ), \qquad WTPA = \beta \cdot QLOSS^{\lambda} \cdot \ln(YADJ), \qquad \textbf{(9.3)}$$

The effect of household adjusted income on WTP bids is weak, which seems to be a common drawback of the CV approach found in other cases (Halstead et al 1991; Bateman et al 1995). The income elasticity of WTPI and WTPA is as follows:

$$\frac{\partial(WTPI)}{\partial(YADJ)} \cdot \frac{YADJ}{WTPI} = \beta \cdot QGAIN^{\lambda} \cdot \frac{1}{WTPI},$$

$$\frac{\partial(WTPA)}{\partial(YADJ)} \cdot \frac{YADJ}{WTPA} = \beta \cdot QLOSS^{\lambda} \cdot \frac{1}{WTPA}, \qquad \textbf{(9.4)}$$

**2b: WTP models considering the household adjusted income per person and other variables explored**

The WTP model with better fit with the data estimated that included the interaction of adjusted household income per person and the effect of the absolute levels of quiet in the reference situation has the functional forms:

$$WTPI = \beta \cdot QGAIN^{\lambda} \cdot \ln(YADJ) + \delta \cdot DUM2QBAS \cdot QGAIN^{\lambda},$$

$$WTPA = \beta \cdot QLOSS^{\lambda} \cdot \ln(YADJ) + \delta \cdot DUMExp \cdot QLOSS^{\lambda}, \qquad \textbf{(9.5)}$$

where YADJ is the adjusted household income per person (1999 Thousand Escudos per month). The others variables in the model were already defined before.

Various functions of the current Housing Service Charge Payments were also modelled as influencing the WTP bids, but no statistically significant effect was found.

**Table 9.3: Nonlinear Regression WTP models based on perceptions (ratings).**

| Model Text ID | Parameter | Estimate (t-stats) GAINS | LOSSES | $R^2$ Gains (Losses) |
|---|---|---|---|---|
| 1a | β | 1370.7344 (5.07) | 1114.1477 (3.75) | 0.062 (0.106) |
| | λ | 0.1791 (2.80) | 0.2339 (2.81) | |
| 1b | β | 1736.5687 (4.75) | 870.2053 (3.17) | 0.086 (0.118) |
| | λ | 0.11769 (1.77) | 0.28273 (3.13) | |
| | δ | 585.713 (1.75) | 247.5336 (1.76) | |
| 2a | β | 611.7396 (4.12) | 578.8883 (3.3) | 0.085 (0.131) |
| | λ | 0.2368 (3.12) | 0.2787 (2.92) | |
| 2b | β | 208.5697 (3.45) | 462.4358 (2.89) | 0.108 (0.155) |
| | λ | 0.1728 (2.21) | 0.3173 (3.13) | |
| | δ | 569.044 (1.82) | 276.8016 (1.81) | |
| **Number of observations:** Models 1a and 1b: 151 (Gains) and 126 (Losses) Models 2a and 2b: 130 (Gains) and 95 (Losses), due to missing income data. | | | | |

$R^2$ = 1 – Residual Sum of Squares/Corrected Sum of Squares
$R^2$ value with the intercept term included is reported.
t-stats= parameter estimate/asymptotic standard error.

Estimation results show that all the parameter estimates had the right expected sign and a lower significance coefficient estimate was accepted on the basis of its right expected sign and theoretical plausibility. If the sample size were bigger, the coefficient for this variable (base level experienced effect) would have been statistically significant. From Table 9.3, the non-linear parameter estimate λ is much higher when changes in quiet are losses than gains (around 1.8 times higher). As a consequence, the WTP is more sensitive to changes in the levels of quiet in the former case. The low magnitude of the λ parameter shows the WTP bids are less sensitive than expected to the environmental changes, and seem to reflect the "round" pattern of bid values earlier referred. This reflects some scope insensitivity.

Theoretical plausibility and previous expectations in line with the plausibility of values' estimates were the criteria to select the model with the best fit with the data. Table 9.3 reports the $R^2$ with a constant (intercept) included in the models because it is only with this term that this measure can represent the proportion of the variance explained by the model, but this is valid only if the models were linear. Since this study uses NLLS regression, the $R^2$ measure is only indicative and does not have the same meaning. As explained by Ratkowsky (1990) about the common misuse of $R^2$, is that "irrespective of whether there is a constant term in the model, $R^2$ does not have any obvious meaning for a nonlinear regression model", and in comparison of models "$R^2$ need never to be calculated". In order to assess the plausibility of the WTP values, the same household types and environmental changes as in the previous chapters is considered. The WTP values and values of quiet per unit of perceived gain (VoQ =Total WTP/QGAIN, for gains, or VoQ = Total WTP/QLOSS, for losses in quiet) are shown in Table 9.4 and 9.5 respectively.

**Table 9.4: Values of Quiet per unit of perceived gain: WTP model 2b.**

| Change QGAIN | Experienced Noise Levels QBAS | Total WTP | VoQ |
|---|---|---|---|
| Adjusted household income per person: 30 | | | |
| 10 | ≥ 65 | 1056.05 | 105.6 |
| 20 | | 1190.4 | 59.5 |
| 10 | < 65 | 1903.2 | 190.3 |
| 20 | | 2145.3 | 107.3 |
| Adjusted household income per person: 60 | | | |
| 10 | ≥ 65 | 1271.3 | 127.1 |
| 20 | | 1433.0 | 71.7 |
| 10 | < 65 | 2118.4 | 211.8 |
| 20 | | 2387.9 | 119.4 |

Units: Total WTP in 1999 Escudos per household per month;
Adjusted household income per person in 1999 $10^3$ Escudos per month.

**Table 9.5: Values of Quiet per unit of perceived loss: WTP model 2b.**

| Change QLOSS | Experienced Noise Levels QBAS | Total WTP | VoQ |
|---|---|---|---|
| Adjusted household income per person: 30 | | | |
| 10 | Back | 3840.5 | 384.1 |
| 20 | | 4785.2 | 239.3 |
| 10 | Front | 3265.8 | 326.6 |
| 20 | | 4069.1 | 203.5 |
| Adjusted household income per person: 60 | | | |
| 10 | Back | 4506.0 | 450.6 |
| 20 | | 5614.5 | 280.7 |
| 10 | Front | 3931.3 | 393.1 |
| 20 | | 4898.4 | 244.9 |

Units: Total WTP in 1999 Escudos per household per month;
Adjusted household income per person in 1999 $10^3$ Escudos per month.

The values of quiet as defined presented in Tables 9.4 and 9.5 confirm *a priori* expectations:

- The WTP is higher for bigger improvements (increasing size of gains in quiet) and deteriorations (increasing size of losses) but at a decreasing rate (marginal value of quiet decreases). This indicates diminishing marginal sensitivity with size of gains (losses) as expected from the reference-dependence theory;

- For the same improvement in the levels (QGAIN), the WTP is higher when the experienced situation is worse (the dummy specification that provided the best fit with the data was when perceived base level was less than 65) than when levels in the current situation are better (i.e. the reference noise level QBAS $\geq$ 65); also, for the same loss in quiet (QLOSS), the WTP is lower when the household is fronting the main road (worse situation) than at the back (quieter façade);
- The WTP for the same change in the levels (QGAIN or QLOSS) and reference situation (QBAS) is higher for households with higher adjusted income per person, as expected from economic theory.

Although the WTP models do not follow exactly the same specification, for the same change in the levels, the values of quiet per unit loss are always greater than the values per unit gain. This result seems to converge to the reference-dependence theory expectations. Figure 9.2 shows the WTP value function obtained. This function is concave in the domain of gains in quiet, and convex in the domain of losses, reflecting an asymmetric S-shaped type where increases in losses have a much higher impact than the correspondent gains. Clearly, respondents seemed to be loss averse.

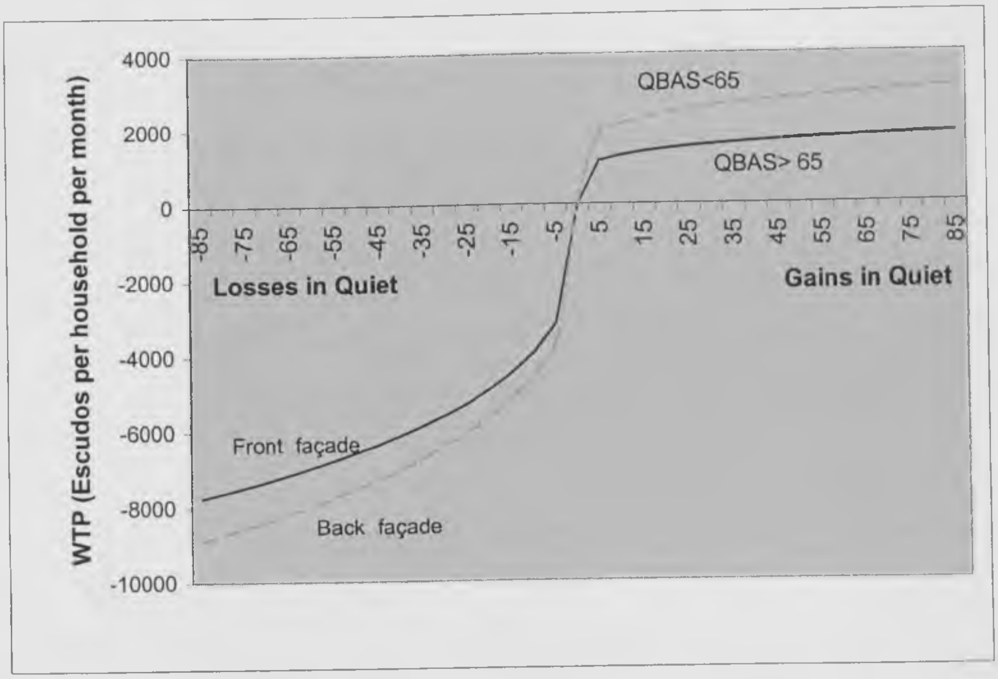


**Figure 9.2: WTP function for changes in quiet from the *status quo*.**

### 9.3.1 Comparison of Models: WTP for perceived noise decreases (gains in quiet) and WTP to avoid increases in perceived noise (losses in quiet)

The WTP models estimated with higher fit with the data presented in Table 9.3 that correspond respectively to gains and losses in quiet do not follow the same specification (model 2b). Therefore, model comparisons will be based on models 2a as they had the same functional form and include the influence of the adjusted household income per person on the stated bids. Table 9.6 presents a comparison of values of quiet (noise) considering several changes in quiet (noise) and adjusted household income per person. The value of quiet (VoQ) is the total WTP divided by the specific change in the levels.

Results in Table 9.6 show that the WTP bids for losses are on average higher than for gains, considering the same change in quiet (noise) and adjusted household income per person. The values of quiet per unit of perceived gain and loss decrease with size of noise changes and are higher when the adjusted income per person increases.

**Table 9.6: WTP for gains in quiet versus WTP for losses in quiet.**

| Change QGAIN or QLOSS | Total WTP | | VoQ | |
|---|---|---|---|---|
| | Gains | Losses | Gains | Losses |
| Adjusted household income per person: 30 | | | | |
| 10 | 3589.2 | 3749.5 | 358.9 | 374.1 |
| 20 | 4229.4 | 4537.6 | 211.5 | 226.9 |
| Adjusted household income per person: 60 | | | | |
| 10 | 4320.7 | 4502.8 | 432.1 | 450.3 |
| 20 | 5091.4 | 5462.3 | 254.6 | 273.1 |

Adjusted household income per person units: 1999 $10^3$ Escudos per month.
WTP values are in 1999 Escudos per month per household.

It shall be noted that the discrepancy between values of quiet is small, with losses on average more valued around 4% and 7% higher than gains, respectively for a change in ratings of 10 and 20. Ideally, one would have liked to have the same number of observations for comparative purposes. However, the sample size of WTP to avoid losses contains 95 usable observations whereas the WTP for gains is a bit larger (130 observations).

## 9.4 WTP MODELS BASED ON THE EQUIVALENT PHYSICAL NOISE MEASURES

The WTP questions presented in section 9.2.1 were framed considering respondents' perceptions of the quiet (noise) levels in the current situation and another three apartment choices in the same block (lot). In this section, the implicit (or equivalent) noise measures in Leq dB(A) correspondent to those situations rated are used to estimate the WTP models. Using the same procedure as in the previous chapters, the dB(A) values are converted to A-weighted sound pressure levels in microPascal (μPa). It shall be noted that during the WTP questions, the household was not told (as occurred during the SP experiment) to consider that the other characteristics of the other flats such as window types were the same as in his/her current apartment. Therefore, the noise measurements' data is not corrected for different mean insulation conditions provided by possibly different window types.

Considering the change in levels as gains (losses) in A-weighted μPa, and assuming $L_i$ (i=1,2,3,4) is the equivalent noise level as measured in the current situation, and $L_j$ (j=1,2,3,4) the other noise level, with $i \neq j$ , it is expected that the difference LGAIN = $L_i$-$L_j$ which involves a noise reduction from the current situation, will be positive (as $L_j < L_i$ in the μPa scale), and that the difference LLOSS= $L_i$-$L_k$ (k=1,2,3,4 $i \neq k$) will be negative ($L_i < L_k$ in the μPa scale). It is plausible to expect that respondents will have positive WTP amounts for noise reductions (gains) or to avoid an increase in the levels (loss of quiet), although it is unlikely that households would pay for increasing the noise levels. However, inconsistency might exist due to the fact that respondents' perceptions might differ from the true physical change.

Considering the WTP for gains (losses) sample, the data screening revealed 38 (43) cases, and these represent 25% (34%) of the total number of usable observations. Of the 38 (43) cases detected, respectively in the WTP for gains (losses) sample, 28 and 20 were referring to noise changes along the same façade. Considering the analysis conducted in chapter 6, the correlation between relative perceptions and relative noise measures was lower for noise changes along the same façade. Therefore, households may have less familiarity with the noise variation in height, and once located fronting the main road some had changed their window types.

For estimating the WTP bid functions based on the equivalent physical measures, the inconsistent observations were excluded. The final usable sample includes 113 and 83 observations, for gains and losses respectively. Table 9.7 presents the parameter estimates of the base WTP models and the best fit models estimated using NLLS regression, following each model specification (see text ID) as follows:

**1: Base WTP models**

Using the same functional form as in section 9.3, the simplest model estimated relating the WTP bids with the physical noise levels' changes described earlier, LGAIN and LLOSS, is as follows:

$$WTPI = \beta \cdot LGAIN^{\lambda}, \quad WTPA = \beta \cdot LLOSS^{\lambda}, \qquad \textbf{(9.6)}$$

where LGAIN (LLOSS) represent respectively gains and losses in the levels of quiet from the current level experienced at the respondent's apartment (status quo), in A-weighted microPascal. In the estimation the absolute values are considered. Again, the models described in equation 9.6 do not include an intercept (constant) term, since inconsistent observations were excluded from the sample (these would have implied WTP positive amounts for a noise increase and/or to avoid a noise decrease, which do not make sense in a real economy). The effect of other observed explanatory variables was tested but all effects were found not to be statistically significant.

Results from estimation (Table 9.7) show that the WTP is not sensitive to the variation in noise levels from the *status quo* as the λ coefficient is not statistically significant. The value of the β parameter is statistically significant at the 10% level of confidence. When estimating the same model with the intercept (constant), the WTP is the mean value of the sample (2462.5 Escudos per month per household for a mean change in the levels in the sample of gains in quiet of 6.61 dB(A), and 2422.9 Escudos per month per household for a mean change of 6.1 dB(A), noting that these are the mean values respectively for the usable sample of 113 and 83 households).

**Table 9.7: NLLS regression WTP models based on A-weighted μPa.**

| Model Text ID | Parameter | Estimate (t-stats) | | $R^2$ Gains (Losses) |
|---|---|---|---|---|
| | | GAINS | LOSSES | |
| 1 | β | 1795.918 (1.992) | 2363.892 (1.682) | 0.004 (0.0002) |
| | λ | 0.0477 (0.641) | 0.0036(0.04) | |
| **Number of observations:** Models 1: 113 (Gains) and 83(Losses) Models 2: 98 (Gains) and 59 (Losses), due to missing income data. | | | | |

$R^2$ = 1 – Residual Sum of Squares/Corrected Sum of Squares
$R^2$ value with the intercept term included is reported.
t-stats= parameter estimate/asymptotic standard error.

Table 9.7 show that the WTP models based on the implicit physical noise measures are meaningless. This indicates that the respondents' stated bids were not explained by the true physical noise measures. The following aspects need to be considered in the discussion:

- The WTP questions were framed considering respondent's perceptions of the noise levels in the situations presented. Even in this case, a lot of random variation remained unexplained in the final models. However, the WTP models based on perceptions were sensitive to the environmental changes (as rated) and other explanatory variables;
- The WTP models based on physical noise measures have a smaller sample size due to inconsistent observations, and the sample selection bias is higher;
- The use of true physical measures (without assuming the same insulation conditions in the current apartment and the other, worse or better level) is consistent with the framing of the WTP questions, but may introduce a higher error in this variable if the respondent thought window types of both apartments were similar (as in the SP experiment).

## 9.5 COMPARISON OF WTP MODELS BASED ON PERCEPTIONS AND PHYSICAL NOISE MEASURES

In this section the WTP models with higher theoretical plausibility based on perceptions (ratings) and the physical noise measures are compared following the criteria:

1. Sensitivity of WTP bids to explanatory variables such as changes in quiet (noise), household income, base noise level in the *status quo*, etc;
2. Plausibility of the WTP values estimates considering the underlying theory;
3. Plausibility of the WTP values for realistic changes in the levels of quiet, using the SP data information (changes in levels across various apartments' situations).

