

# **ESTIMATING THE BENEFITS OF TRAFFIC CALMING**

## **ON THROUGH ROUTES:**

### **A CHOICE EXPERIMENT APPROACH**

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## **ESTIMATING THE BENEFITS OF TRAFFIC CALMING ON THROUGH**

### **ROUTES: A CHOICE EXPERIMENT APPROACH**

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#### **Abstract**

Excessive speed is a major contributory factor in a large proportion of deaths and serious injuries on British roads. One approach to tackling the speeding problem is the use of traffic calming measures as a means of enforcing speed restrictions along roads running through populated areas. But speed reduction is only one of the benefits of traffic calming. This paper reports the results of a series of choice experiments that were used to investigate the willingness to pay (WTP) of a sample of local residents in three English towns for traffic calming measures that would achieve a range of reductions in speed, noise and community severance. Utility difference indices are estimated from logit models based on responses to the choice experiments. These revealed that local people had a positive WTP for a reduction in the negative impacts of road traffic and for more attractive, rather than basic, designs of the traffic calming measures. Some specifications of the logit model corroborate the hypothesis that WTP for reducing the negative impacts of traffic calming is lower for local households living outside visible and audible range of the road.

## **Introduction**

Improving road safety is a major objective of the UK Department of Environment, Transport and the Regions (DETR). In the last decade a series of road-safety initiatives has succeeded in achieving substantial reductions in the numbers of deaths and serious injuries on Britain's roads. Compared with average figures for 1981-85, the number of road deaths in 1997 was 36 per cent lower at 3,599, while the number of serious injuries had fallen by 42 per cent to 42,967 (DETR, 1999). At the same time the number of non-serious road injuries had increased significantly, resulting in an overall increase in road casualties to 327,544 (DETR, 1999).

According to the DETR, excessive speed is thought to be responsible for over 1,200 deaths and a further 100,000 casualties every year and is therefore a key target in any integrated strategy to reduce traffic-related injuries. Recently a number of police chiefs, pressure groups and politicians have all called for reductions in national speed limits both on arterial roads and within urban areas. These calls are supported by the findings of various surveys of the general public in the UK. For example, a recent Council for the Preservation of Rural England (CPRE) survey of users of country lanes showed that 91% of respondents felt that the current speed limit of 60 mph on many such roads should be reduced, with 99% of supporters calling for a speed limit of 40 mph or less, with many supporting a 20 mph limit in villages (CPRE, 1999).

Reductions in speed limits would probably have to be enforced by increased police vigilance, the increased use of speed cameras and a higher incidence of prosecution, even for minor breaches of the speed limit. The achievement of lower speed limits

might be questionable where policing of speed restrictions is ineffective, whilst continual police enforcement might be extremely costly and politically unpopular.

An alternative approach is the introduction of increased traffic calming measures along those roads where excessive speed is judged to be a serious safety risk. Traffic calming comprises a set of modifications to a road layout and associated traffic information signs in order to improve road safety and environmental quality. Unlike legal speed restrictions, the physical barriers placed by traffic calming generally remain effective even when there is no risk of prosecution. A considerable amount of research has been undertaken on the physical outcomes (e.g. speed, accident, and traffic flow reductions) of various traffic calming measures, as well as the cost of their implementation (County Surveyors Society, 1994). However, relatively little is known about the magnitude of the benefits that local residents derive from traffic calming schemes.

The purpose of this study is, therefore, to estimate these benefits and to investigate how they are related to the various outcomes of traffic calming, including reductions in speed, traffic noise and the length of pedestrian waiting time before the road can be safely crossed. The study is novel in that stated preference (SP) choice experiments are used for the first time to estimate the benefits of traffic calming. Also of interest is the observation that a model which is non-linear in some variables is required to generate the most data-consistent and informative measures of benefits.

