EVALUATING THE ECONOMIC COST OF AIR AND NOISE POLLUTION GENERATED BY TRANSPORT

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1. ABSTRACT

This paper presents the main findings of a stated preference study to examine the economic impact of air and noise pollution generated by transport. The purpose of this study was to estimate the economic cost of air and noise pollution using a series of discrete choice experiments. The choice experiments were constructed with varying levels of cost (in the form of a clean environment tax) and reductions in air and noise pollution. A survey was undertaken in Dublin, to obtain preferences for reductions in air and noise pollution using a random sample of individuals.. The estimated model coefficients demonstrate the significance of reductions in air and noise pollution by the time of day and impact of cost on the choices made.

The impacts of socio-economic and attitudinal variables are also tested and presented in the paper. The purpose of this analysis is to highlight what factors influence the choices made by respondents. The results from the choice scenarios are used to calculate willingness to pay amounts which are used to measure the economic cost of the externalities of air and noise pollution generated by transport. The paper concludes with a discussion of the results within a policymaking context, to contribute to the debate on the total cost of transport.

2. INTRODUCTION

The economic cost pollutants caused by transport is gaining increasing importance and relevance due to the ever expanding growth in the number of private cars on our roads. Figure 1 below demonstrates the growth in private cars from 1980 – 2004, this upward trend is set to continue. In 1999 car ownership was 342 per 1000 of population; this is anticipated to increase to 480 per 1000 of population by 2016 (Dublin Transportation Office, 2001). These increases will further exaggerate the problem of air and noise pollution generated from transport, and negatively impact upon our environment, health and the economy.

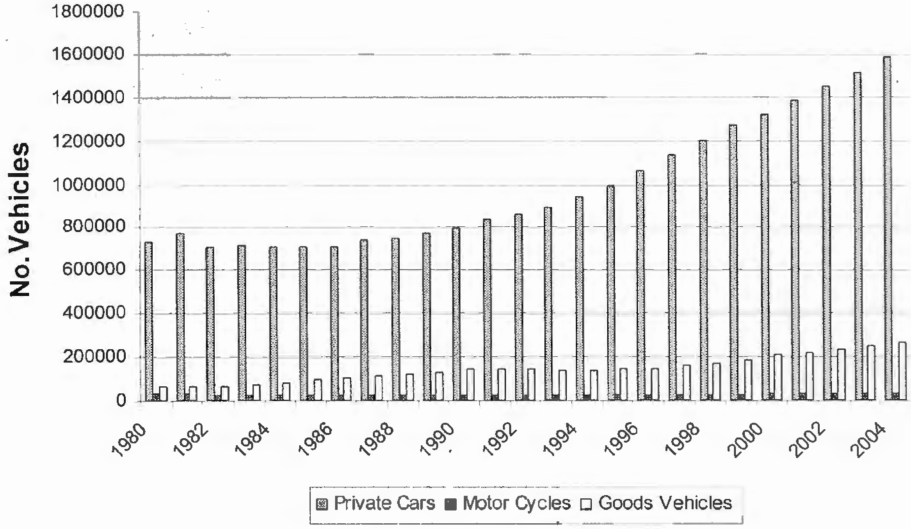

Figure 1 Growth in private (DEHLG, 2004)

This paper presents the findings of a stated preference study undertaken to place an economic value of air and noise pollution generated by road transport.

3. LITERATURE REVIEW

In 1999 Barreiro et.al (2005) conducted an evaluation of the impact of noise in Pamplona in northern Spain. In preparation for the study the levels of exposure to noise were measured. It was found that 59% of the readings taken were above 65dB, which according to the World Health Organisation (WHO) at this level can cause damage to health (WHO, 2004). The survey included several questions to ascertain individuals' levels of annoyance from high noise levels. A one and one half bounded exercise was used in the contingent valuation section of the survey. With the removal of protest bids, they found a WTP of €29 per annum for a 50% reduction in noise levels.