1. Sensitivity of WTP bids to the range of explanatory variables tested

The WTP models based on perceptions (Table 9.3) were sensitive to: a) changes in levels from the current level experienced, b) base noise level in the status quo (WTP for Gains) and general flat exposure to main road (WTP for Losses), and c) household adjusted income per person. Although the variables referred in b) were not statistically significant at the 5% level of confidence they were kept in the model due to its right expected sign which was in line with *a priori* expectations. The sensitivity to household adjusted income was weak, but this seems to be a feature of the OE- CV method. On the other side, the WTP models based on the true physical measures (Table 9.7) were not sensitive to any observed explanatory variable. This result was already justified.

2. Plausibility of the WTP values estimates for losses and gains in quiet considering the underlying theory

The computed values of quiet per unit of perceived gain and loss in Tables 9.4 and 9.5 showed that values were theoretically plausible, and could be explained by the reference-dependence theory. Considering the same model specification, the WTP values for gains and losses in quiet (Table 9.6) showed that losses tend to be valued more than gains. Since the asymptotic 95% confidence interval was large, not all the area of the confidence region was in agreement with this fact.

The WTP models estimated using the true physical noise measures had a very poor performance and only the mean value of quiet (mean WTP of the sample divided by the mean change in noise levels) could be computed for the usable sample. This value is 372.5 for one dB(A) improvement (gain) and 387.2 to avoid one dB(A) increase (loss) (unit: 199 Escudos per month per household). Since the value of quiet per household could not be explained, this number is merely indicative.

3. Plausibility of the WTP values for realistic changes in the levels of quiet

In order to compare the WTP values derived from the models based on perceptions, realistic changes in the levels of quiet are considered. The apartment situations of the SP experiment (UF: Upper floor Front; UB: Upper floor at the Back facade; LF: Lower Floor front; LB: Lower floor at the Back facade) are considered. The mean changes in the levels (as rated) from one situation (e.g. UF) to another (e.g. LF) are used for each case. An adjusted household income level per person of 60 thousand escudos per month is considered in the calculations, and the total WTP divided by the respective mean change in the levels is indicated as VoQ in Table 9.8.

**Table 9.8: WTP for changes in the levels of quiet.**

| | Mean Change in Ratings | Total WTP | VoQ |
|---|---|---|---|
| **Current apartment: UF- Upper Front*** | | | |
| **UF-LF (Gain)** | 11.8 | 1191.2 | 100.9 |
| **UF-LB (Gain)** | 22.2 | 1328.7 | 59.8 |
| **UF-UB (Gain)** | 20.2 | 1307.2 | 64.7 |
| **Current apartment: LB- Lower Back** | | | |
| **LB-LF (Loss)** | 21.2 | 2897.4 | 136.5 |
| **LB-UB (Loss)** | 11.9 | 2411.2 | 202.7 |
| **LB-UF (Loss)** | 20.6 | 2870.3 | 139.3 |
| **Current apartment: UB-Upper Back*** | | | |
| **UB-UF (Loss)** | 15.1 | 2603.1 | 171.9 |
| **UB-LB (Gain)** | 22.1 | 1604.1 | 72.7 |
| **UB-LF (Loss)** | 21.8 | 2920.2 | 134.3 |
| **Current apartment: LF-Lower Front*** | | | |
| **LF-LB (Gain)** | 20.5 | 1584.0 | 77.3 |
| **LF-UF (Loss)** | 12.4 | 1827.9 | 147.4 |
| **LF-UB (Gain)** | 22.7 | 1612.2 | 71.0 |

*WTP model 2b for Gains (Table 9.3), QBAS<65

A general conclusion from Table 9.8 is that gains are on average less valued than losses in the realistic situations represented, and a further examination follows. For two households, one located in an UB- Upper floor Back (X) and another in the UF-Upper floor front (Y), the WTP to avoid losses of household X (i.e. to move to UF) is around two times higher than the WTP of household Y for gains in quiet (i.e. to move to UB). Assuming these respondents have similar characteristics, this finding confirms expectations from the reference-dependence theory, that respondents are loss averse (on average, the value of one unit of perceived loss is 2.7 times higher than one unit of perceived gains). The same convergent finding occurs when considering changes along lower floors: the total WTP for losses (and value of one unit of perceived loss) is around 1.8 times higher than the WTP for gains (and value of one unit of perceived gain), i.e. move from LF to LB. For changes along the same façade, UF-LF (gains) and LF-UF (losses), the WTP for losses is around 1.5 times higher than the WTP for gains, and if the respondent is at the back façade on average one unit of perceived loss is around 2.8 times higher than one unit of perceived gain (if the respondent is fronting the main road this value is 1.5). For changes to opposite floors and facades (e.g. UF-LB), the WTP for losses (one unit of perceived loss) is around 2 times higher than the WTP for gains (one unit of perceived gains). These results seem consistent with previous expectations and converge to the content validity of the WTP questions presented in this research.

## 9.6 CONCLUSIONS

This chapter tested the use of the OE- CV elicitation format for valuing quiet indoors. Non-linear functional forms in parameters were investigated to relate the WTP bids with changes in the levels of quiet and a set of explanatory variables. Changes in quiet (noise) were defined as improvements (gains) or/and deteriorations (losses) from the current level experienced by each respondent (*status quo*). The WTP models based or respondents' perceptions of the levels in apartment situations (these served as a frame to the WTP questions) and the implicit true physical noise measures were estimated with NLLS regression. Considering the environmental valuation literature, this was a novel application.

After data screening, the usable sample for gains and losses was respectively, 151 and 126 observations. This is a much smaller sample than the RP (412 observations) or SP case (4944 observations). Therefore, levels of precision in the parameter estimates are bound to be much lower in the CV. As explained by Davidson and Mackinnon (1993) when establishing confidence regions for nonlinear regression models, "unless the sample is very large, there is not much point in trying to construct sophisticated forms of confidence intervals or confidence regions".

Results showed that the WTP models based on respondents' perceptions of the levels outperformed in a great extent the WTP models based on the implicit physical noise measures. In the former case, all the parameters had the right expected sign, and the stated bids were sensitive to changes in the levels of quiet from the status quo, base noise level experienced (WTP for gains), general flat exposure to main road (WTP for losses) and the adjusted household income per person, although the effect of the last variable was weak- a feature of other CV studies. The WTP values were theoretically plausible. On the contrary, the WTP models based on the true physical noise measures were not sensitive to any explanatory variable. A major explanation for this result may be encountered by the novel frame of reference of the WTP questions that have considered respondents' experience and familiarity using rated situations (as perceived and not measured). Households seemed to respond to the WTP questions using rounded payments, and these may be those with higher familiarity to some frequent monthly payments (hypothesis that requires further investigation). Whereas the data on perceptions can handle attitudinal behaviour, the same does not occur with the true physical noise measures. The respondent had previously rated the four apartment situations and the CV framework generated changes in the good (bad) that were supposed to be familiar. On the other side, the equivalent true noise measures did not include any correction factors for the possible different mean insulation conditions of the respondent's apartment and the other situations. This is in line with maintaining the consistency with the WTP questions asked, but may constitute a departure from what goes in respondents' minds (e.g. they might have assumed all window types of the apartments equal). Using the true noise measurements' data without correction factors, inconsistent observations were found (e.g. that would imply a positive WTP for a noise increase in dB(A)) and, thus, had to be excluded, reducing again the sample size to 113 (gains) and 83 (losses) observations.

Although the WTP model based on respondents' perceptions of the levels of quiet had a much better performance as expected, some parameter estimates in the final model were not statistically significant at the usual 5% level of confidence. Lower significance levels for the coefficients' estimates were accepted on the basis of its right expected sign and theoretical plausibility. Using realistic situations of changes in the levels of quiet (noise), values for losses were found to be much higher valued than gains (between 1.5 and 2.8 times higher, involving changes in the levels along the same façade fronting the main road and involving changes along the façade at the back, respectively). The WTP values seem plausible and confirm previous expectations from the reference-dependence theory that respondents have an asymmetric value (of quiet) function in the domain of gains and losses. Considering the CV literature reviewed, other tests of this theory had been made for the case of two private consumption goods (Bateman *et al.* 1997), but no other reference of a similar test was found for the case of levels of quiet indoors.

Other CV studies for valuing other goods with an OE elicitation format found very low goodness-of-fit measures for the WTP models using OLS regression (Kristöm 1990; Vainio 1995; Bateman et al. 1995). In the present study, the respondents seemed to state round numbers that they were familiar with, but the real reason for this to happen cannot be fully identified since follow-up questions were not included in the survey. On the other hand, some random variation intrinsic to some possible bias in the experiment that will be next explained could not be fully controlled. One of the expected drawbacks of the OE CV elicitation format in generating a considerable number of protest answers was confirmed. Protest zeros bias the sample (sample section bias), since these observations are not considered in the analysis. The use of follow-up questions to respondents in this situation could have served to identify those respondents with positive WTP for quiet (Morrison et al. 2000). The number of protest zeros is believed to be associated with the issue of property rights. As the sample integrated individuals with higher education levels (Chapter 6), most were aware of the "Portuguese Republic Constitution" and felt they had the right for a better environment and that this issue shall be in the government's agenda (therefore provision of quiet was believed not to be the households' responsibility). The majority of the households interviewed gave a positive bid, but this fact might be associated with some implementation bias (interviewer bias), since respondents are bound to associate the name of one sponsors of the study (LNEC) with acoustics. Whereas strategic bias is bound to be present, some respondents may have stated a value only to be sympathetic with myself. As some households mentioned to me, nobody else before wanted to know their opinions about environmental quality in the residential environment (letter sent in advance did not mention "noise" so as not to bias responses).

Some relational bias in the WTP estimates could not be avoided. Changes in the levels of quiet as perceived (improvements or deteriorations of the current level experienced) were supposed to be related with future road traffic decreases or increases. This might have thought to be very unlikely to happen by some respondents, following some respondents' comments during the main survey. On the other hand, the WTP questions were posed after the SP-choice experiment where a lot of effort and concentration from the respondent was asked, and subsequent tiredness could not be totally controlled, and if so answers had increased random variation.

Overall, the WTP questions had a much lower acceptability than the SP-choice part in the main survey, as many respondents wanted to stop at this point during the questionnaire. One interesting comment (from a highly level educated household on floor 5, lot R Mark Athias) stated: "*if this survey would not have been to your PhD, I would have considered my contribution to terminate here...and refused myself to answer this type of question.*" Of course this householder gave a protest bid.

# CHAPTER 10: CONVERGENT VALIDITY OF NOISE VALUE ESTIMATES

## 10.1 INTRODUCTION

This chapter focuses on the convergent validity of noise value estimates based on the SP-choice, A-RP *ex post* and CVM data, using the same sample of households. By convergent validity it is meant the extent to which the three valuation methods agreed on achieving the same findings for the following criteria:

1. Improvement (Gains) versus deteriorations (Losses) in quiet;
2. Sensitivity to Household Income;
3. Income elasticity of marginal values of quiet, and income elasticity of WTP values;
4. Sensitivity of marginal values of quiet to socio-economic, situational and other segmenting variables;
5. Relative attribute valuations using the same modelling framework (SP-choice and A-RP *ex post*);
6. Comparison of values of quiet (point estimates) for realistic changes in the levels;

This discussion is built on the models based on ratings (respondents' perceptions of the levels indoors), because these had a higher performance than those models based on the equivalent physical noise measures, especially in the case of the CVM data.

During the literature review of valuation studies on traffic noise that used stated preference techniques, presented earlier in this thesis (chapter 3), only three studies were found to have addressed the issue of convergent validity of noise values' estimates (Soguel 1996; Pommerehene 1988; Vainio 1995). Soguel (1996) compared the contingent valuation estimates with those from other studies using the hedonic pricing method and found a convergent result (the error was ± 50% which is expected following Cummings et al. 1986). The other two studies cited used the same sample of respondents in the assessment and compared values derived from the CVM and Hedonic Pricing method. Whereas Pommerehene's study found that the WTP values were theoretically consistently lower than those derived from hedonic pricing, in Vainio's (1995) study the CVM value estimates were 2-3 times higher that the HP, but these were said to be consistent with interfering biases and other features of the study. The topic of convergent validity of value estimates is an area where further investigation is needed. Understanding the reasons for a possible convergence (divergence) of findings seems an important step.

In this chapter the comparison of findings with other studies is also addressed, considering the studies reviewed. Since the valuation context of the present study is novel, the comparison of values of quiet/noise with value estimates derived from other studies can only be indicative. This is because a consistent comparison of values across different contexts will require a complete description of the situational, socio-economic characteristics of the respondents and other features of the sample, design of valuation questions and implementation of the survey method. Moreover, confidence intervals should be able to be established for comparative purposes. Not all studies provide the necessary information. Nevertheless, this issue can be the subject of further research in the future (meta-analysis of studies). In this chapter, realistic noise changes (ratings) involving different apartment situations are used (see also sub-section 7.7.3, chapter 7) to serve as a real basis for comparing value estimates. The theoretical framework and type of market experiment items are addressed, as well as the discussion of the possible bias associated with each valuation technique, design and/or its implementation.

The remainder of this section is as follows. Section 10.2 provides a synthesis matrix of the features of the valuation methods used in this study and theoretical expectations. Section 10.3 provides a comparison of valuation models following the criteria set above. Section 10.4 provides a comparison of values of quiet/noise considering other valuation studies. Section 10.5 concludes.

## 10.2 SYNTHESIS MATRIX OF THE VALUATION METHODS USED AND THEORETICAL EXPECTATIONS

As a methodological approach to the problem, the first step is to address the similarities and dissimilarities of the different valuation methods (see also chapter 2) and respective analyses. The fact that different valuation methods were applied to the same sample of households is not a sufficient condition for the expected values to be similar, even if these share the same theoretical framework. Table 10.1 presents a synthesis of the main features of the valuation methods used and the experimental market.

**Table 10.1: Synthesis Matrix of the Valuation Methods and Experimental Market.**

| | SP-choice | A-RP *ex post* choice | Open-Ended CVM |
|---|---|---|---|
| **Main theoretical framework:** | Random Utility Theory | Idem SP-choice | Consumer Theory/Hicksian measures* |
| **Type of experimental market:** | Hypothetical | Attitudinal responses based on the RP set (same apartment alternatives *ex ante)* | Idem SP-choice |
| **Variation in noise levels is set by:** | Experimental design (linked to real apartment situations); Four levels; two levels of noise compared in 12 repeated choices with view and sunlight levels.<br><br>Subject to respondents' perceptions. | Real apartment situations (four levels); one level is compared in relation to the other three linked to real apartment situations (housing data was grouped as Upper Front Floors; Upper Front Back; Lower Front; Lower Back).<br><br>Subject to respondents' perceptions. | Idem SP-choice; Two levels are compared in one single situation.<br><br>Subject to respondents' perceptions. |
| **Variation in the levels of the cost variable is set by:** | Experimental design | Subject to respondents' perceptions of the housing service charge payments and purchase price in the four apartment situations. | Free bid values are stated, subject to the household budget. |
| **Number of observations:** | 4944 | 412 | 126 (WTP to avoid losses) and 151 (WTP for gains in quiet). |

This study was centered on the SP-choice method and it was based on a random utility maximising framework. The A-RP *ex post* method on housing purchases shares a common theoretical framework with the central method of this study, whereas the OE-CVM method is a simplified experimental market based on the SP-choice design. In transport demand analysis observed behavior (RP data) is usually taken as the "true" measure, and thus the market will reveal the true value of the attribute in question (e.g. value of time). In the present study there is not really a "true" value of quiet/noise for each type of household, since there is no established market where one can buy "levels of quiet". Therefore, theoretical considerations on applying stated preference techniques become more important is assessing values in relative terms (Nash et al. 1991; Pearce and Özdemiroglu et al. 2002). Therefore, the main sources of biases are assessed:

- Strategic Bias: During the SP-choice and CVM experiment some respondents may have thought their answers could be used to improve the environmental situation in the area in terms of the noise levels. Since some sponsors of the study had links to Government, some households may have thought this research could influence policy. Therefore, they might have chosen options with higher levels of the environmental attributes but more expensive. However, this type of bias is more prone to occur in the OE-CVM case than in the SP-choice experiment, since in the former case the respondent focuses solely on the attribute 'noise', whereas in the SP several environmental attributes besides 'noise' are presented. The effect of strategic bias is expected to bias upwards the value estimates;

- Hypothetical Bias: Both the SP-choice and CVM experiments are experimental markets, thus not real markets. However, the degree of realism of the situations presented in the SP is high, and the same frame of reference was used for the OE-CVM questions. However, whereas in the SP-choice experimental market households were choosing apartment alternatives, in the OE-CVM experiment they were stating bids. The former case is less subject to hypothetical bias. The SP-choice experiment is expected to be a closer representation of a 'true market mechanism' than the OE-CVM elicitation format: in real markets households do face choices most of the time, but only in special markets they are supposed to state bids. The effect of hypothetical bias on OE-CVM could have been detected if the present survey design would have included follow-up questions seeking for respondent's motivation of the stated bids;

- Sequencing of questions: The OE-CVM questions were placed after the SP-choice experiment and this had required time for the respondent to think. Therefore, some respondents may have experiencing tiring effects at the stage the WTP questions were asked. The effect of the value estimates is expected to occur is varying directions, depending on the degree of correlation of this type of bias with the previous cited hypothetical bias;
- Payment instrument/vehicle bias: Whereas the SP-choice experiment included a realistic and familiar money dimension (housing service charge per month), the OE-CVM omitted deliberately the payment vehicle. This fact had generated some uncertainty on the maximum willingness-to-pay per month to some respondents. On the other hand this may also be related to some *preference imprecision bias*. As alternative payment vehicle could have been explored as "money increases in the housing service charge". However, the effect of the payment vehicle bias is expected not to affect value estimates (Following Pearce and Özdemiroglu et al. 2002 "the WTP for the good alone should be invariant with payment vehicle").
- "Choice/Yea Saying": This type of bias occurs if the household tried to please the interviewer and gave responses that were thought to be more acceptable. In this case, both experimental markets should be influenced in the same extent. The effect is to conduct to value estimates that were biased upwards.