A range of measures exist to calm traffic, many of which can be implemented with varying degrees of quality in design and construction. Because any particular scheme

will consist of one of many thousands of possible combinations of individual traffic calming elements, it is impossible to value individual elements through an additive independent utility function. Hence, the approach adopted in this paper is to value the change in welfare that residents derive from the outcomes of traffic calming, namely varying degrees of reduction in speed, noise, visual impact and the time needed by pedestrians to safely cross the road (a measure of community severance). This information can then be used in assessing the economic benefits of alternative designs of a traffic calming scheme. For example, from the various combinations of traffic calming measures that would achieve specified speed, noise and severance reductions, local highway authority engineers could select a configuration which best equates the benefits and costs of the scheme at the margin.

The next section briefly describes some of the different options available to highways departments for traffic calming. This is followed by a description of the choice experiment methodology adopted in this study to investigate public preferences for the various outcomes of traffic calming. The results of the choice experiments are then discussed along with the implications that they have for the design of traffic calming schemes in the UK.

### **Traffic calming schemes**

Traffic calming schemes on arterial or trunk roads can usually be divided into two parts: (a) on the approach to a settlement, measures to warn drivers of speed restrictions ahead and to encourage them to adopt a different style of driving behaviour

through the settlement; and (b) within a settlement, measures to ensure speed reductions and to restrict traffic flow.

Restricting the flow of traffic contributes to speed reductions and also provides opportunities for pedestrians to cross the road. A variety of traffic calming measures are available to improve environmental conditions to local residents, to reduce speed and the frequency and severity of accidents along roads. The most common generic traffic calming devices are road humps, speed cushions and chicanes (Boulter and Webster, 1997). Numerous other measures exist including: raised junctions; rumble strips; pinch points; street furniture; speed cameras; road signs; speed limits; weight and width restrictions. Combinations of these measures can be used at varying distance intervals along a stretch of road to generate a desired set of outcomes in terms of the speed and flow of traffic (see Collins, 1997).

Research has revealed a link between changes in mean speeds and changes in accident frequencies, with a 1 mph reduction in mean speed resulting in a 5% reduction in accident frequency. Road humps are one of the most effective forms of reducing traffic speed and use vertical deflection to ensure that vehicles slow down when crossing them. Speed cushions, a variant on the basic road hump, are designed to reduce discomfort and minimise delays to buses, ambulances, and fire engines, by only covering only part of the road width and allowing vehicles with wider track widths to straddle the cushions. Vertical deflection for cars is maintained, with these vehicles being forced to ride over at least one of the cushions. Consequently speed cushions

are not as effective as road humps at reducing traffic speed.<sup>1</sup> Chicanes reduce speed by horizontal deflection, with traffic often being restricted to a single lane working through the chicane on a two-way road. Mean speeds on track trials through chicanes have been calibrated against chicane parameters: stagger length, free-view width, land width, and visual restriction (Sayer and Parry, 1994)<sup>2</sup>.

Other elements in traffic calming schemes comprise measures such as countdown signs to the 30 or 40 mph speed limit or 'REDUCE SPEED NOW' signs, 'dragon teeth' markings, red surface treatment, speed camera signs, etc.. Some of these elements are only mildly successful at reducing road speeds. For example, on the A49 at Dorrington, Shropshire, mean and 85th percentile speeds were observed to fall by 8-15 mph at the entry gateways of the village's traffic calming scheme, but to have increased by the time drivers were in the heart of the village, with only a 2-4 mph average speed reduction achieved, with the 85th percentile still 2 mph above the speed limit (Wheeler, 1997). At other sites these measures appear to have been even less effective<sup>3</sup>.

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<sup>1</sup> In a study of 34 traffic calming schemes using speed cushions, Layfield and Parry (1998) estimated the overall average mean and 85th percentile speeds at cushions (17 and 22 mph respectively) to be 2 to 7 mph higher than those measured at 75mm flat top and round top humps; with mean speeds at narrow (1600 mm) cushions of 20 mph and 16 mph at wider 1900 mm cushions. A longer spacing between sets of cushions results also affects speed at the mid-point between cushions: a 60m spacing results in a mean speed of 21 mph; whilst with a 100 m spacing the mean speed is 26 mph.