Lambert, (2000) completed a study in the Rhône-Alpes Region in France, to ascertain WTP to eliminate noise annoyance in residential areas. Respondents were asked to categorise annoyance between five different levels, "not at all", "slightly", "moderately", "very" and "extremely". At each of these levels respondents were willing to pay, €47, €61, €78, €101 and €130 respectively. The average WTP amount was €73 per annum to eliminate noise annoyance, with WTP increasing with levels of annoyance.

Sælensminde (1999) reports one of the first examples of choice modelling to analyse the impact of air and noise pollution. This study was conducted in Oslo, Norway in 1993, where a sample of 1680 respondents was interviewed at home to ascertain their WTP for improvements in air pollution and noise levels. The respondents in the study were offered several choice scenarios, in which journey times, cost, improvements in air pollution and sound levels were all presented and varied by scenario. These results are used to calculate WTP amounts for the population of Oslo, the results of which were also used by the Norwegian roads authority when building road projects.

Another approach used to estimate the value of a reduction in air and noise pollution is to look at the residential property market and vary the exposure to these pollutants. Ortúzar and Rodríguez (2002) adopt the approach of analysing how increases in pollution impact upon individuals choices of where to live, and measure their WTP for a reduction in this pollution. This study was conducted in Santiago, Chile where they experience significant air pollution. The scenario outlined in the study asked how much would the public benefit from a reduction in 'pollution alert days', which are days when air pollution reaches a certain level. The results demonstrated that respondents were willing to pay 1% of household income per year for a decrease of one 'alert day' per year.

One of the difficulties in the valuation of noise levels is how to convey to the respondent the levels of noise pollution. Arsenio *et.al* (2006) used the familiarity approach to illustrate levels of pollution to respondents of a survey in Lisbon. The familiarity approach describes to the respondent the levels of air pollution from a location that they would be familiar with, for example a main street in a city. The results from this study demonstrated that individuals were willing to pay €50 per annum to receive a 50% reduction in noise levels.

Wardman and Bristow (2004) conducted a study to analyse improvements in air and noise pollution, using choice modelling. One novel aspect of this research was that the authors used two different methods to value air pollution contingent valuation and choice modelling. This study was conducted in Edinburgh in 1996, with a sample of 403 households. This study looked at various aspects that might impact upon WTP for example it examined households that had taken noise prevention steps, such as installing double-glazed windows. The results from the study demonstrated that households with younger children had a higher WTP for improvements in air quality, and those that had taken noise prevention steps were willing to pay less. The study demonstrated when choice modelling and contingent valuation results are compared. Open-ended contingent valuation produced less reliable WTP values than choice modelling results.

Carlsson and Johansson (2000) present a contingent valuation study conducted to ascertain WTP for improved air quality in Sweden. The questionnaire developed for the study asked how much the respondents would value a 50% improvement in air quality in residential areas. An extensive econometric analysis was undertaken on the results which found that WTP increased with income, home ownership, education and those that were members of environmental agencies. It was also found that males were willing to pay a higher amount and that WTP reduced with the higher age groups and for those that were retired.

4. METHODOLOGY AND DATA COLLECTION

This section of the paper details the methodologies used to collect and analyse the data presented in this paper.

Data collection

The data collection tool used in this study was a paper based survey which was delivered to respondents homes, and was returned using a stamped envelope which was attached to the survey. A total of 500 surveys were delivered in the two areas. Table 1 details the number of surveys delivered to each area and the response rates. The total response rate for the survey was 38%.

	Area 1	Area 2	Total
Number of surveys delivered	220	280	500
Number of surveys returned	88	102	190
Response rate	40%	36%	38%

Table 1, Response rates

Two residential areas were surveyed in this study. The first site surveyed was in Rathfarham village. The residential units surveyed were in a block of apartments located in Rathfarham village, in Dublin 14. The site is located adjacent to two lane road, where one of the lanes is a bus lane. A map of the location and photograph of the adjacent road are displayed in figures 2 and 3. The residential units are located approximately 20 feet from the road side.