From Table 10.1 it shall be noted that the SP-choice sample size is 12 times the size of the A-RP sample and the CVM sample size is small. Usually the OE- CVM recommended sample sizes for hypothesis testing for a 5% level of significance is much higher (for example, Mitchell and Carson 1989 recommend a minimum sample size of 600 if valuations are for policy purposes). The different sample sizes obtained in the three valuation methods necessarily affect the accuracy of the value of quiet estimates in relative terms.

## 10.3 COMPARISON OF FINDINGS DERIVED FROM THE SP-CHOICE, CVM AND A-RP VALUATION METHODS

### 10.3.1 Improvements (Gains) versus Deteriorations (Losses) in quiet

The models estimated using the SP-choice data and OE-CVM data were shown to be sensitive to the sign of the environmental change (losses versus gains in quiet). The A-RP model specification that led to the highest fit showed that alternative specific coefficients in the conditional indirect utility functions affecting changes along the same façade (e.g. upper front and lower front floors) were not worthwhile in the sense that they did not contribute to a significant statistical improvement. It shall be noted that the final model specification was found when the coefficients for quiet/noise were made alternative specific for apartments exposed to the front (lower front and upper front) and back (upper back and lower back). This is also a consequence of the smaller variability of the levels along the same façade of the current apartment in comparison to changes involving the front and back facades, and the RP sample size.

The models estimated using the SP-choice found that losses in quiet (deteriorations) were more valued than gains (improvements) in quiet (Tables 7.7 and 7.5, chapter 7) *ceteris paribus*. This was in line with the reference-dependence theory (Tversky and Kahneman 1991). Considering a typical household with the average household income per person equal to 93.1 x $10^3$ thousand Escudos per month (sample average), an average change in the levels of 18.8 and the mean housing service charge of 7500 Escudos per month, and assuming a level of noise at the current situation rated as 50, the marginal value of one unit loss is 1.6 and 1.3 times higher than one unit of perceived gain for an household exposed fronting the main road and at the back respectively. Using the CVM data (chapter 9, Table 9.3 model 2a) a one unit perceived loss was valued only 7% higher than one unit perceived gain *ceteris paribus*. Therefore, the loss aversion effect is much smaller in the CVM data, and the smaller sample size shall be noted.

### 10.3.2 Sensitivity to Household Income

All the models were sensitive to adjusted household income per person in the same direction: higher income households had higher marginal values of quiet (SP-choice and A-RP) or higher willingness-to-pay values (OE-CVM). This was expected from economic theory and showed that respondents took into consideration their budget constraints in the hypothetical payments stated.

Nevertheless, the CVM values showed to be less sensitive to income than either the SP or A-RP as reported in the next section.

### 10.3.3 Income Elasticity of Marginal and WTP Values for Quiet

This measure is related to the previous section findings. The income elasticity of marginal values of quiet is considered the central concept for assessing the distributional impacts of policies (Flores and Carson 1997). Nevertheless, this issue had not been investigated by most of the studies reviewed. The present study found that the income elasticity of marginal values of quiet were 0.5 and 0.6 respectively in the SP-choice and A-RP data. This is a convergent result.

The income sensitivity of the WTP values was lower than in the SP or RP data. For example, considering a round change in the ratings of 20, if the adjusted household income per person doubles e.g. from 30 to 60 thousand Escudos per month, the WTP values decrease around 21%. The income elasticity will be discussed again later in this chapter (section 10.4) when these findings will be compared to others from previous studies.

### 10.3.4 Sensitivity of marginal values of quiet to socio-economic, situational and other segmenting variables

Since quiet/noise is more a sensory experience than a physical dimension, the issue of householders' heterogeneity of preferences (taste variation) aimed to be explored during the econometric modelling process using the three sets of data. Considering the sample sizes, it was expected that the OE-CVM models would be sensitive to a much smaller number of influential variables. Interestingly, all the models picked up the effect of being exposed to fronting the main road or at the back and the previous cited adjusted household income per person. These can be classified as common influential variables. Besides these two interaction effects, the SP-choice could pick up a wide range of effects that were theoretically plausible and reflected *a priori* expectations: a) sign and size of the environmental changes (loss or gain in quiet and respective levels as perceived); b) interaction of the base level experienced with the noise change; c) effect of number of years living at the apartment; d) effect of floor number; e) effect of the current monthly payment; f) less familiarity with the choice context; g) gender. Moreover, alternative mixed logit specifications that combined these interaction terms with random parameters showed to provide alternative models for valuation purposes, since the extent of the unexplained random variation around the modelling heterogeneity was found. It can be said that the SP-choice data (4944 observations) provided more variability to be explored in order to detect major effects on the marginal values. This was a convergent finding to what seems to be cited in the literature as a major advantage of using SP data (Chapter 2) since more observations for the same household can be used to generate a more varied market of alternatives to purchase.

### 10.3.5 Relative attribute valuations using the same modelling framework: SP-choice and A-RP

Table 10.1 shows that the SP-choice and A-RP models refer to the same sample of households and both data sets were analysed using the random utility framework. Since the final models were sensitive to a different range of influential variables, it is considered in this analysis to be the respective base models. Table 10.2 summarizes the models and respective parameter estimates (t-stats).

**Table 10.2: SP-choice, WTP and A-RP models.**

| **SP-CHOICE** | | **A-RP *ex post*** |
|---|---|---|
| Variables | Parameters (t-test) | |
| VIEW | 0.02437 (9.39) | 0.02294 (6.2) |
| QUIET | 0.03107 (8.4) | 0.01092 (3.0) |
| HSCH | -0.00007932 (2.96) | -0.00007435 (2.6) |
| SUNL | 0.01782 (6.24) | 0.01932 (4.3) |
| $\rho^2$ w.r.t constants | 0.088 | 0.098 |
| Sample size | 4944 | 412 |

Table 10.2 shows one interesting finding: the view, sunlight and housing service charge coefficients in the SP-choice and A-RP models seem to converge to very similar values, whereas the quiet coefficient differs (note the higher quiet coefficient in the SP-choice). Therefore, whereas the value of view and sunlight seems to converge (point estimate considering the unsegmented sample), the value of quiet is much higher in the SP-choice. This seems to suggest the idea that some strategic bias (section 10.2) is influencing the outcome of the SP-choice experiment. Since around 45% of the sampled households were University graduates (chapter 6), some may have linked my research to the Acoustics Division of LNEC and Governmental Ministries (study sponsors) because of the necessary identification cards. Therefore, these households were seeing the interview as a vehicle to improve policies in the desired direction: to reduce noise levels by attaching a greater importance to alternatives where levels were perceived as quieter, even if those were more expensive.

Next, in Table 10.3 the marginal values of quiet are computed from the SP-choice and A-RP models estimated considering a typical noise change in the sample of 20. A simple method is used to compute the confidence intervals, bearing in mind that other alternatives to compute confidence intervals will benefit to be explored in future studies (see Armstrong et al. 2001). The 95% confidence interval for the value estimates is computed as follows:

$$\Pr\left[-t_{\alpha/2} \le VoQ \le t_{\alpha/2}\right] = 1-\alpha\,, \qquad \textbf{(10.1)}$$

where α is the level of significance of 5% and VoQ the ratio of the quiet parameter estimate (β) over the cost parameter estimate (γ); the value of $t_{\alpha/2}$ (± 1.96) is the quantile of the normal distribution such that the probability that the t ratio will lie outside the interval is α/2. It can be demonstrated that the variance of the ratio VoQ as defined can be given as (MVA 1987):

$$\mathrm{var}(VoQ) = 1/\gamma^2 \cdot \left[\mathrm{var}(\beta) - 2\cdot VoQ \cdot \mathrm{cov}(\beta,\gamma) + VoQ^2 \cdot \mathrm{var}(\gamma)\ \right], \qquad \textbf{(10.2)}$$

where *var* and *cov* stand for the variance of the respective variables and co-variance of parameter estimates (quiet and cost) respectively. This leads to a standard error of 159.3 and 70.1 for the SP-choice and A-RP data sets respectively.

**Table 10.3: Comparison of Marginal Values of Quiet (as Rated).**

| **Model** | **VoQ (95% confidence interval)** |
|---|---|
| **SP-choice** | 392 (± 312) |
| **A-RP** | 147 (± 137) |

It shall be noted that these confidence intervals are symmetrical with respect to the value of quiet point estimate. The higher variance in the SP-choice case is as a consequence of a higher negative correlation between the quiet and cost coefficients (-461/1000), whereas in the A-RP this correlation was less negative (-11/1000). Moreover, in the SP-choice binary choices were presented at a time (two levels are compared), and in the A-RP framework one level of quiet/noise is implicitly compared in relation to the other three (linked to real apartment situations). Considering the above confidence intervals for the sample mean value of quiet estimate, the A-RP data is attached with higher accuracy. This may suggest the effect of strategic bias in the parameter estimates in the former case.

Regarding that the CVM sample is very small and analysis used non-linear least squares regression, the WTP values are somehow difficult to compare with the SP-choice values. It shall be noted that the confidence region of the WTP is elliptical, and that the sampling distribution is never known exactly in the non-linear regression case. There is not much point to construct sophisticated confidence intervals for non-linear regression models when the sample size is small (Davidson and Mackinnon 1993).

### 10.3.6 Comparison of values of quiet (point estimates) for realistic changes in the levels

One of the important features of the SP design is that changes in the levels of quiet/noise are attached to real situations (e.g. noise level as you perceive at floor 10 fronting the main road versus the noise levels as you perceive at floor 1 fronting the main road, can be model as equivalent to a change from the upper front floor to a lower front floor). Therefore, in this section realistic noise changes are considered to compare the value estimates derived from the final model specifications. For this purpose the mean change in the ratings is considered in each situation (e.g. mean change for comparisons of upper front with lower front floors, noting that these imply a gain in quiet following the analysis in chapter 6). Following the three model specifications, this analysis is conducted for the SP-choice and WTP models. Bearing in mind that absolute values cannot be compared since the samples have a different number of observations and estimates and have different random errors, the ratio of values is considered. Table 10.4 represents the ratio of situations involving losses in quiet divided by the gains in quiet (e.g. changes from the UF-upper front to LF-lower front floor involve a gain in quiet, this was due to shielding effects of terrain elevations, noise barriers, etc.; a change from the LF to UF involves a loss). This notation was already used throughout this thesis. In Table 10.4 the ratio of values (loss/gain) is represented by the logos of the apartment location changes e.g. (LF-UF)/(UF-LF).

The ratio of the noise levels as represented (losses/gains) takes into account the specific features of the site, and therefore cannot be transferred to other studies.

**Table 10.4: Comparison of Ratios for Average Changes in the Levels of Quiet: Values for Losses divided by Values for Gains.**

| Changes | SP-choice | CVM |
|---|---|---|
| **Back-Front façade** | | |
| (UB-LF)/(UF-UB) | 2.1 | 2.7 |
| (LB-LF)/(LF-LB) | 2.6 | 1.8 |
| **Lower-Upper floors along the same façade** | | |
| (LB-UB)/(UB-LB) | 1.1 | 2.8 |
| (LF-UF)/(UF-LF) | 0.9 | 1.5 |
| **Lower-Upper floors in opposite façades** | | |
| (UB-LF)/(LF-UB) | 3.3 | 1.9 |
| (LB-UF)/(UF-LB) | 1.8 | 2.3 |

Table 10.4 shows that the ratios of value are more dissimilar when changes involve lower/upper floors along the same façade. The SP ratios reflect more the reality since along the same façade the levels are smaller in comparison to those when changes involve moving from one to another façade. The CVM data reflects a close to homogenous pattern since the models had a weaker sensitivity to the size of changes in the levels.

Table 10.5 represents the ratio of the marginal values of quiet for the SP-choice and A-RP (Back divided by Front exposure values) and the average values of quiet for the CVM data (total WTP divided by the average of the sample 18.8). Considering the common model specifications, only the situation involving deteriorations in the levels can be shown.

**Table 10.5: Ratio of Values of Quiet for the SP-choice, A-RP and OE-CVM (Back/Front) for a Situation of Deterioration in the Levels.**

| | | | Ratio of values (Back/Front) |
|---|---|---|---|
| **Base level of quiet** | **SP-choice** | **A-RP** | **OE-CVM** |
| 40 | 1.7 | 1.5 | 1.2 |
| 50 | 1.7 | 1.5 | 1.2 |
| 60 | 1.6 | 1.5 | 1.2 |

Table 10.5 shows that the ratios of value of quiet for a situation involving losses are quite close for the SP-choice and A-RP models. All methods were irresponsive to the base noise levels experienced, since this situation involves a loss. It shall be noted that the SP-choice models were

sensitive to the base levels experienced in the case of improvements. This shows that the respondents located at the back are loss averse and this effect was picked up by the SP-choice and A-RP more markedly.

## 10.4 COMPARISON OF FINDINGS AND VALUES OF QUIET/NOISE WITH OTHER STUDIES

### 10.4.1 Valuation Studies using the Residential Context

This section looks at results from other studies that had compared traffic noise values using different valuation approaches or that used the residential context. These studies were summarised by a set of descriptors in chapter 3. Following the analysis criteria introduced earlier in this chapter, Table 10.6 describes some major findings in comparison with this study.

**Table 10.6: Features of the Valuation Studies on Traffic Noise (Residential Context).**

| Criteria: | **Pommerhene (1988)** | **Vainio (1995)** | **Wardman et al. (1998)** | **This study** |
|---|---|---|---|---|
| Gains versus Losses in Quiet | Only gains | Only gains | Gains and Losses | Gains and Losses |
| Sensitivity to Income | Yes | Yes | Yes | Yes |
| Income Elasticity of Marginal values of Quiet | n.a. | n.a. | * | 0.5 (SP-choice); 0.6 (A-RP) |
| Income Elasticity of WTP values | 0.68** | 0.4 | n.a. | 0.20 (typical value) |
| Sensitivity of Values of Quiet to other segmenting variables | Yes | Yes | * | Yes |

n.a. : not applicable; * not analysed;
**the logarithm of the WTP for a noise reduction was a logarithmic function of income; coefficient estimated (income) was only statistically significant at the 90% level of confidence.

#### 10.4.1.1 Income elasticity of WTP (CVM) and Income elasticity of Marginal Values of Quiet (SP-choice)

Results of the contingent valuation study by Pommerhene (1988) who used familiar locations (known by respondents) and 50% reductions to the base level at the residence, are higher than those found in this study using the OE-CVM data. However, the quality of the scenarios presented for valuation to respondents in Pommerhene's study was superior to the one presented in this study. This is because he did not ask a direct WTP for a noise reduction by 50%, and households were involved in a larger study focusing on environmental problems. The study used familiar locations to respondents in the city of Basle, and these were internally related to a 50% reduction from the situation at each individual's residence. The number of observations was higher (217) than in this study, and the adjusted $R^2$ reported (OLS squares regression) was high (0.613). A weaker income effect is hence expected in this study considering the possible strategic bias.

Vainio (1995) found an income elasticity of WTP of around 0.4, and this is a lower value than in the previous study cited. The WTP models estimated in Vainio's study had an adjusted $R^2$ of 0.10, which is of similar magnitude to this study.

#### 10.4.1.2 Marginal Values of Quiet

This section aims to compute the range of values obtained from the studies reviewed (chapter 3) using a common metric to this study. The comparison of values per unit of rating or dB(A) cannot be established with the Wardman et al.'s study (1998) because the study presented noise to households as percentage changes. Since the population in Edinburgh may perceived % changes differently from the sampled population in Lisbon (the present study) the comparison of values would have needed some validation on the conversion of scales, and on the assessment of the range of influential variables (e.g. noise barriers at the site, continuous traffic levels or not, etc.). The values obtained are indicated as reference for future studies that use a similar metric. In Wardman et al.'s study (1998) the noise variable was initially segmented according to three situations: 1 – Improvements from the current situation ("movement from a worse situation to the current situation"); 2 – Improvements from the current situation ("movement from the current situation to a better situation") and 3 – Improvements from a worse level than current ("movement from a worse than current situation to a better than current situation"). Noise variables 1 and 3 were combined in the final model and, hence, represent Improvements in the levels. The marginal values of quiet were 5.50 pence per % change (Noise variable 1 and 3) and 3.23 pence per week % change (Noise 2 variable). This means the marginal values of quiet (point estimates) were in the range of 12.9 – 17.8 £ per household per month per % change (1996 prices).