<sup>2</sup> In a subsequent study of 49 chicane schemes (each involving between 1 and 10 chicanes) Sayer *et al* (1998) found average mean and 85th percentile speeds of 23 mph and 28 mph respectively at the chicanes. Each represented average speed reductions of 12 mph, compared to speeds observed before the schemes were installed; and average reductions of 7-8 mph were recorded in mean and 85th percentile speeds between chicanes. Chicanes are not always installed as site specific accident reduction measures, but 17 schemes studied by Sayer *et al* (1998) which had known before and after accident data, there was a 54% reduction in accident frequency.

<sup>3</sup> For example, on the A59 at Copster Green, Lancashire, where mean and 85th percentile speeds fell by 3-5 mph inbound at the gateways and by 2-3 mph within the village. Overall at this site the reduction in speed was probably not enough for the change to be subjectively noticeable in the village (Wheeler and Nicholls, 1996).

## **Choice Experiments**

In this study the value of some benefits of traffic calming (reductions in speed, noise, and waiting time to cross the road, as well as the value of improvements to the physical appearance of traffic calming measures) are estimated through a choice experiment. Choice experiments apply the probabilistic theory of choice (Ben-Akiva and Lerman, 1985), where the choices made by individuals from a non-continuous set of alternatives are modelled in order to reveal a measure of utility for the choice attributes (Hanley *et al.*, 1998). This technique has only recently been extended to estimate the impacts on economic welfare from changing the provision of public goods in the US and Europe (e.g. Viscusi *et al.*, 1991; Opaluch *et al.*, 1993; Adamowicz *et al.*, 1994; Garrod and Willis, 1998), but various types of choice experiment have been used by psychologists since the 1960s, and in transportation (e.g. Hensher, 1994) and marketing research (see Louviere, 1988; 1996; Batsell and Louviere, 1991) since the early 1970s.

The use of SP choice experiments in the transport sector has been outlined by Kroes and Sheldon (1988) who illustrate their application to preference evaluation, demand analysis, and forecasting. Louviere (1988) has reviewed the pros and cons of different types of estimation procedures to investigate particular transport issues, and advocates the use of discrete choice tasks over ranking or rating exercises where the purpose is to make inferences about choice behaviour. Particular problems in choice experiment methodology, such as the consistency of estimators when the number of observations per respondent is increased, have been tackled by Ouwersloot and Rietveld (1996); whilst Peterson and Brown (1998) have analysed whether the paired comparison

approach reveals inconsistent choices and yields preference order over the set of items being compared. Questions of validity of SP estimates have been assessed both by comparing revealed preference and SP values (Wardman, 1988; Preston, 1991); and by correctly accounting for the error structure of SP models (Bates, 1988).

The factors used in the choice experiment designed for this study were three outcomes of traffic calming: (i) an effective speed limit (ESL); (ii) reduced noise level from road traffic; (iii) reduced length of waiting time for pedestrians to cross the road;<sup>4</sup> and two other factors: (iv) the overall appearance of the traffic calming scheme; and (v) the annual cost per household of the traffic calming in terms of increased local taxation. The focus on outcomes, rather than on technical design of the traffic calming scheme, makes for an easier and more immediate interpretation of the policy effects. In the choice experiment, respondents were offered two profiles based on this attribute set and asked to choose the one that they most preferred. A 'no-choice' option was available to respondents who preferred the status quo to either of the alternatives offered: the omission of this option could lead to sample-selection problems. The choice experiment was repeated with different paired alternatives eight times.

In order to reduce the complexity of the design of the choice experiments only a limited range of factor or attribute levels were used in the profiles. Thus, only two ESL levels (20 or 30 mph) and three noise levels (60, 70 or 80dB) were used; while the aesthetic component of the traffic calming layout could be either 'basic' or 'improved'; and waiting time for crossing the road could be either short (1 minute) or

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<sup>4</sup> Reduction in the frequency of accidents was not included in the choice experiment since it is a function of the reduction in speed; whilst studies of the value of safety have revealed that people's

long (3 minutes). The latter two attributes were coded using 0-1 dummy variables. Three annual cost levels (£10, £20 or £30) were used to explore local households' WTP for traffic calming schemes. The interviews took place in person and respondents were exposed to pre-recorded traffic noise which was played in their presence at the three decibel levels. An example of the aesthetic effects associated with the basic and improved design was portrayed using pictures of existing traffic calming schemes.