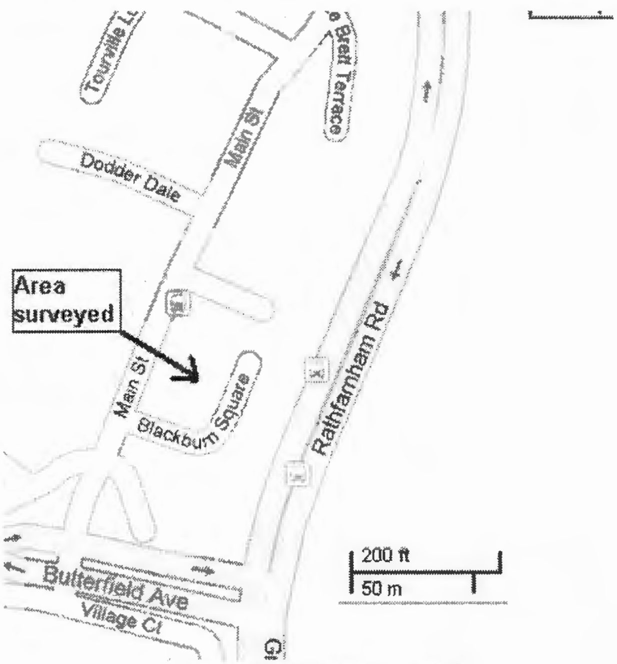

Figure 2, Rathfarham site – map

Figure 3, Rathfarham Site - Photograph

To get an indication of the traffic levels at both sites, a series of traffic counts were completed. At the Rathfarham site counts were taken on the two consecutive Tuesdays, the 20th and 27th September 2006. An average of both days is presented in figure 4. Counts were taken between 07.30 and 09.30, 16.30 and 18.30 and 22.00 and 23.00. The results from the traffic counts show that in the morning traffic volumes are in excess of 1,100 vehicles per hour during the peak. In the evening peak the traffic count shows that approximately 1,300 per hour vehicles were counted. The night time count shows that on average 460 vehicles per hour use the road.

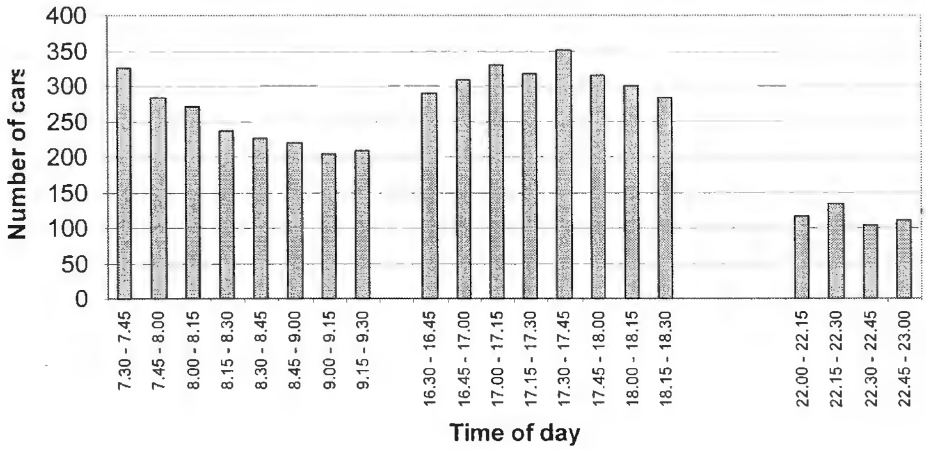

Figure 4, Traffic count - Rathfarham

The second site surveyed, was a large residential estate between Dundrum and the Sandyford Industrial Estate, in Dublin 18. The residential units in this estate are typically 3 bed roomed semi-detached houses. A map of the area and a photograph of the adjacent road are presented in figures 5 and 6. The road adjacent to the estate is a single lane road, and it is located approximately 100feet from the nearest residential unit.