The CVM study by Pommerhene (1988) and Soguel (1996) found a value of 75 Swiss Francs and a range 56-95 Swiss Francs respectively for a 10 dB(A) reduction in the levels. This is around 5.5 and 3.8 – 6.5 EUR per dB(A). No variation in prices is allowed for simplifying the comparison. In order to compare this values with the ones derived from this research, it shall be noted that the purchasing parity to country GDP is much higher is Switzerland relative to Portugal (was around 5 times higher in 1988, considering the first study year as reference[1]). Therefore the equivalent range is around 0.73 to 1.3 EUR per dB(A). Following the MNL base models estimated based on physical noise measures (Table 7.7, chapter 7) a range of 89-161 Escudos per dB(A) was obtained (or 0.44 to 0.80 EUR per dB(A)). This seems a convergent result considering the simplified analysis.

Vainio (2001) updated the value estimates obtained in the CVM study (Vainio 1995). The willingness-to-pay for a marginal reduction of traffic noise was FIM 48.9 per dB(A) above Leq 55 dB(A) per household per year (around 0.68 EUR per household per month per dB(A)). Interestingly, the value found by Vainio (1995, 2001) using an urban context is within this study's range. Table 10.7 summarizes the findings.

**Table 10.7: Comparison of Values of Quiet per dB(A), Adjusted for Different Purchasing Power Parities to GDP for the Base Year of the Study.**

| Base SP Models | Average values of quiet (Euros per month per household) |
|---|---|
| **This study (1999)** | 0.4-0.80 |
| **Pommerehene (1988)** | 1.1 |
| **Soguel (1996)** | 0.73-1.3 |
| **Vainio (1995, 2001)** | 0.66 |

Further research needs to be conducted when comparing values derived from studies, but this is only possible through a meta-analysis of studies. This was outside the scope of this thesis.

[1] Purchasing power parities for country GDP: http://www.oecd.org/st/ppp.

### 10.4.2 Estimates from Other Studies on the External Costs of Noise in Portugal

The aim of this section is to assess if the marginal value of quiet estimates obtained are in the range of those found in other studies, focusing on those that produced estimates for Portugal. Comprehensive synthesis of estimates of the external costs of road noise as % of GDP can be found in ECMT (1998) and INFRAS/IWW (2000). Most stated preference studies therein reviewed used the exposed population data (country estimates) to several noise levels expressed within noise exposure bands. Usually a community threshold for noise annoyance is established in each case, such as 55 Leq or 65 dB(A). These estimates are aggregate by nature since they are based on average exposure data and not on the individual's.

The INFRAS/IWW (2000) study estimated a total WTP for noise of 416 Million Euros per year for Portugal. The component due to annoyance represented 68% of the costs and the other part was due to health effects. Considering the population exposure estimate to traffic noise of 4.2 million people (IWW/INFRAS 1995) this would give an average value estimate of 8.3 EUR per month per person exposed. This estimate is bound to be subject to inevitable aggregation errors. Considering the empirical studies reviewed by INFRAS/IWW (2000), the WTP per dB(A) ranged from 0.09% to 0.12% (share of per capita income). Taking as reference value the GDP/capita for Portugal of 7829 EUR in base study (INFRAS/IWW 1995) and the population exposed to road noise of 4.2 million people, this would give a range of 1.7 - 2.2 EUR per person exposed per dB(A) above 55 Leq dB(A). This estimate is bound to be subject to inevitable aggregation errors and uncertainties but since it considers the health effects of traffic noise it seems plausible the higher value in comparison to the present study.

Considering the SP-choice models estimated in chapter 7, a range of values can be obtained for a typical household facing realistic changes (household living in a lower floor level below four for less than five years and adjusted income per person of 90000 Escudos per month (sample mean), and payment of an average housing service charge of 7500 Escudos per month): this would give a marginal value of quiet in the range of 281- 529 Escudos per dB(A) or 1.5 to 2.6 EUR per dB(A) per household. This is a convergent finding to the range found previously (1.7 – 2.2 EUR per person exposed per dB(A) above Leq dB(A)). It shall be noted that the empirical value estimates reviewed by INFRAS/IWW (2000) were based on WTP values (Contingent Valuation).

## 10.5 CONCLUSIONS

The closeness of the income elasticity of the marginal values of quiet derived from the SP-choice and A-RP data, 0.5 and 0.6 respectively, as well as the convergence of ratios in influential situations (back/front exposures) seems to indicate some important convergent findings. The CVM sample was much smaller, and a weak income effect was picked up.

One interesting finding is that the average values of view and sunlight are close for both the SP and A-RP models, and the main difference was on the value of quiet. Considering theoretical expectations, this suggests the influence of potential biases such as strategic bias in the value estimates. To this hand, both experimental markets (SP-choice and OE-CVM) may be affected (values of quiet may be biased upwards), but the effect is prone to be higher in the second case as respondents were focusing only on one attribute (noise).

Overall, the A-RP random utility framework of housing purchases at the local level seemed to work well to represent absolute valuations for the attributes. The SP-choice models had the major advantage of examining more variation in the levels and hence had picked up several other influential variables besides income whose effects were theoretically plausible and confirmed *a priori* expectations. This means the SP-choice models converged to the central objective of this study that was to assess the heterogeneity of householders' preferences for quiet. On the other hand, the A-RP estimates are free from any effect of strategic bias. This suggests that combined models A-RP and SP may be recommended as an important issue to explore for further research.

# CHAPTER 11: CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

## 11.1 SUMMARY OF RESEARCH

This chapter aims to provide a synthesis of the research and findings of the work presented in the previous ten chapters. As outlined in chapter 1, this research study was motivated by the need for valuing environmental externalities from road transport (CEC 1995; ECMT 1998). Chapter 2 reviewed the theory and methods for valuing environmental externalities from road transport, and the use of stated preference techniques was seen as an appropriate method to value changes in quiet/noise that have not yet occurred (e.g. as a result of a proposed transport infrastructure). In chapter 3, previous valuation studies that used stated preferences techniques for valuing traffic noise externalities were reviewed. In chapter 4, the development of the computer survey was presented as a result of findings from chapter 2 and 3, as well as receiving other additional contributions from Psychoacoustics and Psychophysics and acoustical noise surveys of community reactions to traffic noise. The context set for valuing noise was indoors (at the home). Considering the features of the housing market segment in Lisbon, lower and upper floors and their exposure to road traffic (fronting the main road or located at the back façade) played a central role in the experimental design. This provides variations in the levels of noise that are realistic. In chapter 5, the data collection methodology was presented as integrating various steps: previous information sent to the sampled population, personal assisted computer interviews at each apartment, noise measurements at the apartment (indoors and outdoors) and characterisation of the study area in terms of traffic and noise levels.

Chapters 6 to 9 provide the results of the data analysis and modelling work. Chapter 6 focused on the analysis of the situational, socio-economic, behavioural and attitudinal data. This was an important step to inform the modelling work conducted in subsequent chapters, as well as to inform future studies that aimed to compare values using a similar context. Chapter 7 reports an extensive analysis of the stated preference-choice data and multinomial logit models with interaction terms as well as combined with random parameters' specifications (mixed logit). Chapter 8 considers the same sample of householders, and provides the results of modelling the revealed preference data in two situations (apartment purchases *ex ante* and *ex post*). Chapter 9 provides the analysis of the Open-Ended Contingent Valuation data. In chapter 10, the issue of convergent validity of noise value estimates and related findings are discussed, having as their basis the main research principles in relation to theory and *a priori* expectations that guided the analysis in chapters 7 to 9. Finally this chapter concludes by reporting the findings and directions for further research.

The remainder of this chapter is organized as follows. Section 11.2 discusses issues identified in developing the research. Section 11.3 presents the main findings of the research study and their implications. For this purpose, the main objectives of the research outlined in chapter 1 (section 1.4) are considered. Section 11.4 provides some ideas for further research and experimental work.

## 11.2 RESEARCH FINDINGS FROM A STEP-BY-STEP APPROACH

### 11.2.1 The Estimation of Marginal Values of Quiet

The estimation of marginal values of quiet/noise was found to be important to serve as an input in cost-benefit analysis of transport infrastructures, especially in metropolitan areas such as Lisbon with high development pressures. Other justifications of the research interest include the need to consider people's preferences at the community level, environmental impact assessment, inform transport and environmental policy decisions and environmental damage compensation.

A relevant body of research projects conducted at the European level used state of the art noise values to derive the external costs of transport. As an example, the mentioned European Commission project QUITS- Quality Indicators for Transport Systems (EC 1998) reported to have used the values by Hansson (1985) taken from the INFRAS/IWW (1995) study. The reference values were said to be chosen because they were an "European mean of current assessments", and included noise costs per person exposed for each class of noise exposure (e.g. for a 55-60 Leq dB(A) exposure this was 61.85 ECU/year). As a "methodological good practice" the ECMT (1998) study recommended to use more than one valuation method to generate lower and upper bound estimates. For valuing noise nuisance, it was referred that "stated preference could be regarded as an indicator of what is desirable and avoidance programs as a minimum measure of what is feasible".

In Portugal, no noise value estimates had been derived before using individuals' preferences. This study is a contribution in trying to fill this gap, but efforts need to be conducted by Government on funding more experimental research in this domain. This study is the former one to valuing noise at the local level using the stated preference-choice method.

### 11.2.2 Stated and Revealed Preference Methods

Although the theory, methods and practice of economic valuation are well established for environmental goods and services, there is not yet an agreement on the best approach to follow to valuing traffic noise (chapter 2). Using stated preference methods, individual's preferences for quiet can be assessed not only for the current situation, but also for proposed environmental changes (not yet implemented as a result of some policy action). By setting an adequate experimental design the levels of the environmental attributes can be varied in the desired range. This is a major advantage of the stated preference technique in comparison to the revealed preference approach. Revealed preference methods do not necessarily reflect individuals' actual preferences in all circumstances, and behaviour is conditioned on available alternatives. Bearing in mind that stated preference-choice experiments are resource intensive, other valuation approaches were explored as alternative approaches in specific situations. In this study the revealed preference data on housing purchases and the open-ended contingent valuation methods were applied.

### 11.2.3 Existing Noise Valuation Studies

Existing valuation studies on traffic noise used different methodologies and were conducted in different contexts and had varying features considering the set of descriptors outlined (chapter 3). Results of these studies seemed to be related to some extent to the type of elicitation format used and presentation of the good (bad) being valued in each context. Contingent Valuation studies that explored respondents' experience with current noise levels and used 50% noise changes from the current situation (Pommerhene 1988; Soguel 1996; Navrud 2000) had performed better than others using alternative presentation means, because the WTP was sensitive to household income and other segmenting socio-economic variables. One advantage is that a 50% noise change is physically equivalent to a 10 dB(A) change, and a link can be directly established between values of noise per percentage change and dB(A). The contingent valuation studies had a lower number of observations than the

Stated Preference-choice experiments, and this affects the robustness of the models in comparative terms.

From the SP-choice experiments it seemed clear that the most effective means of presenting noise to respondents is far from being established. Some studies have explored more than one presentation format (Nelson 1998; Wardman et al. 1998). Results of Wardman et al. (1998) suggested that presentations as percentage changes can be difficult to understand. On the other hand, the use of familiar location descriptions in relation to the actual and perceived levels seemed to have worked well. The study recommended further research on the link between the presentation of the noise metric and the physical noise measures, by setting the appropriate SP design in relation to the choice context devised to simulate the "market for noise". If respondents cannot understand the "environmental good" they are supposed to choose (and implicitly to purchase) they cannot value it without a large random error.

Few studies had been concerned with the convergent validity of the noise estimates using the same sample of respondents. This is an important issue that needs to be addressed, since most studies were only concerned with the application of a sole method.

The noise valuation studies showed that valuing traffic noise is not a simple economic problem of deriving the marginal values of quiet. This is because noise is not only a simple physical stimuli restricted to a quantity but a sensory perception of an environmental bad. Further insights from other scientific areas that have quiet/noise as an object of study need to be gathered into the discussion in order to contribute to the most appropriate experimental design.

### 11.2.4 Development of the Survey

Since individuals experience traffic noise in a variety of contexts, each specific context shall define the boundaries of the experimental market. In this study, the context set was the residential environment, when individuals are in their homes (apartments). The development of the survey (chapter 4) received contributions from psychoacoustics and psychophysics and community reactions' studies to traffic noise. The analysis showed the following:

- Psychologically the meaning of "noise" for one individual may differ from another, depending on other various non-acoustical factors (not related to the physical characteristics of the sound). This is because sound is mainly a "sensory perception" in which context, experience, relationships (e.g. between stimuli), judgment, meaning, and memory play a role (Schiffman 1996);

- Physically, noise is measured on a logarithmic scale and reflects a variation of sound pressure levels relative to the sound pressure level that corresponds to the threshold of hearing;
- Sounds are perceived as "noise" if they interfere with individual's well-being and quality of life; therefore, noise is an "unwanted sound" that depends on each individual's perspective;
- Our hearing system is non-linear with regard to the physical intensity of sound; the minimum perceived change in intensity of a sound is between 1 to 2 dB, changes of 3 dB are clearly noticeable in real life, and a change of 10 dB corresponds to a doubling of loudness;
- Shepard's theory (Shepard 1981) states that it is primarily the relationship between stimuli and not the magnitude themselves that are perceived by the individuals. This theory provided an interesting base from which to explore changes in the levels (as perceived or measured) from a specific reference level;
- According to the psychological analysis of value, the use of reference values was supported by several psychological theories such as the reference dependence and adaptation level theories. This directed the interest to exploring the effect of the level of noise experienced at each situation (apartment);
- The literature in environmental, experimental economics and marketing supports the test of the theory of reference dependence preferences (Hogarth and Reder 1986; Hartman et al. 1991; Bateman et al. 1997; Bell and Lattin 2000). This motivated the interest in finding out how householders value noise improvements (gains) versus noise deteriorations (losses);
- Studies on community reactions to traffic noise provided information of the range of factors that could affect individual's response to road traffic noise: household income, length of residence, behavioural actions, position of room to the noisier side of the house, shielding effects, changes in traffic noise exposure and others; these were important variables to include in the design of the survey.

The SP experimental design explored respondent's experience with the levels of environmental attributes experienced at the current apartment (view, noise, sunlight) as well as in other apartment situations in the same block (lot) exposed at fronting and at the back façades and different floor levels. The variables were presented as those perceived by the respondent e.g. "noise as" (you perceive at apartment) "10T" ("T" means at the back). Since all the attributes including the payment vehicle (housing service charge) were familiar to the respondent, this conveyed a great level of realism in the SP experiment. This was expected to minimize the hypothetical bias. Whereas the use of respondent's perceptions is not new in choice experiments, the link of the "perceived stimuli" with apartment situations fronting the main road and at the quieter façade and with lower-upper floors was novel in simulating a real market experiment of apartment (attributes) purchases. Following the survey structure, a wide range of variables related to the situation of each household, socio-economic, attitudinal and behavioural variables were collected. The use of a computer survey proved to be successful when dealing with this more complex survey design.

### 11.2.5 Implementation of the Survey and Data Collection

Computer aided personal interviews (CAPI) at the residence had a high acceptability by households. Considering that this type of survey was novel in Lisbon some difficulties arose in finding interviewers that were familiar with the use of computers for surveying.

The data collection was conducted in several steps and this showed to be time (cost) intensive. Since there was a preoccupation of gathering high quality data, qualified acoustic and traffic technicians of the LNEC were employed for the noise data collection. The CAPIs were the most time consuming part. The duration of each interview was between 30 to 45 minutes. The questionnaire was quite extensive and demanded time from the respondent to think. Many households commented that this survey required them to think a lot. Future valuation studies may benefit of having a reduced extension of the questionnaire by selecting the key influential variables on the marginal values of quiet, or by trying to use mixed methods to improve efficiency (e.g. shorter CAPI at the home complemented by a mail or telephone survey).

The pilot study conducted prior to the main survey proved to be an effective means of testing the computer survey and to support necessary adjustments, namely to the levels of housing service charge. The open-ended Contingent Valuation Method was not so well accepted by the households as it generated some uncertainty with the (omitted) payment vehicle and protest zeros. This was expected considering other findings from previous studies (Vainio 1995; Bateman et al. 1995). Nevertheless, this question was kept on the basis of testing the new frame of the WTP questions based on individual's perceptions of the levels of noise in the same apartment situations as in the SP experiment. The pilot study helped to assess directly individual's reactions, the use of simulation tests could have helped to establish the acceptable range of values if there were previous reference values of quiet on the context. That was not the case. Future valuation studies in Lisbon may benefit by conducting simulation tests covering the range of values obtained in this study and test the adequacy of the statistical design. However, it is recommended to conduct a pilot study in order to verify if the questions are understood by individuals and can assess their impressions and acceptability of the overall survey.

## 11.3 MAIN FINDINGS FOLLOWING RESEARCH OBJECTIVES

The central objective of this study was to develop a methodology to obtain monetary valuations of traffic noise externalities in the residential environment, based on stated preference-choice methods (choice experiments). For this purpose, the plan was set to use individual's perceptions of the levels and the equivalent physical noise measures in Leq dB(A). It was also envisaged to derive marginal cost estimates attached to environmental gains and losses in quiet, and to consider the wide range of behavioural, attitudinal and contextual variables besides the characteristics of the respondent (i.e. to model heterogeneity of preferences for quiet). Moreover, it was aimed to use other valuation approaches using estimates for the same sample of respondents in order to address the issue of convergent validity of noise value estimates. As other approaches, this study used the open-ended contingent valuation method and the revealed preference of housing purchases made *ex ante* (some time before the CAPI was conducted) and the preferred apartment choice "now" (*ex post* situation after experience of the environment indoors) considering the same apartment alternatives at the *ex ante* situation.