Since individuals were asked to choose only one alternative from each set of profiles shown to them, a random utility model (e.g. McFadden, 1973) could be used to investigate how the choices relate to attribute levels. Such models are based on the hypothesis that individuals make choices based on the attributes of the alternatives (an objective component) along with some degree of randomness (a random component). This random component is consistent with random individual preferences. It is also consistent with the realistic notion that the researcher only has a partial knowledge of the real structure of the respondent's preference, while the unknown component is assumed to behave stochastically.

Based on repeated observations of choices, one can examine how the levels of various attributes influence individual utility and compare them with *a priori* expectations. In this study the derivation of these *a priori* expectations is straightforward. An increase in the noise level (in decibels) generated by traffic should reduce an individual's utility, as should an increase in the ESL (which would be expected to increase the likelihood

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ability to process simple probability information to derive coherent, consistent, and reliable answers, is disappointing (Jones-Lee et al, 1985).

of speed-related road accidents). This would suggest that the estimated coefficient values for the associated attribute variables *Noise* and *Speed* should be negative. Similarly, an aesthetically improved design and a shorter waiting time should increase utility: as both of these are indicated in the dummy variables *Beauty* and *Wait* by values of 1, the estimated coefficient values for the associated coefficients should both be positive. Finally, as most individuals have a positive utility for income the estimated coefficient value for the cost variable *tax* should be negative.

A number of different assumptions can be made about the distribution of the random term in the model. An assumption of normality leads to the multivariate probit model, while the assumption of a Gumbel distribution means that the conditional (e.g. McFadden, 1973) or Mother Logit (MOL) (Anderson *et al.* 1992) can be employed to examine the factors explaining the choice of one alternative over another.

In practice, many choice experiments are designed under the assumption that the decision process can be modelled using an MOL approach. The MOL approach is based on the estimation of likelihoods and odds and is thus suitable for examining discrete choices. Typically, choices are predicted based on the premise that in choosing amongst alternatives respondents seek to maximise their utilities.

A key assumption of the MOL model is the independence of irrelevant alternatives (I.I.A.). This means that the researcher assumes that the probability of choosing one alternative in preference to another is not influenced by other available alternatives that are not being considered. Thus, in a pairwise comparison the choice between the two profiles on offer is assumed not to be influenced by the possibility that other profiles

could be chosen. Some critics regard this assumption as a flaw in choice experiment methodology, suggesting that in empirical applications this assumption is usually violated (Carson *et al.*, 1999). For example, before making a decision on a particular choice, rational consumers may consider all other available choices. However, in the context of public policy often the domain of alternatives is restricted to very few, for example in local referenda the choice is normally between two alternative courses of action. For this reason the I.I.A. assumption is maintained here *a priori*. It is worth mentioning that recent developments in the computational speed of microcomputers allow researchers to employ estimation methods based on simulations. These make estimation feasible for logit models that do not rely on the I.I.A. assumption, such as the mixed logit model (Train, 1998).

Where MOL is used to specify a linear-in-parameters utility difference model the values of the coefficient attributes can be used to determine the relative utilities across attributes (Lareau and Rae, 1989; Mackenzie, 1993). When cost is included in this specification, utility changes resulting from a change in attribute levels may be rescaled to monetary measures. This allows the analysis of how respondents trade-off changes in the utility of money with respect to the utility of other attributes.