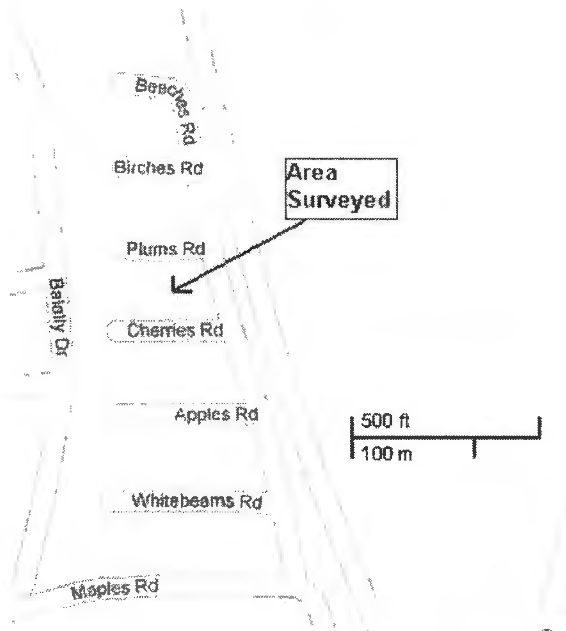

Figure 5, Dundrum Site - Map

Figure 6, Dundrum Site - Photograph

A traffic count was taken on the road adjacent to the Dundrum site on two consecutive Wednesdays the 19th and 26th of September 2006, an average of the counts on both days are presented in figure 7. The results of the traffic counts show that in the morning peak approximately 1,100 vehicles per hour use the road. The evening peak figures show that 1,200 vehicles per hour use the road, and the night time count found that approximately 460 cars per hour travel on the road.

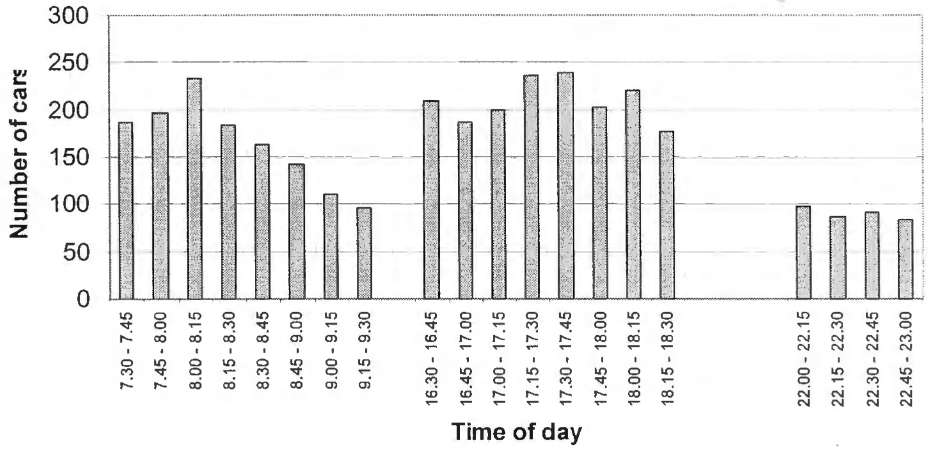

Figure 7, Traffic count – Dundrum

The traffic volumes measured at both sites display similar traffic flows per hour, with the Rathfarham site experiencing marginally higher flows. The specific difference between the two sites is the proximity of respondents to the road and the residential unit type. Residents at the Rathfarham site live in a much closer proximity to the traffic, whereas those at the Dundrum site are based further away from the traffic. These differences are explored in the subsequent sections, to ascertain if the proximity of the respondents impacts upon their opinions of air and noise pollution. In the interests of brevity from this point forward the Rathfarham site is referred to as area 1, and the Dundrum site as area 2.