### 11.3.1 Location Choice Factors in the *Ex Ante* Situation

Location choice factors were assessed at the level of the residential area and the building (apartment location). Proximity to work, price of apartment, neighbourhood quality, quiet and housing quality were the three most important factors stated for choice of the residential area. These five factors were ranked as the most important factors by around 31%, 21%, 12%, 11% and 11% respectively by the sample of respondents. Quiet was referred to by 25.5% of the respondents as first and second most important factors for having chosen the residential area. At the level of the block/lot "less noise from road traffic" was only ranked by 2.9% and 5.7% of the households as the most important factor. Price of flat, availability, number of rooms, sunlight and view were the factors ranked first by a higher percentage of households, 31%, 14%, 12%, 16.5% and 10% respectively. The importance ranking of the attribute quiet seems to have changed. This finding is in line with the fact that householders when they did purchase the apartments did not experience the levels of noise indoors (they visited an apartment model in the study area located elsewhere, probably over the weekend), and therefore "quiet" was an attribute perceived at the level of residential area (outdoors) and not indoors. This explains why "less noise from road traffic" was only ranked first by a small percentage of households. On the other hand, the household budget constraints and availability of apartment alternatives had a higher influence in households' decisions to buy the apartment. Sunlight and view seemed to be more important than "less noise from road traffic" as a location choice factor, and this suggests that the sensory experience of these attributes does not require the same level of experience. This point needs further research. Overall, the more importance of view and sunlight in urban locations is in line with current published information by the estate agents. It was noted that most apartments were bought some time ago. Overall, 196 households (47.6% of the sample) reported to be living in the apartments for more than 5 years, and only 10.2% for less than or equal to one year. Therefore, it is expected that householders already experienced indoors the negative impacts of traffic noise.

### 11.3.2 Location Choice Factors if Choice was "Now" (*Ex Post* Situation)

During the survey householders were told to consider that the same apartment choice that led to the current observed apartment choice were available to purchase, and for them to reveal the choice "now" (i.e. if this were to happen at the moment the survey was conducted). It was found that the majority of households (70%) would choose now the same apartment as in the *ex ante* situation. From the households who would have shifted their positions, 41% would do it mainly in order to have a better view, 15% to have a greater number of rooms, 26% to have less noise from road traffic and 11% in order to have more sunlight. This finding indicates a moderate change of preferences for quiet since most households seemed to be attached to the current apartment. This may be due to the fact that households had associated this question to moving costs, and since they would remain in the same block (lot) the hassle of moving may not be considered worthwhile. On the other hand it was shown in chapter 4 that "home" is both a physical place and a cognitive concept, and thus not only the physical characteristics of the place play a role in individuals' minds (Tognoli 1987). The research would have benefited if another follow-up question could have been asked for those who remained with the same apartment, by asking if they would like to change some features of it (e.g. window types, etc.) and why.

### 11.3.3 Situational, Socio-Economic, Attitudinal and Behavioural Variables

One of the central objectives of this study was to assess the nature and extent of heterogeneity in preferences for quiet when indoors. For this purpose a wide range of variables was collected related to the noise environment (indoors and outdoors) and the household. In chapter 6 the main descriptors of the sample of respondents and their respective context were comprehensively analysed. In the study area, 90% of the surveyed building locations exceeded the 55 Leq dB(A) noise standard set by the Portuguese Noise Regulatory Framework. Following the WHO guidelines for noise, it can be expected that individuals will be seriously annoyed during daytime and evening (Berglund et al. 1999). The impact of existing noise barriers at the site was not significant for upper floors (four and above) as demonstrated by the measurements taken at each floor.

The noise measurements indoors showed that 59% of the cases (total number of measurements was 243) have noise levels indoors greater than 35 dB(A). The WHO guideline values for dwelling indoors are between 30 to 35 dB(A), a threshold for moderate annoyance and speech intelligibility during the daytime and evening period.

The sample had more females (64.2%) than males (37.6%), and gender was correlated with the number of hours spent at home. Around 45% of the respondents were University graduates and this may also have explained why the computer survey was well accepted. Low income households are under-represented (less than 245 x $10^3$ Escudos per month per household). It was noted that the Lisbon Metropolitan area (LMA) has higher socio-economic indicators than the country average. The purchasing power index is 155 for the LMA whereas this value is 100 for the whole country. On the other hand, considering the 18 councils that comprise the LMA, Lisbon residents have a purchase power index around four times the average (INE 2000). Therefore, the marginal values of quiet obtained in this study are expected to be higher than in other locations.

Around 49% of the households surveyed were living in upper floors (four and above) and 51% in lower floors. Considering the sampling strategy, one of the objectives was to have a similar proportion of households in each situation. Considering that the buildings surveyed were all in the vicinity of the main roads, the effect of distance to road is highly correlated with floor number and exposure (fronting the main road or at the back façades). The independent samples t-test showed that respondents perceived upper floors as noisier than lower ones in terms of the mean perceived levels. This fact was in agreement with the real mean variation in Leq dB(A). This is consistent with the topography and features of the study area such as noise barriers, terrain elevations, possible effect of reflections to more complex design of buildings, etc.

The majority of the households (71%) stated that they stay usually in the sitting room during the reference day noise period (7am-10pm). This confirms the importance of the exposure of this room to the main road. The general flat exposure considered in this study used the exposure of the sitting room and bedroom of the respondent. If one of these rooms were exposed to fronting the main road, then the flat was classified as fronting the main road. 25% of the households have conducted some noise averting measure indoors, whereas the majority did not.

The correlation between respondents' perceptions and the physical noise measures was higher when using relative measures. This confirmed expectations from the relation theory (Shepard 1981). Results showed that correlations between ratings and physical noise measures were lower when changes were along the same façade of the current apartment (difference in the levels between the current apartment and other extreme floor). This may be explained by other confounding factors such as noise averting behaviour in upper floors, existence of noise barriers or terrain elevations affecting the lower floors, etc. The higher correlation between relative ratings and the physical noise measures occurred when changes involved a change of façade (front ↔ back) in the same floor. This was expected considering the greater physical variation in the levels, and also because respondents may be more familiar with the situation of their nearest neighbours. The final model estimated relating the physical energy and the subjective experience was found to be non-linear. The same difference in noise levels, for example, 10 dB(A) would give an average rating value of 19.98 or 25.25 if this change corresponds to a gain or loss respectively. The interest on having derived this relationship resides on the possibility of using a simple model for the initial impact analysis of future residential developments in the context. Whereas individuals' ratings are impossible to know at the planning stage of any development since the population is unknown, the physical noise measures can be easily available through direct measurements or using predictive models. The marginal values expressed per unit of perceived ratings can then be converted to average changes in dB(A), assuming the future population has the same characteristics.

Noise ratings for the current situation were assessed at the end of the questionnaire using a 5 point rating scale for the day (7am-10pm) and night reference noise periods (10pm-7am). The reference day noise period was considered noisier than the night (10pm-7am). This may be explained by situational factors: commuters use main roads in the vicinity of the residential area during am and pm, and traffic levels are substantially lower during the night (Appendix 2). The noise ratings during the day and night were highly correlated with the levels of annoyance during the day and night respectively. Further research is needed on relating annoyance levels with noise ratings using alternative scales.

### 11.3.4 Modelling Householder's Heterogeneity of Preferences for Quiet Indoors using Perceptions (Ratings) and the Physical Noise Measures: the SP-choice Data

A wide range of variables collected was tested as possible influential variables in the marginal values of quiet (chapter 7). The noise variable was expressed using respondent's perceptions (ratings) and also the physical noise measures indoors. Results showed that the models based on perceptions outperformed those based on physical noise measures. Models using the physical noise measures outdoors were not satisfactory. This means that the outdoor noise environment cannot be a proxy for the noise levels as heard indoors. Since the SP-choice experiment was driven by respondents' perceptions of qualitative housing attributes, this result was expected. In the models based on perceptions, the range of effects that were found to have a significant influence on the marginal values of quiet were: a) general flat exposure (fronting the main road or at the back); b) sign of changes (deteriorations versus improvements in the levels); c) base noise level experienced; d) number of years living at the apartment; e) gender; f) less familiarity to choice context (lot); g) adjusted household income per person; h) floor number (upper floors greater than 4), and i) current housing service charge payment. Results seemed theoretically plausible. It was shown that the value of quiet function is symmetric (deteriorations in quiet are valued higher than improvements). The function is steeper if the household is fronting the main road than if he is at the back façade. This is a convergent finding to the reference-dependence theory (Tversky and Kahneman 1991). According to this theory losses have a greater impact on individuals' preferences than the same gains (size), gains and losses are defined as relative to a reference level and the marginal values of changes (gains and losses) decrease with their size (diminishing sensitivity). Considering realistic changes in the levels across different positions in the apartment (e.g. upper front to upper back), results showed that on average losses were valued between 2 to 3.7 times higher than gains in quiet.

The models based on physical noise measures indoors have captured some of the most influential variables, but it was not sensitive to the base noise level experienced. This finding pointed out the importance of non-acoustical factors besides the physical noise measures in explaining preferences for quiet.

Since the model based on perceptions performed better than the physical noise measures, being the former more sensitive to a higher number of variables, the mixed logit specifications were only made for the former case. Mixed logit specifications provided a better fit with the data when comparing to the standard multinomial logit with interaction terms. The observed heterogeneity (influential factors on quiet) were allowed to vary randomly over each household. These models aimed to provide a better understanding of the unobserved influences that may interact with observed influential variables. Households' observed taste variation was associated to a statistically significant random variation in the case of the following interaction effects with quiet: a) households located at the back façade; b) number of years living at the site; c) less familiarity to the choice context; d) gender. On the other hand, the random variation for the other environmental variables (view, sunlight) was statistically significant pointing out the importance of householders' taste variation for these attributes. The use of random parameters specifications showed to give information on the magnitude of household's taste variation for these variables.

The modelling work was novel in considering householders' heterogeneity (nature and extent) of preferences on the marginal valuations of traffic noise using combined model model specifications with random parameters.

### 11.3.5 Marginal Values of Quiet: the SP-choice Data

The values reported here consider the real changes in the levels as perceived and measured (mean values) across different situation in the SP experimental design (i.e. mean changes from upper front floors to lower front floors, etc., Table 7.16 in chapter 7). Considering a typical male householder living in a lower floor (below floor level four), and with an adjusted household income per person of $60 \times 10^3$ (sample mode was a closer value, $63 \times 10^3$), a one unit perceived loss (gain) in quiet was valued in the range 671 (403) to 1145 (1052) Escudos per month per household (1999 prices). Considering the Euro equivalence (1Euro=200.084 Escudos), the above values are 3.3 (2.0) to 5.7 (5.3) Euros per exposed household per month respectively. For the same household, one dB(A) increase (decrease) was valued on average between 277 (197) to 451 (370) Escudos per month (or between 1.38 (0.98) to 2.25 (1.85) Euros per dB(A) per month).

The above results show that on average, a one unit perceived gain (loss) as rated was found equivalent to 2.9 (2.7) dB(A) respectively. This is an interesting finding since the human perception threshold is usually taken as 2 dB(A).

The income elasticity of marginal values of quiet was 0.5. This finding seems to be in line with the income elasticity found for other non-market goods such as the value of time (Wardman 2002), as well with other evidence on other environmental goods (Morey et al. 1993; Hökby and Söderqvist 2001). This issue needs further research.

The values obtained from mixed logit modelling were lower than those found in previous models (multinomial logit with interaction terms allowing for repeated observations) for households fronting the main road (range of 10% - 40% lower), and around 70% higher for households located at the back if the situation involves an improvement (from upper back to lower back) and only 2% higher if the household was at the back but facing a loss (e.g. changes in the levels from upper back to upper front or upper back to lower front floors). The higher value for households facing a change in the levels from upper back to lower back floors seemed to have picked up possible situational features of the site (noise barriers implemented as well as noise barriers that affect lower floors – quieter). Since the mixed logit model results penalize on average substantially a typical household located at the back facing noise changes as in lower floors, results from the standard multinomial logit model with interaction effects may be more acceptable from the policy point of view.

### 11.3.6 Policy and Planning Implications: SP-choice models

Results showed the importance of the quieter (back) façade of the building on the marginal values of quiet. This means households located at the quieter façade are willing to pay more for the same level of quiet than those fronting the main road (or that because they have higher preferences for quiet they decide to locate back to the road). Therefore, developers should take this into consideration when planning the buildings' layout. One mitigation noise measure is as simple as increasing the surface of the block exposed to the back and minimize its exposure to traffic noise (perpendicular dispositions to main road instead of parallel). On the other side the locations of rooms (sitting room and bedrooms) shall be placed at the back, whereas other rooms (less used) can be placed fronting the main road. On the other hand, if householders located at the back have a higher value of quiet they are willing to pay higher housing service charges, and this needs to be explored.

In terms of input to cost-benefit analysis, the marginal values derived from this study may be higher than the average and adjustments are necessary to be made considering the characteristics of the population exposed. Nevertheless, the marginal values were sensitive to a wide range of variables, and this helps to build a more democratic process of assessing benefits and costs at the community level.

Considering the average adjusted household income per person was 93.1 $x10^3$ thousand escudos per month (464.8 Euros per month), and the mean change in the levels as perceived (measured) of 18.8 (5.7 Leq dB(A)), and average monthly payment of housing service charge of 7500 Escudos per month, some marginal values can be derived for several types of households considering the influential variables (Table 7.3, chapter 7):

- for a male respondent/household living in a lower floor fronting the main road and experiencing a base level (ratings) in the range of 20 to 70, and facing an improvement or deterioration in the levels of 18.8, the marginal values of quiet are in the range of 2.7 to 3.3 and 4.2 to 4.8 Euros per household per month respectively;
- the same respondent/household living in upper floors, the marginal values of quiet for the same gain and loss in quiet are in the range 4.7 to 4.1 and 5.6 to 6.2 Euros per household per month respectively;
- the same respondent/household located in a lower floor at the back façade, the marginal values of quiet for the same gain and loss in quiet are in the range of 6.3 to 5.7 and 7.2 to 7.8 Euros per month respectively;
- the same respondent/household located in a upper floor at the back façade, the marginal values of quiet are in the range of 7.7 to 7.1 and 8.6 to 9.2 respectively.

These values are in units of perceived noise changes. For cost-benefit analysis purposes, the equivalence of 2.9 (2.7) dB(A) for a gain (loss) respectively can be used.

### 11.3.7 Alternative Approaches for Valuing Quiet: the Revealed Preference Techniques

Considering the literature reviewed on housing decisions using discrete choice analysis, this modelling work was the first to derive marginal values of quiet (noise) using the RP data on observed apartment characteristics at the micro level, considering as the unit of analysis the same block (or lot) of the household. In the *ex post* situation (i.e. at the moment where the survey was conducted) qualitative attributes had already been fully experienced indoors.

The revealed preference approach based on housing purchases seemed to be internally consistent considering the characteristics of the housing market and location choice factors that had been said to explain householders' locations in the building (lot). The analysis showed that data on the underlying factors that had explained householder's true choices is a necessary condition for the internal validity of noise values estimates. The housing choice may have been taken some time ago, therefore location choice factors *ex ante* and *ex post* need to be assessed prior to valuations, and if possible to control for other possible influential variables: household income and number of members, sudden traffic changes, implementation of noise barriers, etc.

The marginal values of quiet obtained from the A-RP *ex post* models were lower than the SP-choice values. Whereas the RP data does involve offering existing alternatives, the SP experiment (repeated choices as combinations of attributes) may dilute the effects of attachment to the status quo, and it is not subject to availability constraints. The income elasticity of marginal values of quiet was found to be a close to that found in the SP of 0.6. This was a convergent result. On the other hand, strategic bias may have influenced the experimental market. Households may though they could influence policy responses in improving the environmental situation in the area, since the LNEC is the main research organization in the country dependent upon the Ministry of Transport.

Considering the much smaller RP sample (12 times smaller than the SP), the range of effects on marginal values captured was much lower: a) income effects and b) general flat exposure. The marginal value of quiet was 118 Escudos per household per month for the sample average. The marginal values of quiet for an household located at fronting (back) the main road were 74.3 (109.9) for an adjusted household income per person of 90000 Escudos per month (sample average).

### 11.3.8 Alternative Approaches for Valuing Quiet: the Open-ended Contingent Valuation

The WTP models based on respondents' perceptions of the levels in the same apartment locations as in the SP experiment were estimated using NLLS regression. Considering the environmental valuation literature this was a novel application. Non-linear functional forms were used in order to test the reference-dependent theory, namely to verify diminishing sensitivity with size of gains and losses in quiet.

The open-ended CVM questions were framed considering respondents' perceptions of the levels of noise indoors in situations as presented during the SP experiment. Results showed that the WTP models based on respondents' perceptions of the levels outperformed in a great extent the WTP models based on the implicit physical noise measures. In the former case, all the parameters had the right expected sign, and the stated bids were sensitive to changes in the levels of quiet from the status quo, base noise level experienced (WTP for gains), general flat exposure to main road (WTP for losses) and the adjusted household income per person, although the effect of the last variable was very weak- a feature of other CV studies. The WTP values were theoretically plausible. The WTP values were higher for bigger improvements and deteriorations but at a decreasing rate. This indicated a diminishing marginal sensitivity of WTP with size of gains (losses) as expected from the reference-dependence theory. Nevertheless, the WTP values were less sensitive to differences in perceptions (as rated) and to the levels experienced at the current situation in comparison with the SP-choice models. This is a shortcoming.