In order to reduce the magnitude of the task facing respondents and to reduce the computational complexity of estimation, the desired set of attributes and attribute levels used to define the profiles can be specified using a factorial or fractional factorial experimental design (Adamowicz *et al.*, 1994). A common approach to this is to select the smallest orthogonal main-effects plan, sampled from the complete factorial design, to select the profiles to be used in the choice experiment (Louviere and

Woodworth, 1983; Louviere, 1988). This is a necessary and sufficient condition for estimating the parameters of the MOL model (Louviere and Woodworth, 1983). In this case, the use of only five attributes each with only two or three levels meant that a fully factorial design could be used, though this was reduced by the omission of dominated choices, where one profile offered an unambiguously higher utility than the other. Inclusion of these cases offers no additional information to the researcher as the choice decision is trivial.

### **Study sites and sample**

Three locations without any existing traffic calming measures were selected for the study. These were (1) Haydon Bridge on the A69 west of Hexham; (2) Rowlands Gill on the A694 near Gateshead; and (3) Seaton Sluice on the A193 between Whitley Bay and Blyth. Prior to the implementation of the surveys measurements of noise, speed, and potential severance were taken at each location. Noise was measured at each location in respect of two sites: the pavement (site A) and the nearest residence to the line of traffic (site B). Dim noise and peaks were measured at various times throughout the day. Measurement points for speed varied with the features of each place, but speed was generally measured between the gateway and some point at the centre of the settlement. The median and 85<sup>th</sup> percentile speed for the three locations are presented in Table 1. Severance was measured by the average time it took a sample of local residents to cross the road at different times throughout the day. These measures were used to calibrate the choice experiments. Status quo conditions were used to define the values of the attributes in the zero-option alternative during the estimation.

Prior to the surveys, the authors used a combination of focus groups and informal interviews with local people to investigate the negative impacts of traffic at each site. As a means of improving prediction when modeling choice decisions, interviewers recorded approximately how far a respondent's house was from the main road (Category 1 - less than 50 yards; Category 2 - between 50 and 100 yards; Category 3 - between 100 and 200 yards; and Category 4 over 200 yards), whether or not the road (and potentially any future traffic calming) was visible from the house, and whether or not road noise could be heard from inside the house. These observations were used to generate the following variables *Dist* (1,2,3,4), *Visible* (0-1) and *Audible* (0-1), which were modeled interactively in the SP analysis (see Table 2).

### Estimation and Results

A total of 414 usable interviews were carried out across the three locations, yielding 3312 responses for the choice experiment. In 77 of the 414 cases the main road was visible from the respondent's house, though road noise was audible from within the house in 30 cases.

The usual assumption supporting the conditional logit model are invoked here. The probability of respondent  $i$  choosing alternative  $j$  conditional on the set of attributes  $\mathbf{x}$  (row vector) and a column vector of parameters  $\mathbf{b}$  is specified as:

$$\Pr(ij|\mathbf{x},\mathbf{b}) = \exp(\mathbf{x}_i\mathbf{b})/\sum_j\exp(\mathbf{x}_i\mathbf{b}), \quad (1)$$

as a consequence the likelihood of the sample is:

$$L = \prod_i \Pr(ij|\mathbf{x},\mathbf{b}) = \prod_i \exp(\mathbf{x}_i\mathbf{b})/\sum_j\exp(\mathbf{x}_i\mathbf{b}). \quad (2)$$

Maximum likelihood estimates ( $\mathbf{b}_{ML}$ ) for the parameter vector can be obtained by maximizing the logarithm of the above likelihood. As McFadden shows (1973, see also Anderson 1992) the linear index

$$V_{ML} = \mathbf{x}\mathbf{b}_{ML} \quad (3)$$

is consistent with random utility theory and it can be interpreted as an estimate of the utility difference.

Table 2 reports the conditional logit estimates for  $\mathbf{b}_{ML}$  of six specifications of  $v$  investigating the impact of traffic calming attributes on utility. These models all include the various traffic calming attributes incorporated in the choice profiles (i.e. *Noise*, *Speed*, *Beauty*, *Wait* and *Tax*) but differ in the use of interaction terms based on variables indicating distance from the main road (*Dist* and *Dist*<sup>2</sup>), its visibility from the house (*Visible*) and the audibility of road traffic noise (*Audible*).