Scenarios examined

In stated preference studies individuals are asked to choose between a number of alternatives which vary by their attribute levels. An alternative in this study refers to a reduction in air or noise pollution levels. The attributes of these alternatives are the identifying factors which define these alternatives; in the case of this study, cost of a reduction in air or noise pollution, reduction in air or noise pollution.

In order for individuals to choose between the options presented in this study, it is necessary to place a monetary and percentage reduction in air and noise pollution levels. The attributes and attribute levels used in the study are presented in tables 2 and 3. The cost of reducing air and noise pollution was presented to respondents by way of an annual tax. The monetary amounts for these taxes were taken from the Irish figures for noise and air pollution estimated in the HEATCO report (HEATCO, 2004). The values for percentage reductions in air and noise pollution levels were applied having examined the literature (Ortúzar and Rodríguez, 2002 and Wardman and Bristow, 2004). Option three in the study represents a status quo option, in other words respondents were given the option of choosing not to change the current levels of air or noise pollution.

	Attribute Levels		
Attributes	**Option 1**	**Option 2**	**Option 3**
Cost	€50 per annum	€50 per annum	-
	€250 per annum	€250 per annum	-
	€500 per annum	€500 per annum	-
Reduction in noise pollution	10%	10%	-
	25%	25%	-
	50%	50%	-

Table 2, Attributes and Attribute Levels – Noise study

	Attribute Levels		
Attributes	**Option 1**	**Option 2**	**Option 3**
Cost	€50 per annum	€50 per annum	-
	€250 per annum	€250 per annum	-
	€500 per annum	€500 per annum	-
Reduction in air pollution	10%	10%	-
	25%	25%	-
	50%	50%	-

Table 3, Attributes and Attribute Levels – Air pollution study

Modelling approach applied

Discrete choice models are usually derived under the premise of a utility maximising consumer and therefore use random utility theory. This sub-section presents the main aspects of this theory. In random utility theory it is assumed that an individual will derive utility from alternatives J. The utility that one derives from alternative j, is $U_{nj}, j = 1,...,J$. An individual will choose the alternative that he/she will derive the highest utility from. As stated in equation 1, the individual will only choose alternative i, if and only if the utility he/she derives from this alternative is greater than all the other alternatives in the choice set.

Equation 1

$$U_{in} > U_{ij} \forall j \neq i$$

In the case of this study, the respondent will only choose the real-time transport information option he/she derives the maximum utility from. Utility is assumed to be composed of a deterministic component V_i and a random component ε_i. The deterministic component can be measured, as this component is related to the alternatives in the choice set. The random section cannot be measured, and the most appropriate way to model this component is to assign a distribution to the random element and estimate the probabilities of choice. Therefore, in random utility models the utility expression is outlined in equation 2.

Equation 2

$$U_i = V_i + \varepsilon_i$$

Therefore, the probability that the respondent will choose alternative i is the probability that the utility of that alternative is greater than any of the other alternatives in the choice set. These probabilities are then modelled using the multinomial logit model (MNL).

The MNL is one of the most widely used discrete choice models, used to analyse stated preference studies. The model is derived under the premise that the error term is identically and independently distributed or Gumbel distributed. This results in the probability of choosing an alternative as expressed in equation 4.

Equation 4

$$P_i = \frac{e^{V_i}}{\sum_{j=1}^{J} e^{V_j}}$$

P_i is the probability that the individual will choose alternative i, V_i is the deterministic element of utility for alternative i and J is the number of alternatives in the choice set. The coefficients presented in table 4 are then estimated using the maximum likelihood estimation procedure; see Train, 2003, Hensher et al 2005 or Louviere et al 2000 for a comprehensive review of this procedure.

5. CHARACTERISTICS OF THE SAMPLE

Socio-economic characteristics

Table 4 details the findings from a series of demographic and attitudinal questions presented to respondents in the survey. 46.3% of respondents were found to be male and 53.7% female. The age profile of the respondents was found to be representative of all age groups, 37.0% were aged 25-34, 22.2% were aged 35-44 and 22.2% aged 55-64. Respondents were found to have income at the top end of the scale presented. 16.7% of respondents earn €50,001 - €60,000 and 37.0% earn more than €60,000 per annum.