Considering two changes in the ratings of 10 and 20, and an adjusted household income per person of 60 $x10^3$ Escudos per month the average WTP per unit for an household facing a gain in quiet is 127.1 (71.7) Escudos per month per household (if the base level experienced was rated greater than 65). This is equivalent to 0.64 (0.36) Euro per household per month. The correspondent WTP in a situation involving a loss is respectively 450.6 (280.7) Escudos per month per household, or 2.25 (1.4) Euro per month per household. The values indicate diminishing marginal sensitivity with both size of gains and losses, and confirm expectations from the reference-dependence theory.

The WTP models based on the true physical noise measures were not sensitive to any explanatory variable. A major explanation for this result may be encountered by the novel frame of reference of the WTP questions that have considered respondents' experience and familiarity using rated situations (as perceived and not measured). Households seemed to respond to the WTP questions using rounded payments. These money values may be those currently used in some frequent monthly payments, but this requires further investigation. Whereas the data on perceptions can handle attitudinal behaviour, the same does not occur with the true physical noise measures.

One of the expected drawbacks of the OE CV elicitation format in generating a considerable number of protest answers was confirmed (34% and 37%, Table 9.1 in chapter 9). Protest zeros bias the sample (sample section bias), since these observations are not considered in the analysis. The use of follow-up questions to respondents in this situation could have served to identify those respondents with positive WTP for quiet (Morrison et al. 2000). The number of protest zeros is believed to be associated with the issue of property rights. As the sample integrated individuals with higher education levels (Chapter 6), most were aware of the "Portuguese Republic Constitution" and felt they had the right for a better environment and that this issue should be in the government's agenda (therefore provision of quiet was believed not to be the households' responsibility). Overall, the WTP questions had a much lower acceptability than the SP-choice part in the main survey.

### 11.3.9 Convergent Validity of Noise Values Considering the Same Sample of Respondents

The SP-values and A-RP values seemed to converge in the case of view and sunlight, but not on quiet. This may be explained by the higher random variation (observed and unobserved) that interact with people's preferences for quiet when indoors. The SP-choice models picked up various influential variables, but since the A-RP sample was much smaller only the income and exposure effects were found significant. This may also indicate that during the SP-choice experiment respondents were looking for the same view and sunlight attributes (as in the RP data) but with less noise. Since the experiment offered combinations of attributes in binary alternatives (and not apartments as in the RP), this may have helped respondents to enter easily in the experimental market as they felt it a natural process. However, it shall be noticed that all interviews were conducted at the home of the resident and he/she had time to think. This was a novel feature that increased the duration of each interview. Most respondents behaved in the experiment as a serious task, and quality of responses in terms of consistency was high.

The average WTP values were lower than in the SP-choice experiment. This may be due to sample selection bias (deletion of protest zeros and a much smaller number of observations) and to the type of elicitation format. Since the payment vehicle was omitted and the WTP questions were placed after the SP-choice experiment, respondents may have felt confused with the nature of the question. This explains the uncertainty generated around the bid values. As already referred, the bids seemed to be clustered around round values and these may be familiar payments used on a monthly basis by the respondent. The test of this hypothesis requires further research. The income sensitivity of the WTP values was lower than in the SP or RP data. For example, considering the same noise change in ratings (20), if the household income doubles from 30 to 60 thousand Escudos per month the average value of quiet increases around 21%. This seems to be a lower value than expected. Income elasticities of WTP values for other environmental goods (environmentally friendly car, reducing eutrophication effects in the Baltic sea, preserve forest in Sweden etc.) were found of similar magnitude (Hökby and Söderqvist 2001). Following Vainio (1995) who also found an income elasticity of 0.4 a higher value was expected but less than one (Kriström and Riera 1996). In this study, the SP and RP income elasticity of marginal values of quiet converged, respectively to 0.5 and 0.6. As already referred, some strategic bias may be present in the SP-sample, although it is difficult to confirm this supposition.

The range of SP values' estimates were within the range of values found in other studies (INFRAS/IWW 2000). Regarding the ratio of the SP values over the RP values, the former were found consistently higher, considering the features of the housing market and interfering bias in the experimental market (e.g. strategic bias, hypothetical bias). Existing studies are not conclusive in the magnitude of the ratio. Pommerehene's (1988) study found that the WTP values were in practice theoretically consistently lower than those derived from the hedonic pricing, in Vainio's study in 1995 the CV value estimates were 2-3 times higher that the HP, but these were said to be consistent with interfering biases and other features of the study. The issue of convergent validity of noise value estimates using the same sample of respondents requires further research.

From the point of view of acceptability, the SP-choice experiment had generated some more interest in the sampled population, whereas the OE-CVM questions were less acceptable. However, it shall be noted that in the former case they did not know that that was an experimental market for valuing noise, and therefore an additional option (neither A or B) seems to increase the fairness in the decision making not to raise ethical questions. Overall, values from the SP-choice models showed that householders' preferences vary according to several influential variables, and thus the assumption of homogeneity of preferences for the same good (e.g. same level of quiet/noise) does not apply.

## 11.4 DIRECTIONS FOR FURTHER RESEARCH

### 11.4.1 Design of SP-choice Experiments

This research found that using respondents' perceptions of the levels experienced at the current situation and at familiar locations worked well. Because of particular features of the study area already cited, the relative perceptions along the same façade had a lower correlation with the relative physical noise measures. Therefore the physical variation in noise levels along the same façade of the respondent (e.g. between extreme floors) is lower than in the other situations involving a change from front to back façade or vice-versa. The actual SP design did not account for this situation. Therefore, the design did not explore the maximum physical noise variations in the site as aimed. Hence, other simpler SP experimental designs involving changes between front and back façade seem to be more worthwhile to explore, since relative perceptions had a higher correlation with the relative noise measurements, and the effect of confounding factors along the same façade is controlled for.

Considering the data collection, respondents were comfortable choosing alternatives as presented (binary choice situations at a time). Nevertheless, the effect the introduction of a "non-choice" option or "neither A or B" needs to be tested in the future. This stems from the fact that respondents when answering the CVM questions had a considerable number of protest zeros, but in the SP experiment that did not happen. Hence, it will be useful to test in the same study area the two SP designs, i.e. binary choices at a time and with (without) an additional option "neither A or B" and compare results.

In this research the SP-design focused on environmental attributes since the analysis was conducted at the micro level (building). Other designs shall explore the mix of quantitative attributes such as "number of rooms" or "area", since the RP models showed householders may prefer bigger flats. Of course, this will depend on the characteristics of the population particularly on the household size and state.

### 11.4.2 Design of the OE-CVM Questions

The use of follow-up questions to protests and zero bids seems desirable since a protest zero does not mean necessarily that there is no preference for quiet. This study did not use follow-up questions, and hence protest zeros had been deleted from the sample. Further investigation shall be conducted using improved OE-CVM studies for valuing traffic noise. This includes the valuation scenario and payment vehicles (these can be tested by using focus groups) as an alternative to an open bid.

### 11.4.3 Convergent Validity of Noise Values Using the Same Sample of Respondents and Different Valuation Methods

This is an interesting research area that needs further investigation. This thesis aimed to address this issue by using valuation methods that had in common the same theoretical framework (SP-choice and RP) and experimental market basis (SP-choice and OE-CVM). Since the main thesis objectives were centered on the SP-choice experiment, this was a secondary objective of the work that now needs further investigation. Using other different valuation methods (e.g. SP-choice and Hedonic Pricing), the reasons for a possible convergence (divergence) of values need to be carefully examined, and more control/information of the exogenous variables that may lead to possible bias need to be assessed. On the other hand, the problem needs to be theoretically approached using combinations of various methods and modelling frameworks, and the conducting of sensitivity analysis of alternative model specifications.

There is a few research works on the confidence intervals of value estimates. Regarding the construction of confidence intervals to bound the value of time, see for example Armstrong et al. (2001) who also reviewed existing methods for setting confidence intervals. For policy and project evaluation it is important to establish methods to give an indication of the random error associated to the value of quiet estimates. This study also did not go far on this issue, since the methods applied to establish confidence intervals were simple due to time constraints and length of thesis.

### 11.4.4 Econometric Analysis

The principles that guided the econometric analysis in this study were related to existing theories. The literature on experimental economics and environmental psychology showed the utmost interest of exploring the utility of gains and losses. Future noise valuation studies should be guided by a set of common principles in order to be able to compare estimates of noise obtained in Lisbon with those found in other contexts (convergent validity of findings within different contexts). On the other hand, further analysis can be conducted by combing different types of data (e.g. SP and RP), and assessing possible improvements. Other revealed preference methods such as hedonic pricing are worth to be analysed jointly with SP-choice methods for the same sample of respondents. This will need updated housing data with quality, and possible involve the collaborations of various estate agents.

Alternative model specifications such as mixed logit models need to be explored to address the issue of taste variation. The use of combined interaction terms from standard multinomial logit specifications with random parameters, as used in this study, can provide alternative models for valuation purposes. However, this requires more data to be collected. In this thesis, the random components were assumed uncorrelated. However, depending on the SP experimental design, two environmental attributes (e.g. air pollution and noise) can be positively correlated, and even can be valued as a group by households. More research is needed on testing alternative model specifications that allow the random components to be correlated.

Also, the use of alternative functional forms for the utility functions is worthwhile to be explored.

### 11.4.5 Meta-analysis of SP-choice Studies

The valuation studies reviewed showed that the comparison of values of quiet obtained in different contexts seems to be difficult, since no common base line conditions can be set for such a diversity of contexts. This results from the fact that studies used different noise metrics, collected different explanatory variables (accounted for different tastes of the population), had a different final number of observations in the models estimated, followed different econometric analysis, besides other particular features related to the aim of study and implementation. Moreover, the incomplete definition of the context makes it difficult if not impossible to compare noise values across different studies since the potential biases and divergences in the contextual variables cannot be fully identified. By establishing an "expert team" the future studies on SP-choice methods will benefit if those previous studies can be consistently analysed following a common set of criteria, and the necessary information (not published) completed. Meta-analysis of noise valuation studies had already been conducted for the case of aircraft noise (Shipper et al. 1998) using a statistical analysis of 19 hedonic pricing studies. The meta-analysis of SP-choice studies will add to compare values across different contexts, help to consolidate the use of experimental markets to valuing the negative impacts of transport, and to recommend the best means of presentation, experimental design in each situation and econometric principles and analysis to follow. Until then, further advances need to be made progressively by following the best practice in terms of noise valuation and by making successive improvements. This is only possible if more resources can be dedicated to experimental research.

### 11.4.6 Policy and Appraisal

Several European countries already use monetary values of various environmental impacts in the appraisal of transport projects. This is not the case of Portugal, where no reference values for noise impacts due to road traffic existed so far. Economic values of noise are now under discussion at the European level, as well as the valuation approaches used to derive them. The marginal values of noise derived in the present research study can aid in this discussion, and serve as support to the cost-benefit analysis of transport projects and policies. Since the monetary values estimated using SP-choice data are sensitive to a wide range of variables (socio-economic, behavioural, etc), the possible transferability of values across different contexts is facilitated.

Monetary values of quiet can also aid in compensation procedures and noise mitigation plans in other residential areas. Since the best fit models were based on respondents' perceptions, the noise values need to be converted to Leq dB(A) using the multiple regression models estimated. Further research needs to be conducted on improving the explanatory power of the model relating individuals' noise ratings and the physical noise measures. Valuations across different residential areas will benefit to be investigated considering the outdoor noise levels. Since individual's perceptions may reflect more closely individual choices (preferences), more research is needed on the link of respondent's perceptions with traffic noise levels in different contexts with varying levels of traffic and types (e.g. continuous; interrupted; congested; etc.).

The monetary values of quiet can also aid on setting road traffic taxes and road pricing considering the environmental externalities of traffic. The range of values obtained could reflect householders' heterogeneity of preferences for quiet when indoors but in a situation of continuous road traffic outdoors. Other urban situations will benefit to be explored in the future (e.g. congested roads) for comparative and differentiation purposes.

### 11.4.7 SP-choice and the Valuation of Transport Externalities

Other valuation studies using SP experiments need to be conducted as well for other transport externalities such as air pollution and accidents (Ortúzar and Rodriguez 2002; Rizzi and Ortúzar 2002). This is a necessary step for recommending the use of stated preference techniques for valuing transport externalities.

The number of choice experiments will expand in the near future, following new developments in discrete choice modelling and simulation techniques (for recent developments, see for example Hensher 2001b). However, cooperation between experienced researchers in the field can produce better results. The strategic involvement of the EU and other international organisations shall be envisaged to provide a sustainable growth of SP applications.

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# APPENDIX 1 – COMPUTER SURVEY

(Screen 1)

**Research Study Sponsors:**
**Portuguese Ministry for Science and Technology/F.C.T.**
**and**
**LNEC- Transportation Networks Department**



(Screen 2)

**Information to be CODED by the interviewer for each respondent (or flat)**

- **Block layout: orientation relative to main traffic road**

**F1. Main facade is parallel to main traffic road** ☐

**F2. Main facade is perpendicular to main traffic road** ☐

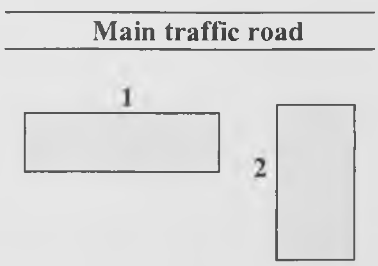


Figure 1

**Please, refer the name of main road :**
**(please, tick the appropriate box)**

**M1. Av. Norton de Matos (2ª Circular)** ☐

**M2. Eixo Norte-Sul** ☐

**M3. Av. Padre Cruz** ☐

(Screen 3)

- **Block type: number of households per floor**

**H1. Four households per floor (A,B,C,D)** ☐

*** Use SP 1**

**H2. Two (A,B) or Three (E,F,D) households per floor** ☐

***Use SP 2**

(Screen 4)

**We are conducting a research study that aims to characterise some flat attributes and the local environment in this residential area. For this purpose, we would like to ask you some questions, and we thank you in advance for all your cooperation and attention.**

(Screen 5)

**First, we would like to complete with you the following information:**
**name of street ..................................................................**

**Call - List of Streets**

**block number ..............................................................**
**number of floor ...........................................................**
**flat type (e.g. A) ..........................................................**

**position of your bedroom (please, use the initials B (for 'back'), F (for 'front') or S ( for'side') to main traffic road (*from Screen 2) ......................**

**position of your living/sitting room (please, use the initials B (for 'back'), F (for 'front') or S ( for'side') to main traffic road (*from Screen 2).......**

**Is the location of those rooms the same as in the map provided by the EPUL:**

***Information to confirm**

**1. Yes** ☐ **2. No** ☐

**2.1 bedroom location is different** ☐

**2.2 sitting room location is different** ☐

**If 2.1 or 2.2 ask question 29 in this questionnaire**

***Begin main questionnaire**
**(one question per Screen)**

**Q1. Are you ?**

**1. Female** ☐ **2. Male** ☐

*** Household familiarity with actual flat location**

**Q2. How long have you or your household lived here (year, month) ? ..... ....**

**Q3. Please, indicate the number of people in your household**

**1 person** ☐ **3-4 people** ☐

**2 persons** ☐ **more than 4 people** ☐

**Q4. How many people live with you permanently in this flat ?**

**Total number of people:** ☐
**(Total np)**

**If Total np ≥ 2 , identify later in the questionnaire the two main members in terms of their employment status and type of job, and highest education level attended**

**Q5. If there are any children living in this flat, please refer their ages fllling the table below:**

**Youngest child: (.... age), Second youngest child (...age), third child (...age), fourth child (...age), fifth child (...age)**

**Q6. Do you or your household have any of the following health problems ? (Please, tick on the appropriate boxes)**

**1. Insomnia** ☐

**2. Hearing difficulties** ☐

**3. Heart disease** ☐

**4. Circulatory or Blood pressure** ☐

**5. Other (please, refer)......................** ☐

***Generation of traffic noise by local residents**

**Q7. Please, refer the number of each vehicle types that are frequently used by you and your household:**

**Car (gasoline)...................**
**Car (diesel) .......................**
**Van ................................**
**Motorbike..........................**

***Household's actual residential area and flat location choice factors**

**Q8. Please, refer by order the main reasons for you and your household to move to this location (allocate 1 for the most important, 2 for the second most important, etc.):**

**proximity to work location** ☐

**price of flat** ☐

**quiet** ☐

**public transport** ☐

**no industry nearby** ☐

**car accessibility** ☐

**school for children nearby** ☐

**quality of the area (neighbourhood)** ☐

**quality of housing** ☐

**other (specify)..............................................................** ☐

**Q9. Please, refer the four main reasons for you and your household to choose this flat in this block (allocate 1 for the most important, 2 for the second most important, etc.):**

**view** ☐

**price of flat** ☐

**number of rooms** ☐

**less noise from road traffic** ☐

type of construction ☐

sun orientation ☐

availability of enclosed parking ☐

housing service charge ☐

availability ☐

safety ☐

other (specify)............................................................ ☐

If block type is H1 (from Screen 3) then

*Assess respondents' familiarity with characteristics of the flats in the same block:

Q10 -1. We would like to assess your familiarity with some characteristics of the flats in your current block named A1, A2, A3 and A4 (show card or explain respondents the definitions). Please, refer the characteristics that you were aware at the time of your purchase ('now') on the table below, indicating values when known by you (price, rent, housing service charges, area, number of rooms and number of parking spaces in garage):

| Flat type → <br> (example: Codes) | A1 (your current choice) <br> 12F | A2 (flat in same floor, different side) <br> 12T | A3 (flat in same side, different floor) <br> 1F | A4 (flat in different side, different floor) <br> 1T |
|---|---|---|---|---|
| Price or rent | | | | |
| Housing service charge | | | | |
| Number of rooms | | | | |
| Area ($m^2$) | | | | |
| Number of parking spaces in garage | | | | |

Note: "T" ("Tardoz"-T term for "Back")

If block type is H2 (from Screen 3) then

* Assess respondents' familiarity with characteristics of the flats in the same block and lot

**Q10 -2. We would like to assess your familiarity with some characteristics of the flats in your current block and lot named A1, A2, A3 and A4 (<u>show card or explain respondents the definitions</u>). Please, refer the characteristics that you were aware at the time of your purchase ('now') on the table below, indicating values when known by you (price, rent, housing service charges, area, number of rooms and number of parking spaces in garage):**

**Present same Table, as before, but A2 is defined as 'flat in same floor, different block in the same lot', and A4 is 'flat in different side and floot in different block in the same lot'.**

**Q11) We would like that you classify now the same flat types, taking into account some characteristics represented on the table below. Please, give a rating from 0 to 100 on the following flat attributes :**

**(on each screen, View, Noise, Sunlight)**

| Flat attributes | Rating |
|---|---|
| View (100 - very good; 0 - very poor)<br>0 ________________ 100 | |
| A1 (e.g. 12F) | |
| A2 (e.g. 12T) | |
| A3 (e.g. 1F) | |
| A4 (e.g. 1T) | |

| Flat attributes | Rating |
|---|---|
| Noise (100 - very quiet; 0 - very noisy)<br>0 ________________ 100 | |
| A1 (e.g. 12F) | |
| A2 (e.g. 12T) | |
| A3 (e.g. 1F) | |
| A4 (e.g. 1T) | |

| Flat attributes | Rating |
|---|---|
| Sunlight (100 - very quiet; 0 - very poor)<br>0 ________________ 100 | |
| A1 (e.g. 12F) | |
| A2 (e.g. 12T) | |
| A3 (e.g. 1F) | |
| A4 (e.g. 1T) | |

***Begin Stated Preference questionnaire**

**We would now like that you can consider a series of situations where you are able to choose between 2 different apartment options. Both of the apartments that will be presented to you would involve the same flat as you have now, but they would differ in terms of:**

COMPUTER SURVEY

- view;
- number of floor/side in the block (and/or lot);
- housing service charge;
- sunlight.

We are going to present you several pairwise comparisons at a time. In each situation, we would like you to consider flat option 1 and flat option 2 and tell us which one you think you or your household would prefer if such a choice were possible.

If block type is H1 (from Screen 3)

Please, consider that the options that will be next presented to you are in the same block you and your household actually live.

Use definitions
A1 - current choice
A2 - flat in same floor, different side
A3 - flat in same side, different floor
A4 - flat in different side, different floor

Select randomly 12 pairwise apartment comparisons to present at a time

If block type is H2 (from Screen 3)

Please, consider that the options that will be next presented to you are in the same block or different block in the same lot you and your household actually live.

Use definitions (logos and remind/point block in underlined explanation):
A1 (e.g. 12F) - current choice
A2 (e.g. 12T) - flat in same floor, different block in the same lot
A3 (e.g. 1F) - flat in same side, different floor
A4 (e.g. 1T) - flat in different side and floor in different block in the same lot

Select randomly 12 pairwise apartment comparisons to present at a time
Example of screen (SP-choice):

| Apartment option A | Apartment option B |
|---|---|
| VIEW as (you perceive)<br>12F | VIEW as (you perceive)<br>12F |
| NOISE as (you perceive)<br>12F | NOISE as (you perceive)<br>1T |
| HOUSING SERVICE CHARGE<br>7500 | HOUSING SERVICE CHARGE<br>9000 |
| SUNLIGHT as (you perceive)<br>12F | SUNLIGHT as (you perceive)<br>1F |

**Note: underlined terms were orally mentioned. This makes it easier the choice task, as less text appears in the screen.**

**WTP QUESTIONS – link with Question 11) Ratings for Noise**

**WTP question type 1: if respondent rated his flat as the best in terms of levels of quiet**
**WTP question type 2: if respondent rated his flat as the worst**
**Otherwise, ask both**

**(Type 1)**
**Q12a) How much are you willing to pay per month to avoid your indoor noise levels being as bad as in apartment (1F) ?**

**(Type 2)**
**Q12b) How much are you willing to pay per month to improve your indoor noise levels to be as good as in (12T) ?**

**Q12) How many hours per day on average is your flat (current choice) exposed to sunlight (please, refer to the situation in the month of survey ) ? ............**

**Please, specify which situation best describes your case:**

**1. all rooms have sun at least half of the day** ☐

**2. some rooms have sun at least half of the day** ☐

**3. only 1 room or sitting room has sun half of the day** ☐

**4. only 1 room has few hours of direct sun exposure** ☐

**5. no room is directly exposed to sun during the day** ☐

*** Household preferred flat type choice and reasons**

**If block type is H1 (from Screen 3) then**

**Q13 -1. Bearing in mind the prices of the flats, which flat in this block would you have chosen ? (Please, consider that flats A1,A2, A3 and A4 are all available at the time) .........................................**

**If block type is H2 (from Screen 3) then**

**Q13 -2. Bearing in mind the prices of the flats, which flat in this block and lot would you have chosen ? (Please, consider that flats A1,A2, A3 and A4 are all available at the time) .........................................**

**If answer to Q13-1/2 is ≠ A1 (current choice) then**

**Q14. If your choice would have been different from the present one, please state the main reasons by order of importance (please, allocate 1 for the most important, 2 for the second most important, etc.):**

view is better ☐

more sunlight ☐

more rooms ☐

more parking spaces in the garage ☐

less noise from road traffic ☐

other (please, specify:)...................................................... ☐

*** Information on flat tenure**

**Q15. How do you classify your current flat choice tenure (please, tick the appropriate box)**

**1. Owned by me or my household** ☐ **2. Rented** ☐

**If answer is 1., then ask**

**1a) How much did you pay for the flat (million of escudos) ?...............**
**1b) The date of your purchasing (year, month) ....... ......**
**1c) How much do you pay per month as housing service charge ?.............**
**1d) How much do you pay per month as mortgage (thousand of escudos) ?**
**(Please, write '0' if the flat is paid)......................**

**If answer is 2., then ask:**

**2a) How much is the rent per month (thousand of escudos) ? ....................**
**2b) How much do you pay per month as housing service charge ? .............**

*** Time spent in the home by the household, place, activities and habits**

**Q16. How many hours are you normally at home during the day (please, consider a weekday from 7 a.m. to 10 p.m.) .............**

**From Q4. if Total np ≥ 2 , ask the following question for <u>each member</u> of the household**

**Q17- a. Please, refer the place in the home where <u>you</u> (your partner; child 1; child 2, etc.) usually stay more than 50% of the time when you are at home during a weekday from 7 a.m. to 10 p.m. (please, tick the appropriate box)**

**1.Bedroom/Sleep** ☐ **3.Living/sitting room** ☐

**2. Kitchen** ☐ **4.Other** ☐

**Q17-b. During this period when <u>you</u> (your partner; child 1; child 2, etc.) are in the home which is your usual activity ?**

**1.Listening music** ☐

2. Cooking/Eating ☐

3. Sleeping ☐

4. Working/Studying ☐
5. Watching TV ☐
6. Other (please, specify).................. ☐

Q18. Do you or your household frequently have the windows open when in the home (please refer to the situation in Spring and Summer time)?

1.Yes ☐ 2. No ☐

Q19. Where do you or your household usually spend the weekends ?

1. Home ☐

2. Out ☐

**If answer is 1. then ask:**

Do you or your household usual work/study home during that period ?

1.Yes ☐ 2. No ☐

***Perception of noise impacts in the place of residence**

We would like that you consider the levels of the outside noise, ignoring other sources of noise indoors, when asking the following questions:

Q20. How would you describe the general day-time noise level inside your home as it affects you and your household ? (please, consider the period from 7 a.m. to 10 p.m.).

1. Very Noisy ☐

2.Noisy ☐

3.Neither Noisy or Quiet ☐

4. Quiet ☐

5. Very Quiet ☐

**If answer is 1 or 2 then ask:**

Q21. How much does noise annoy you and your household in the home during the day (please, consider in a weekday the period from 7 a.m. to 10 p.m.) ?

1. Very much ☐

2. Moderately ☐

3. A little ☐

4. Not at all ☐

**If answer is ≠ 4 then ask**

**Q22. How does noise from road traffic disturb you and your household in the home during the day (please, tick more than one if necessary?**

Interferes with conversation ☐

Listening to TV, radio, etc. ☐

Affects concentration for studying ☐

Causes fatigue and headaches ☐

Causes frustation and irritation ☐

Difficulty in resting/falling asleep ☐

Other (specify)................................... ☐

**Q23. How would you describe the general night-time noise level inside your home as it affects you and your household ? (Please, consider the period from 10 p.m. to 7 a.m.)**

1. Very Noisy ☐

2.Noisy ☐

3.Neither Noisy or Quiet ☐

4. Quiet ☐

5. Very Quiet ☐

**If answer is 1 or 2 then ask:**

**Q24. How much does noise annoy you and your household in the home during the night (Please, consider the period from 10 p.m. to 7 a.m.) ?**

1. Very much ☐

2. Moderately ☐

3. A little ☐

4. Not at all ☐

**If answer is ≠ 4 then ask**

**Q25. How does noise from road traffic disturb you and your household in the home during the night ? (Please, consider the period from 10 p.m. to 7 a.m. and tick more than one if needed)**

**Interferes with conversation** ☐

**Listening to TV, radio, etc.** ☐

**Affects concentration for studying** ☐

**Causes fatigue and headaches** ☐

**Causes frustation and irritation** ☐

**Awakening during the night** ☐

**Difficulty in falling asleep** ☐

**Other (specify)...................................** ☐

**Q26) When does traffic noise bother you and your household more ?**

**1. Indoors at home during the day-time (7 a.m. to 10 p.m.)** ☐

**2. Indoors at home during the night-time (10 p.m. to 7 a.m.)** ☐

**3. When walking in the area** ☐

**4. All equally** ☐

**If answer to Q26 is 1. then ask Q27. During the day, ....**
**If answer to Q26 is 2 then ask Q27. During the night,...**
**If answer to Q26 is 3 then stop**
**If answer to Q26 is 4 then ask Q27. In general,...**

**Q27. <u>During the day/During the night/In general</u>, which of the following factors are the three most important causes of noise in your home (1,2, 3 per order of importance) ?**

**Road traffic** ☐

**Aircraft** ☐

**Neighbours** ☐

**People passing through the area during the day** ☐
**People passing through the area during the night** ☐

**Construction work** ☐

**Other (specify)..........................................................** ☐

***Measures taken by the household to reduce the impact of noise**

**Q28. Have you taken measures to reduce the impact of noise in the home ?**

**1. Yes** ☐ **2. No** ☐

**If YES (1.), please specify type measures in the following table, their approximate costs, year of installation, and other purposes of installation besides avoiding noise**

| Type of measure | Costs | Year of installation | Purpose(s) of installation |
|---|---|---|---|
| 1. double glazing | | | |
| 2. secondary glazing | | | |
| 3. double ceiling | | | |
| 4. shutters | | | |
| 5. other | | | |

**Q29. Have you changed the location of your bedroom (or sitting room) because of the outside noise ?**

**1. Yes** ☐ **2. No** ☐

***Respondent's awareness of the health impacts of noise**

**Q30. Are you aware of any health impact of noise on you / others ?**

**Yes** ☐ **No** ☐

**Finally, we would be very grateful that you would tell us some socio-economic data related to you and your household. These data will be used only for the purpose of this research study.**

*** For each main member of the household ask Q31. Q32. and Q33**

**Q31. What is your (your partner) highest education level ?**

**1. Primary School** ☐

**2. Secondary School** ☐

**3. Technical/Professional School** ☐

**4. Polytechnics (Bachelor)** ☐

**5. University (Degree)** ☐

**6. Post Graduate (Master)** ☐

**7. PhD** ☐

**8. Other (specify)** ______________________ ☐

**Q32. Please, indicate your (your partner) employment status and type of job:**

**1. Part-time employed** ☐

**2. Full-time employed** ☐

- **a) Public Administration** ☐
- **b) Private Company** ☐
- **c) Other (specify):** ☐

**3. Unemployed** ☐

**4. Retired** ☐

**5. House work** ☐

**Q33. To which age group do you (your partner) belong ?**
**(Age groups classification used by INE - National Institute of Statistics, in Portugal)**

**1. Between 15 to 19** ☐

**2. Between 20 to 24** ☐

**3. Between 25 to 29** ☐

**4. Between 30 to 34** ☐

**5. Between 35 to 39** ☐

**6. Between 40 to 44** ☐

**7. Between 45 to 49** ☐

**8. Between 50 to 54** ☐

**9. Between 55 to 59** ☐

**10. Between 60 to 64** ☐

**11. Between 65 to 69** ☐

**12. Between 70 to 74** ☐

**13. Over 75** ☐

**Q34. What is your Net Household Income (thousands of escudos per month) ?**

**1. < 65** ☐

**2. 65 - 245** ☐

**3. 245 - 425** ☐

**4. 425 - 605** ☐

**5. 605 - 785** ☐

**5. 785 - 965** ☐

**6. 965 - 1145** ☐

**7. 1145 - 1325** ☐

**8. > 1325** ☐

# APPENDIX 2 - TRAFFIC DATA

This Annex reports the traffic data collected in the study area, regarding the three main roads in the vicinity of the study area:

1- Second Inner Road;
2- North-South Ring Road;
3- Padre Cruz Avenue.

Figures A2.1 to A2.5 represent the traffic characteristics for the main road 1- Second Inner Road (3 lanes per each direction, and lane 1 is the lower speed one, grade is approximately horizontal). Flow direction 1 (Lisbon to other destinations, or Campo Grande-Lisbon) affects the majority of the buildings surveyed in the vicinity of this road (Figure 5.1 in chapter 5). Flow direction 2 affects mostly the respondents located on the other side of the road, where no noise barrier is installed. Considering the width of the road, flows are in number of vehicles per lane.

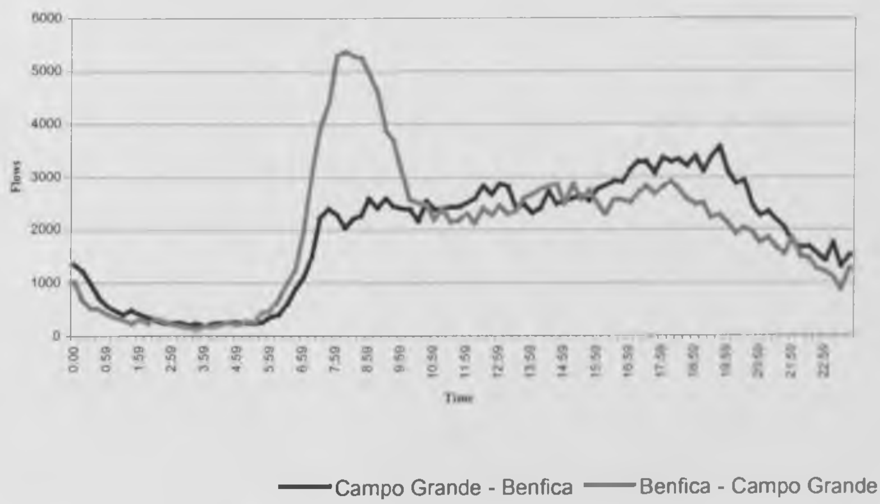


**Figure A2.1: Traffic flows (direction 1 and 2), Second Inner Road.**

Figure A2.1 points out that flows per lane are relatively stable during the period 11:00am to 22:00. According to the Portuguese Noise Regulations the day-time reference noise period is between 7am-22:00. The morning peak period is more intense in terms of flows than during pm, as expected from the situation reported in the recent mobility survey within LMA (DGTT 2000). As expected, during am the inbound traffic is much higher (flow direction Benfica-Campo Grande. During the night-time period as defined by the Portuguese Noise Regulations (22:00- 7am) the flows decrease substantially. As most householders are in their apartments after 17:30, it can be expected that the effect of continuous traffic during this period will act as a dominant environmental stressor in their homes.

Private cars, light commercial vehicles and heavy goods were counted separately. Figure A2.2 represents the percentage of heavy goods vehicles for each lane. Figures A2.2 and A2.3 show that the higher proportion of heavy goods vehicles circulates during the night period, probably in order to minimize transport and other costs. Considering the traffic data, the majority of vehicles that circulate during the day reference period occupy the slower lane (lane 1 in Figures A2.4 and A2.5).