Model I only incorporates the five attribute variables but it can be seen that all coefficient values are significant and have the predicted signs. Model II is similar to Model I but the dummy variables *Visible* and *Audible* are entered interactively with respectively *Beauty* and *Noise*. The combination of a higher standard of design combined with the possibility of being able to see the traffic calming measures from the house should have a positive impact on individual utility, while the combination of higher noise levels and being able to hear road traffic noise from a house should have a negative impact on utility. The estimated coefficient values for the interaction terms are again consistent with these expectations.

Model III omits the previous two interaction terms and instead introduces three additional interaction terms between *Dist* and respectively *Noise*, *Speed* and *Beauty*. It is expected that the first two interactions would have a positive impact, as when distance away from the road increases then the negative impacts of increased noise and speed should reduce incrementally. Similarly, the positive effects of improved design will diminish with increased distance and the combination will have a negative impact on utility. Again, estimated coefficient values confirm these expectations. Model IV combines the interaction terms used in the previous two models, though some changes in sign and significance can be noted.

Model V omits the interaction terms on *Visible* and *Audible* but provides further investigation of the impact of the distance variable by adding interaction terms combining  $Dist^2$  with *Noise*, *Speed* and *Beauty*. These additional interaction terms are all highly significant. Finally, Model VI combines all of the interaction terms investigated in the earlier models.

Table 3 reports *p*-values from a series of likelihood ratio tests carried out to determine the specification of the conditional logit model most consistent with the set of observed choices in the sample. These suggest that Model VI is the most consistent of the alternative specifications.

The surface depicted in Figure 1 is a graphical representation of the predicted impacts on utility of changing traffic calming attributes from the particular baseline situation of a house bordering on a road with ESL of 30 mph and current noise exposure of 80dB. Each point on the surface can be seen as indicating the welfare effect of a particular

change in the attribute values for a baseline household in the  $x$ - $y$  space. The value of  $z$  (£) indicates willingness to pay (or to accept compensation) for a move from the baseline condition to the one represented by the particular  $x$ - $y$  combination.

As a result, only one point on the surface is associated with the proposed change alone (i.e. a specific increase in ESL or in noise) while the other points indicate changes in all the other attribute values too, from the baseline to the particular location in the  $x$ - $y$  space, which *includes* the proposed change being investigated. This is where the non-linearity so evident in the surface arises. The negative values indicate that for a baseline household some changes in the  $x$ - $y$  space more than compensate for the decrease in utility that could be caused by the proposed increase in ESL, i.e. the total welfare improvement generated by moving from the baseline to a particular  $x$ - $y$  co-ordinate more than outweigh the WTP to avoid the utility lost by the increase in ESL.

For example, in the distance-noise space shown in Figure 1 we investigate WTP to avoid a 10 mph increase in the ESL from 30 mph to 40 mph. Consider a move from the baseline to the  $x$ - $y$  co-ordinate in the extreme bottom right-hand corner of the surface. This change implies a negative WTP for the baseline household because the utility gain achieved by avoiding the increase in ESL is more than outweighed by the benefits derived by moving from a house on the road to a more distant location (i.e. category 4 - over 200 yards) and a lower noise exposure (i.e. 60 dB rather than 80 dB). Of course keeping distance fixed, as the noise exposure increases to 80 dB this effect decreases and consequently WTP increases.

Figure 2 provides another example of the use of a surface to illustrate variation in WTP across changes in the baseline characteristics of a house. The baseline house is again located on the road being studied but this time the ESL is only 20 mph and the noise exposure is 60 dB. The WTP surface depicts changes related to a small increase in noise exposure to 65 dB. Again, consider a move from the baseline to the  $x$ - $y$  coordinate in the extreme bottom right-hand corner of the surface. This change also implies a negative (though smaller) WTP as the utility gain from avoiding the small increase in road noise is outweighed by the benefits of a lower ESL and moving to a location over 200 yards away from the road. Keeping distance away from the main road fixed at Category 4, and varying ESL, shows that WTP for the noise reduction never becomes positive. This does not change until distance from the road is narrowed into Category 2. Thus, in both examples distance from the road seems to be more influential in determining the magnitude of WTP than reducing either noise or ESL.