Characteristic		N	%
Gender	Male	88	46.3
	Female	102	53.7
	Total	190	100.0
Age	Under 24	7	3.7
	25-34	70	37.0
	35-44	42	22.2
	45-54	42	22.2
	55-64	28	14.8
	65 and over	-	-
	Total	190	100.0
Income	Less than €10,000	4	1.9
	€10,001 - €20,000		-
	€20,001 - €30,000	18	9.3
	€30,001 - €40,000	25	13.0
	€40,001 - €50,000	21	11.1
	€50,001 - €60,000	32	16.7
	More than €60,000	70	37.0
	I do not wish to answer	21	11.1
	Total	108	100.0

Table 4, Socio-economic Characteristics of the sample

Perceptions of current public transport information sources

The findings in this section relate to how respondents perceive the current air and noise pollution levels in their respective residential areas. In the survey respondents were asked to indicate their opinion on the current levels of air pollution, these results are presented in table 5. 7.5% of respondents in area 1 indicated that the air quality in their area was either very poor or poor. In area 2 none of the respondents indicated that air quality was very poor or poor. 57.5% of the respondents from area 1, and 37.9% of respondents from area 2, indicated that air quality was good.

Option	All	Area 1	Area 2
	%	%	%
Very Poor	6.8	2.5	-
Poor	2.7	5.0	-
Fair	28.8	25.0	37.9
Good	46.6	57.5	37.9
Very Good	15.1	10.0	24.2
Total	100.0	100.0	100.0

Table 5, Residential Air Quality Levels

Table 6 presents the results from the noise survey with regard to the perceived noise pollution levels. The results demonstrate that 13.5% of respondents in area 1 indicated that the noise levels to be very poor and 18.9% that the levels are poor. In area 2, 8.7% think the noise levels are very poor and 21.7% are poor. 43.5% of respondents in area 2 and 24.3% of respondents in area 1 indicated that the noise levels were good in their respective areas.

Option	All	Area 1	Area 2
	%	%	%
Very Poor	11.7	13.5	8.7
Poor	20.0	18.9	21.7
Fair	33.3	40.5	21.7
Good	31.7	24.3	43.5
Very Good	3.3	2.8	4.4
Total	**100.0**	**100.0**	**100.0**

Table 6, Residential Noise Quality Levels

In the survey, respondents were asked to indicate their level of annoyance with current air and noise pollution levels, the results of which are presented in tables 7 and 8. 21.1% of respondents from area 1 and 36.8% from area 2 indicated that they were not at all annoyed by noise pollution. 16.5% of respondents from area 1 and 5.3% from area 2 were very annoyed by noise levels. None of the respondents indicated that they were extremely annoyed by the current noise pollution levels.

Option	All	Area 1	Area 2
	%	%	%
Not at all annoyed	35.2	21.1	36.8
Slightly annoyed	25.4	31.6	21.1
Moderately annoyed	33.8	30.8	36.8
Very annoyed	5.6	16.5	5.3
Extremely annoyed	-	-	-
Total	**100.0**	**100.0**	**100.0**

Table 7, Annoyance levels related to noise pollution

Table 8 presents the results from the air pollution results relating to the annoyance with current air quality levels. The results demonstrate that regardless of area surveyed the majority of respondents were not annoyed by current air pollution levels. 27.5% of respondents from area 1 and 30.0% from area 2 indicated that they were moderately annoyed by air pollution. The results show that only a small percentage of respondents were either very annoyed or extremely annoyed by air pollution levels.