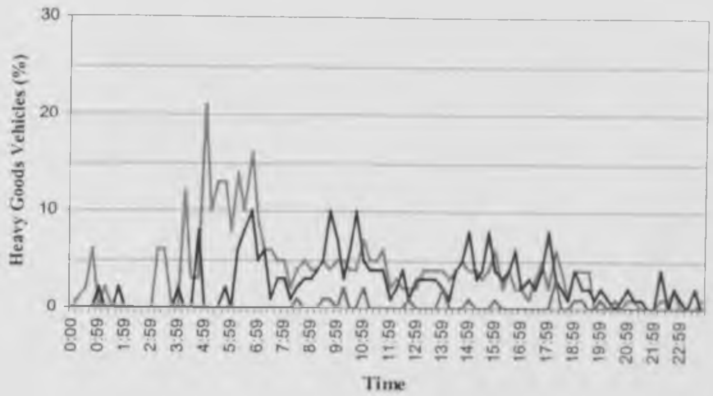


**Figure A2.2: Percentage of heavy goods vehicles per lane (direction 1).**

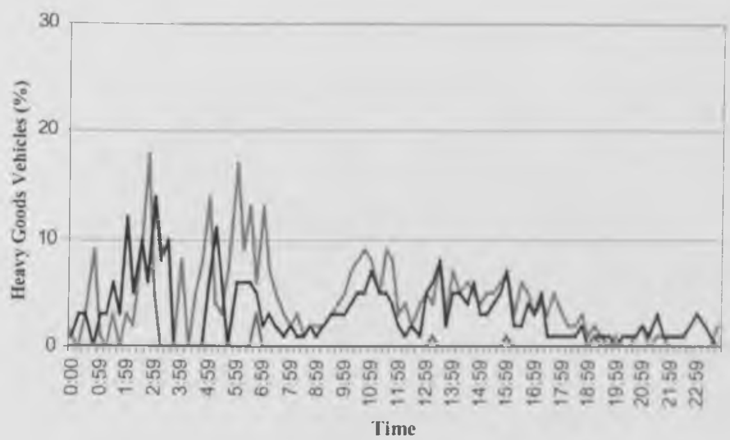


**Figure A2.3: Percentage of heavy goods vehicles per lane (direction 2).**

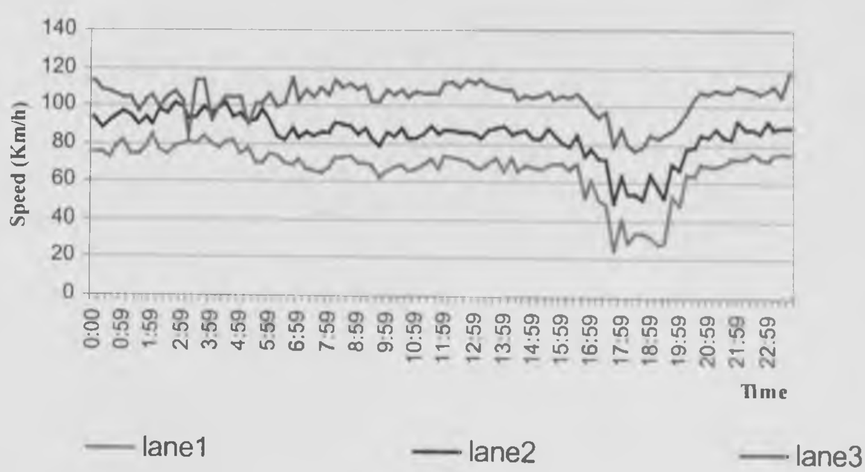


**Figure A2.4: Mean speeds (Km/h) per lane (direction 1).**

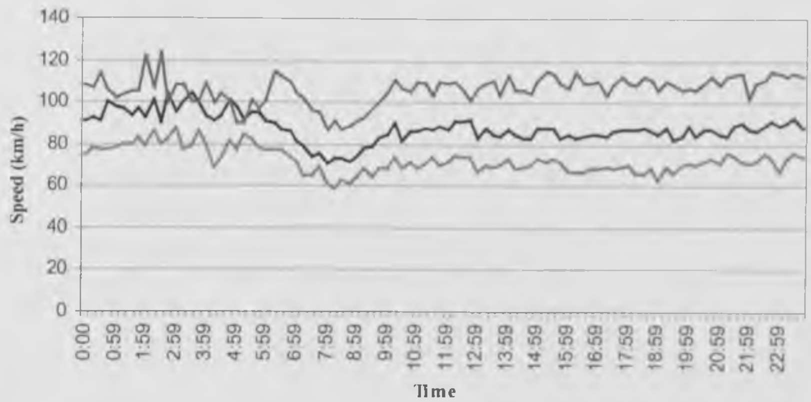


**Figure A2.5: Mean speeds (Km/h) per lane (direction 2).**

Figures A2.4 and A2.5 show that the speed of passenger traffic (lanes 3 and 2) in this main road exceeds 80 km/h in the off-peak periods. The sole effect of a 80-90 Km/h speed results in an increase of 2-3 dB(A) from the reference speed (60 Km/h) in the outdoor noise levels in Leq, following the mentioned noise prediction model used in Portugal, and assuming other characteristics of the traffic are equal.

Other traffic data related to the site can be requested from LNEC/NTSR Av.do Brasil 101, 1700-066 Lisboa Codex. Thanks to NTSR/Dr. Eng. Joao Cardoso, J. Gil and Cristina Claudia and Cristina Cabral.

# APPENDIX 3 – Mean Insulation Factors and Range of Indoor and Outdoor Noise Measurements at each Apartment Floor

The window types were coded as a 3 digit number, each takes a possible value of 1 or 2: first digit is 1 if window opens/closes through an horizontal sliding movement (Type "Janela de correr") and 2 otherwise; second digit is 1 if there is no secondary window indoors and 2 otherwise; third digit is 1 if there is no double glazing and 2 otherwise.

**Table A3.1: Insulation Factors by Building and Window types.**

| Building ID – Street name | Window types | Mean Insulation (*) |
|---|---|---|
| Estrada de Telheiras N.2 | 112 | 29.1 |
| | 212 | 31.3 |
| R. Prof. Armindo Monteiro | 211 | 24.5 |
| | 121 | 39.9 |
| | 221 | 40.5 |
| | 212 | 27.8 |
| R. Prof. Virginia Rau | 121 | 39.9 |
| R. Vitor Fontes | 121 | 36.2 |
| R. Frederico George | 112 | 28.7 |
| R. Prof. Prado Coelho | 111 | 25.0 |
| | 112 | 27.0 |
| | 121 | 35.0 |
| R Cesar Oliveira | 112 | 28.8 |
| R. Manuel Cav. Ferreira | 212 | 28.8 |
| | 112 | 30.5 |
| Lot Mark Athias | 122 | 29.0 |
| | 221 | 30.8 |
| | 222 | 37.5 |
| | 111 | 24.2 |
| R. Barbosa Soeiro | 111 | 25 |
| | 212 | 29.5 |
| R. Prof. Aires de Sousa | 111 | 25.4 |
| | 212 | 31.3 |
| | 112 | 27.1 |
| R. Carvalhao Duarte | 212 | 32.2 |
| | 112 | 26.0 |
| Lot Jardim dos Ulmeiros | 222 | 41.8 |
| | 212 | 33.7 |
| | 112 | 25.7 |
| R. Nuno Ferrari | 112 | 29.5 |
| | 122 | 31 |

The range of variation of indoor and outdoor noise measures per floor number in the surveyed apartments in the vicinity of each road segment (Figure 5.1, chapter 5) is presented in Table A3.2.

**Table A3.2: Range of Indoor and Outdoor Noise measurements (Leq dB(A), at each floor number**

| Main road Segment | Floor number | Indoors Min , Max | Outdoors Min, Max |
|---|---|---|---|
| **1.1** | 1 | 26.6, 40.8 | 55.4, 75.9 |
| | 2 | 30.4, 39.1 | 59.5, 67.8 |
| | 3 | 28.0, 44.7 | 51.7, 73.9 |
| | 4 | 31.5, 45.7 | 56.5, 74.9 |
| | 5 | 30.5, 45.7 | 55.4, 73.9 |
| | 6 | 31.6, 41.8 | 56.6, 71.8 |
| **1.2** | 1 | 31.5, 44.9 | 62.8, 73.6 |
| | 2 | 32.7, 42.0 | 62.8, 62.8 |
| | 3 | 34.8, 38.8 | 67.0, 72.0 |
| | 4 | 36.0, 45.9 | 45.9, 75.9 |
| | 8 | 41.3 | 66.9 |
| **2.1** | 1 | 31.0, 43.8 | 57.2, 73.2 |
| | 2 | 27.7, 42.4 | 58.1, 69.8 |
| | 3 | 27.7, 44.8 | 58.0, 72.5 |
| | 4 | 29.2, 58.0 | 43.6, 71.0 |
| | 5 | 23.7, 44.1 | 60.4, 71.5 |
| | 6 | 31.3, 46.1 | 58.5, 73.2 |
| | 7 | 34.1, 42.9 | 59.2, 70.3 |
| | 8 | 33.5, 41.0 | 62.3, 71.1 |
| | 9 | 25.8, 45.8 | 61.0, 73.2 |
| | 10 | 30.8 | 58.5 |
| | 11 | 33.0, 35.8 | 63.5, 64.9 |
| **2.2** | 1 | 25.1, 41.9 | 54.2, 68.2 |
| | 2 | 26.7, 41.9 | 58.8, 68.2 |
| | 3 | 30.8, 42.5 | 58.8, 72.5 |
| | 4 | 36.0, 41.2 | 63.0, 66.0 |
| | 5 | 33.0, 43.9 | 54.2, 70.5 |
| | 6 | 34.2, 45.4 | 56.4, 70.4 |
| | 7 | 31.4, 43.8 | 60.1, 70.4 |
| | 8 | 36.0 | 64.8, 70.0 |
| **3.0** | 1 | 31.9, 45.4 | 58.2, 72.6 |
| | 2 | 31.2, 40.4 | 62.8, 74.4 |
| | 3 | 31.1, 47.1 | 64.2, 71.1 |
| | 4 | 34.6, 47.5 | 59.7, 75.9 |
| | 5 | 34.0 | 74.1 |
| | 6 | 38.8 | 70.0 |
| | 7 | 21.9, 49.5 | 61.8, 74.5 |
| | 8 | 33.8, 48.5 | 58.8, 74.9 |
| | 9 | 38.9, 48.1 | 66.3, 74.1 |
| | 10 | 39.3, 40.9 | 65.3, 74.5 |
| | 11 | 21.9, 49.5 | 58.2, 75.9 |

# APPENDIX 4 - STUDY AREA AND NOISE DATA COLLECTION

**Figure A4.1: The survey area in the vicinity of main road 1.**

**Figure A4.2: Lot "Jardim dos Ulmeiros" (Pilot Study).**

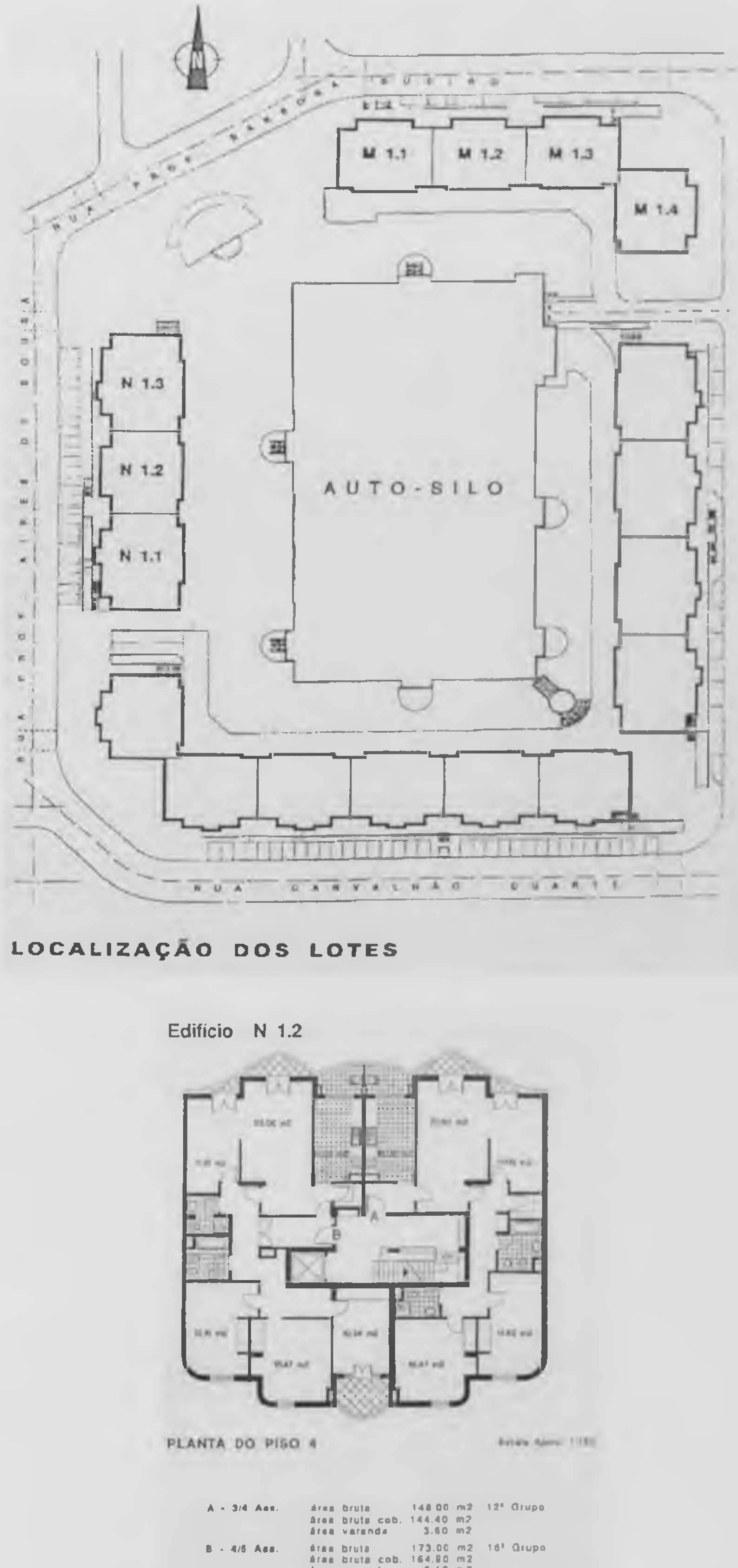


**Figure A4.3: Pilot study lot (Map of buildings and internal layout example).**

**Figure A4.4: Noise measurement at the apartment façade.**

**Figure A4.5: Outdoor noise measurements at each apartment.**

# APPENDIX 5 - FRACTIONAL FACTORIAL DESIGN

Following Kocur et al. (1982) the Experimental Plan code 26 was used for the SP design. Considering the binary choice experiment, the number of variables is four (DVIEW, DNOISE, DHSCH, DSUNL) with four levels each. For the fractional factorial design the Master Plan 5 is used (columns number 1,2,3,4) and this implies a minimum of 16 tests for identification of main effects as follows (Table A5.1).

**Table A5.1: Fractional Factorial Design.**

| DVIEW | DNOISE | DHSCH | DSUNL |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 2 |
| 0 | 2 | 2 | 3 |
| 0 | 3 | 3 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 3 |
| 1 | 2 | 3 | 2 |
| 1 | 3 | 2 | 0 |
| 2 | 0 | 2 | 2 |
| 2 | 1 | 3 | 0 |
| 2 | 2 | 0 | 2 |
| 2 | 3 | 1 | 3 |
| 3 | 0 | 3 | 3 |
| 3 | 1 | 2 | 1 |
| 3 | 2 | 1 | 0 |
| 3 | 3 | 0 | 2 |

In this study 12 tests were randomly selected within 16 to each respondent. The distribution of all 16 alternatives presented to the sampled households is represented in Table A5.2.

**Table A5.2: Distribution of all 16 SP Alternatives in the Sample.**

| SP | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 300 | 320 | 310 | 318 | 301 | 292 | 321 | 309 | 326 | 311 | 304 | 308 | 315 | 313 | 312 | 284 |
| % | 6.1 | 6.5 | 6.3 | 6.4 | 6.1 | 5.9 | 6.5 | 6.3 | 6.6 | 6.3 | 6.1 | 6.2 | 6.4 | 6.3 | 6.3 | 5.7 |

# APPENDIX 6 – OUTPUT FROM GAUSS WITH ALL STATISTICALLY SIGNIFICANT ADDITIONAL VARIABLES

The effects on the marginal utility of quiet that were found statistically significant (Table 7.2, Chapter 7) were also tested together. Table A6.1 represent the estimation results using GAUSS considering the effect of repeated observations.

**Table A6.1: Output from GAUSS with all Statistically Significant Additional Variables.**

| Variable name | Parameter Estimate (t-stats) |
|---|---|
| View | 0.0244 (9.21) |
| Quiet | 0.0422 (3.91) |
| Sunlight | 0.0193 (6.74) |
| Adjusted Household Income per person | -0.0153 (2.80) |
| Missing Income | -0.0001 (2.16) |
| Less Familiar SP (lot) | -0.0163 (2.02) |
| Flat exposure at the Back | 0.0187 (2.01) |
| Floor Number (Upper) | -0.0145 (2.31) |
| Gender (Female) | 0.0066 (1.11) |
| Presence of Children | -0.0058 (1.02) |
| Number of Years Living at the Flat | -0.0128 (1.93) |
| Presence of Noise Barriers | 0.00573 (0.79) |
| Base Level of Quiet | 0.0169 (1.48) |