ARTICLE IN PRESS

Case Studies on Transport Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

Contingent valuation of road traffic noise: A case study in the urban area of Quito, Ecuador

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ARTICLE INFO

Keywords:
Contingent valuation
Road noise
Noise transportation costs

ABSTRACT

The aim of this study was to estimate the value of noise pollution generated by transportation using a discrete choice survey. This paper reports the main findings of a contingent valuation of road traffic noise in Quito, Ecuador. In this sense, it was conducted a social survey in Quito in order to identify the respondents' noise perception, and their willingness to pay in order to reduce the annoyance caused by road traffic noise. The respondents' road noise exposure levels were obtained through an RSL-90 acoustic model. The econometric model succeeded 81,43% of the willingness to pay for the validation dataset. This study contributes toward assessing the environmental costs of transport in an Andean city within a policymaking context.

1. Introduction

Traffic noise is a common environmental issue in urban areas where population and vehicle density have grown considerably without having the proper development of transportation infrastructure. Moreover, road traffic is the most significant source of noise in cities and presents the largest growth, followed by community, recreation, and construction noise (Hurtley, 2009). Strategic noise maps presented by some European Union (EU) counties have indicated that a large portion of the population living in big agglomerations is exposed to hazardous noise levels exceeding the limits that the World Health Organisation (WHO) considers safe (Berglund et al., 1999).

In particular, road traffic noise is the most significant contributor for noise pollution, with more than half of the EU population regularly exposed to over 55 dB in urban areas. Above this level, noise causes annoyance, sleep disturbance, cognitive deterioration, cardiovascular disorders, tinnitus, or even premature death. These effects can be particularly dangerous for children and other vulnerable groups (Guarinoni et al., 2012).

The WHO developed a methodology to assess the impact of environmental noise on the health of human beings (Fritschi, 2011). This methodology uses the Disability-Adjusted Life Years index (DALYs), which represents the sum of lost years due to health disturbances, disability, and premature death. With conservative assumptions applied to the calculation methods, it is estimated that DALYs lost from environmental noise are 61.000 years for ischemic heart disease, 45.000 years for cognitive impairment in children, 903.000 years for sleep disturbance, 22.000 years for tinnitus and 654.000 years for annoyance in the EU member states and other Western European countries. The study concludes that one of every three persons in Europe has experienced noise annoyance during the day, and one of every five has experienced sleep disturbance due to traffic noise.

Action plans focused on mitigating noise and its impact on human beings have propose the use of low-noise technology, insulation for sound-proofing homes, the development of low-noise tires and road surfaces, urban planning, noise awareness campaigns, updating noise regulations, etc. However, these measures are costly, and their implementation would only be justified if the economic benefits of noise reduction were comparable to those costs (Barreiro et al., 2005).

In 2000, the total external costs for transportation in the EU were estimated to be EUR 650 billion, which represented 7,3% of their total GDP. Noise pollution accounted for 7% of the total cost (OECD, 2006).

Navrud (2002) conducted a review that supports the relevance of this topic. His study is considered state-of-the-art when it comes to evaluating the financial impact of noise in developed countries. Correa et al. (2011) described the costs of noise in other Latin American countries, showing the results of studies in Chile, Argentina, and Colombia.

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http://dx.doi.org/10.1016/j.cstp.2017.08.003
Received 3 August 2016; Received in revised form 25 May 2017; Accepted 4 August 2017
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Please cite this article as: Bravo-Moncayo, L., Case Studies on Transport Policy (2017), http://dx.doi.org/10.1016/j.cstp.2017.08.003

To valuate noise abatement measures, two methodologies were identified: the revealed preferences (RP) method and the stated preferences (SP) method. Hedonic pricing (HP) is the most used RP approach. On the other hand, contingent valuation (CV) is a well-stablished method for an SP approach (Galilea and Ortúzar, 2005).

The HP method measures the benefits of a noise reduction using property prices and therefore undervalues the real benefits of real noise reduction (Barreiro et al., 2005). This method is very sensitive to the housing market conditions; in Ecuador, the housing market is not efficient since most houses are owned and there is low mobility once one's first house has been bought.

Another alternative is to value the reduction in road traffic noise annoyance through a CV study. This kind of studies ask questions that help estimate the monetary trade-off that each person would make concerning the value of goods and services (Carson, 2012). The CV method creates a hypothetical market and values the environmental or welfare changes. Subjects are asked questions regarding their WTP or willingness to accept (WTA) to get or accept the environmental change.

Several valuating question forms have been suggested to conduct CV studies, such as open questions, single-bound, double-bound (Vainio, 1995, 2001; Navrud, 2000; Lambert et al., 2001), one-and-one-half-bound (Cooper and Hanemann, 1995; Cooper et al., 2002; Barreiro et al., 2005), referendum, etc. The way to estimate the value of noise has also been presented by several forms. Andersson and Ögren (2011) estimated a road infrastructure charge based on the short-run marginal costs (SRMC). Arsenio et al. (2006) suggested an approach based on the noise-experience of the respondents. Bjørner (2004) suggested a combination of socioacoustic studies to assess traffic noise annoyance and relate it to WTP.