Option	All	Area 1	Area 2
	%	%	%
Not at all annoyed	38.6	35.0	43.4
Slightly annoyed	28.6	32.5	23.3
Moderately annoyed	28.6	27.5	30.0
Very annoyed	2.8	2.5	3.3
Extremely annoyed	1.4	2.5	-
Total	**100.0**	**100.0**	**100.0**

Table 8, Annoyance levels related to air pollution

6. MODEL RESULTS

Model performance and interpretation

In the MNL models presented in this paper there are two methods of measuring model performance by examining the *t*-ratios and the $\rho^2(0)$ and $\rho^2(c)$ values. The coefficients *t*-ratio measures the level of significance of the variable in question. Values above ±1.9 indicate that the variable is significant at the 95% confidence level and above ±2.56 significant at the 99% confidence level.

Results of the Air pollution model

One of the main objectives of surveying individuals in two areas was to ascertain how the different characteristics of each area impact upon the benefits derived from an improvement in air quality. To this extent the sample was split by the areas surveyed. Model M1 represents respondents from area 1 and model M2 those from area 2 (see table 9). To recap area 1 is the site in Rathfarham were higher traffic volumes were recorded and residential units are closer to the road, area 2 is the site in Dundrum, with lower observed traffic volumes and residential units are situated a greater distance from the road. See section 1.3 for a full description of these areas. The models presented in table 9 both demonstrate good model specification, as the $\rho^2(0)$ and $\rho^2(c)$ values were estimated to be 0.247 and 0.204 for model M1 and 0.254 and 0.231 for model M2.

The estimated coefficients for the cost of reducing day time air pollution levels were both found to be negative and significant at the 99% confidence level with t-ratios of -2.9 and -2.8 from models M1 and M2 respectively (see table 9). A comparison between the costs of an improvement in day time air pollution levels demonstrates that respondents in area 2 have a lower cost coefficient of -0.014 compared to -0.042 for area 1. This result suggests that respondents in area 2 are more likely to pay for an improvement in day time air quality. The coefficients estimated to represent an improvement in day time air pollution for areas 1 and 2 were -9.893 and -4.757 respectively (see models M1 and M2 in table 9). These results show that respondents residing in area 1 derive a greater benefit from a reduction day time air pollution compared to those living in area 2.

The cost coefficients were found to be negative and significant at the 95% and 99% confidence levels with t-ratios of -2.4 and -2.6 for areas 1 and 2 respectively (see models M1 and M2 in table 9). The estimated value for area 1 was -0.053 and -0.034 for area 2. As with the findings for a reduction in day time air pollution levels, these coefficients show that individuals in area 2 are more likely to be willing to pay for a reduction in night time air pollution. The estimated coefficients for a reduction in air pollution were found to be negative and significant at the 99% confidence level (see table 9). The coefficient value for area 1 was found to be -4.571 and -3.677 for area 2. These values show that respondents in area 1 derive a greater benefit from a reduction in air pollution levels compared to those residing in area 2.

Finally, a comparison between day time and night time reductions in air pollution levels shows that respondents in both areas are more likely to pay for a reduction in day time air pollution levels as the cost coefficients were found to be lower for a day time reduction. The utility derived from a reduction in air pollution was found to be higher for a day time reduction compared to a night time reduction as the estimated coefficients were found to be higher.

Variables		Model M1	Model M2
Day time reduction	Cost of improvement	-0.042 (-2.9)	-0.014 (-2.8)
	Reduction in air pollution	-9.893 (-3.2)	-4.757 (-2.8)
Evening reduction	Cost of improvement	-0.053 (-2.4)	-0.034 (-2.6)
	Reduction in air pollution	-4.571 (-2.7)	-3.677 (-2.9)
N		762	894
$\rho^2 (0)$		0.247	0.247
$\rho^2 (c)$		0.204	0.231
Final Likelihood		-312.72	-367.05

Table 9, Air Pollution Models – Area 1 and 2

Results of the noise pollution model
This section of the paper compares the two areas sampled in this study for differences in the reported preferences for reductions in noise pollution levels. This subsection applies the same methodology used in section 3.4 to split the data set between the two areas surveyed to produce coefficients specific to the respondents in each area. The $\rho^2(0)$ and $\rho^2(c)$ values for the models presented in table 10 were estimated to be 0.307 and 0.253 for model M3 and 0.295 and 0.249 for model M4. The $\rho^2(0)$ and $\rho^2(c)$ values for both models are within acceptable bounds and demonstrate a good model performance.