A recent cross-sectional study conducted in five EU countries in order to evaluate the WTP and reduce the risk of health issues due to road traffic noise concluded that the mean WTP estimates to avoid the effects of road traffic noise effects were €90 per person per year (pp/y) for general health risks, €100 pp/y for a 13% increase in severe annoyance, and €320 pp/y for a combined risk scenario related to an increase of noise levels from 50 dB to 65 dB (Istamto et al., 2014a).

Based on literature review, the authors aimed for a contingent valuation method to achieve an ordered probit econometric model in order to value a reduction of road noise annoyance in the population of Quito, as a first attempt to assess the social impact of traffic noise in monetary terms in Ecuador. The outcomes of the model come from a socioacoustic survey that collected the respondents' WTP. Certain characteristics were used as model inputs: a) respondents' environmental noise perceptions, b) modelled day-night noise exposure level (L_{DN}) at the façade of the respondents' dwellings, and c) respondents' demographic and socioeconomic statuses.

The paper is structured as follows: Section 2 describes the geographical scope of the study, and Section 3 deals with the methodology used for sampling, the questionnaire, and predicting noise exposure. The econometric specification is mentioned in Section 4. Results are discussed in Section 5 and Section 6 shows the main conclusions.

2. Geographical scope

This study focused on the urban area of Quito, which has 1,6 million inhabitants and covers 305 km^2. This territory is part of the Quito Metropolitan District, which is the second most populous district in Ecuador (with 2,24 million inhabitants). We considered the urban area of Quito (Fig. 1b) because its population is affected more by noise pollution. Over 425.000 vehicles move on the roads in the Metropolitan District (Fig. 2) and its mean growth rate has increased by 4% between 2010 and 2016.

This study considered all kinds of urban roads (Table 1), excluding pedestrian roads, which have a lower impact caused by traffic noise.

3. Methodology

Considering the lack of an official noise map in Quito, the authors defined a select sample over the city in order to assess noise exposure through a predictive acoustic model. WTP to reduce noise annoyance, subjective noise experience, and demographic and socioeconomic data collected through a survey as described bellow.

3.1. Sample design

To select the sample size, official data from the 2010 Census of Population and Housing were used. The population affected by road traffic noise was determined using a geographical information system (GIS), which was used to link every expressway, semi-expressway, arterial streets, and main streets with its adjacent housing blocks. The criteria used for sampling were housing density ($>$ 1.000 houses/km^2), and road density ($>$ 3 km road/km^2). Ten urban sectors met these criteria. In addition, another 10 control sectors were included in the study to ensure a homogeneous geographic distribution over the city, as shown in Fig. 3. One noise measurement point was included in every sample sector in order to validate a predictive noise model.

The socioacoustic survey was conducted over twenty sample sectors in thirteen urban districts (Table 2). Six hundred housing samples were used. These samples were proportionally distributed by the size of each sample sector. In this study, protest responses (14,6%) and those with any unanswered variables (7%) were excluded from the analysis, leaving 469 valid responses.

3.2. Questionnaire design

The questionnaire used in the study was designed according to the guidelines established in the NOOA report for contingent valuations (Arrow et al., 1993), which suggests the following approach. The first part assessed the noise experiences of respondents, their subjective valuation of road noise annoyance and the noise effects on human health. Secondly, the questionnaire asked respondents about the economic valuation, describing a hypothetical market wherein the WTP to reduce road noise annoyance and a payment method were described. Finally, a third part collected demographic, socioeconomic, and geographical information (Table 3).

In the first Section, 9 questions were asked concerning the following issues: environmental quality importance (EI); the relevance of noise pollution as an environmental issue (N_P); whether silence was a factor in the decision of whether to inhabit a dwelling (S_H); the years of residence at the home (YH); the daily hours at home (H_H); the day (DA) and night (NA) road noise annoyance according to ISO 15.666 (2003); home refurbishment investments for noise mitigation purposes (NC_H); and the perceived noise effects on health, such as stress (S), sleep disturbance (SD), hearing loss (HL), headaches (HA), and lack of concentration (CL).

The second section evaluated one's WTP in order to reduce road noise annoyance. It was initially explained the need to create a hypothetical market, which showed the noise mitigation action plan investments for the next 10 years (awareness, mapping, road infrastructure, mobility, etc.) A payment method through a monthly fee applied to basic utilities was also proposed. A closed-ended referendum question with bids based on a range of percentages regarding the cost of technical vehicle inspection ($26) was used. Although the CV literature has no consensus on how to treat protest responses, individuals who did not agree with the payment in this study did not face the valuation referendum question due to the risk of bias in the estimations (Soliño et al., 2010). The results of this study excluded 14,6% protest responses. These responses were related to several reasons for giving a zero WTP value to reduce road noise annoyance: (a) costs should be included in transportation prices, (b) government should pay all costs to reduce noise, (c) the effects of noise pollution from road traffic are negligible.

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