The estimated cost coefficients for reducing day time noise pollution levels were both found to be negative and significant at the 99% confidence level with values of -3.8 for model M3 and -5.5 for model M4. A comparison between the costs of an improvement in day time noise levels demonstrates that respondents in area 1 have a lower cost coefficient of -0.030 compared to -0.048 for area 2 (see models M3 and M4 in table 10). These findings indicate that respondents in area 1 are more likely to be willing to pay for a reduction in noise pollution levels compared to their counterparts in area 2.

The coefficients estimated to represent an improvement in day time noise pollution levels for areas 1 and 2 were -4.023 and -3.145 respectively (see models M3 and M4 in table 10). These coefficients were also found to be significant at the 99% confidence levels with t-ratios of -6.1 and -5.1 in models M3 and M4 respectively. The results show that respondents residing in area 1 derive a greater benefit from a reduction day time noise pollution compared to those living in area 2.

The cost of reducing night time noise pollution coefficients were found to be negative and significant at the 99% confidence level with t-ratio values of -5.2 and -6.7 for models M3 and M4 respectively (see table 10). The cost coefficient from the area 1 model was found to be -0.021 and -0.042 for area 2. These findings indicate that individuals living in area 1 have a greater likelihood of being willing to pay for a reduction in noise levels than the respondents who reside in area 2.

The estimated coefficients for a reduction in noise pollution were found to be negative and significant at the 99% confidence level (see models M3 and M4 in table 10). The coefficient value for area 1 was estimated to be -4.023 and -3.145 for area 2. These values show that respondents in area 1 derive a greater benefit from a reduction in noise pollution levels compared to those residing in area 2.

The estimates produced in table 10 show that respondents in both areas derive a greater benefit from a reduction in night time noise levels. This preference for a reduction in night time noise levels is demonstrated by the lower cost of improvement coefficients and the higher reduction in noise coefficients for a night time improvement.

Variables		**Model M3**	**Model M4**
Day time reduction	Cost of improvement	-0.030 (-3.8)	-0.048 (-5.5)
	Reduction in noise	-2.346 (-2.3)	-2.597 (-2.6)
Evening reduction	Cost of improvement	-0.021 (-5.2)	-0.042 (-6.7)
	Reduction in noise	-4.023 (-6.1)	-3.145 (-5.1)
N		811	953
$\rho^2 (0)$		0.307	0.295
$\rho^2 (c)$		0.253	0.249
Final Likelihood		-459.16	-501.35

Table 10, Base Air Pollution Models – Area 1 and 2

7. CONCLUSIONS

The sampling strategy used in this study was designed to collect data from two different sites in a similar area with differing proximity to road traffic. In the first area the residential units were located in close proximity to the adjacent road. The second location was also located near a busy road with heavy traffic; however the residential units were located further away the adjacent road. A comparison between the sites demonstrated that those individuals living in close proximity to the adjacent road were found to derive a higher benefit from reductions in air and noise pollution.

In the study, respondents were asked to value both reductions in day time and night time air and noise pollution levels. The results from the air pollution models and the willingness to pay estimates demonstrate that respondents were willing to pay more for a day time reduction in air pollution levels. The opposite results were found from the noise models, with respondents exhibiting a preference for a reduction in night time noise levels.

The results of this study demonstrate that individuals do place an economic value on the impacts of air and noise pollution on their quality of life. The values presented in this study provide an indication of how air and noise pollution negatively impact upon the economy and how steps toward reducing current levels will generate an economic benefit to society.

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