## **Conclusions**

Despite reductions in the number of deaths and serious injuries on Britain's roads, the issue of road safety remains an important focus for transport policy-makers in the UK. One of the most important factors in many road casualties is excessive speed. Average road speed may be reduced in a number of ways. One common suggestion is that current national speed limits should be lowered by up to 10 mph and that the new speed limits should be more rigorously enforced than has hitherto been the case. Such enforcement might be achieved through the increased use of speed cameras and would be financed by the consequent increase in income derived from speeding fines.

Such an approach may prove unpopular with many members of the public who already resent the increasing number of prosecutions for road traffic offences at a time when the perpetrators of many more serious crimes remain unpunished. As an alternative, significant effective speed reductions could be achieved through the sensitive use of traffic calming measures at key locations. While such measures may also be controversial in practice, they place physical rather than legal restrictions on the actions of citizens and can be argued to provide a more socially equitable and efficient solution than increased regulation (though without the same revenue generating potential!).

This study used a choice experiment to estimate the utility function of residents affected by through traffic in trunk roads. The sample of respondents was drawn from the population of three towns in the North East of England. To increase generality, these attributes were based not on the specific design of the schemes but on their outcomes in terms of their ability to reduce noise, speed and community severance as well as their attractiveness. Utility was defined over these attributes as well as over the cost of the traffic scheme depicted through an increase in local taxes. Therefore changes in utility could be mapped into the monetary space and the associated WTP could be inferred.

The choice experiments revealed that local people have a positive WTP for a reduction in the negative impacts of road traffic and for an improved, rather than a basic, design of the traffic calming measures used.

Specifications of the logit model with interaction terms between attributes level and relevant respondents characteristics, further reveal that WTP decreases as the distance between the respondent's home and the road increases. Similarly, WTP for reductions in noise is lower when traffic is not audible from the house, as is WTP for improvements in the visual quality of traffic calming design for those households who cannot see the road from their homes.

The majority of local residents enjoy benefits from traffic calming in terms of improved road safety and a reduction in community severance, while it is likely that some drivers may experience a loss in utility due to the impacts of traffic calming measures on their journeys. The results suggest that the benefits of traffic calming schemes are enjoyed most by those residents living close to the road under observation and therefore most affected by the negative impacts of traffic. This finding can be interpreted as evidence supporting the theoretical validity of the stated preference non-market valuation method used in the study (Bishop *et al.* 1995).

The response surfaces shown in Figures 1 and 2 illustrate the potential range of traffic-calming benefits over two different scenarios and indicate the scope that these techniques offer to decision-makers investigating options for traffic calming. Given information on the size of the affected populations and estimates of the magnitude of WTP to move from the current situation to an improved one, the benefits of traffic calming measures should be readily identifiable and available for comparison with the costs.<sup>5</sup> If effective speed reduction is the only aim of traffic calming, then the option

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<sup>5</sup> These can be considerable: for example, for single lane working chicane schemes, construction costs varied from £1,000 to £8150 per chicane, with an average of £3,000 per chicane (Sayer *et al.* 1998).

that achieves the desired speed reduction at least cost is the logical choice. If, however, the other benefits of traffic calming are also considered, then this information will provide a means of selecting traffic calming measures to maximise the ratio of social benefits to costs. Information on distance-decay effects with regard to benefits will also permit estimates to be linked to the location of the house with respect to the road. Armed with these additional insights, decision-makers should be able to make better informed decisions about implementing traffic calming measures in residential areas.

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**Table 1. Noise, speed, and severance characteristics at study sites.**

|               | Dim     |         | Peak    |         | Percentiles |        | Waiting time |       |
|---------------|---------|---------|---------|---------|-------------|--------|--------------|-------|
|               | Site A  | Site B  | Site A  | Site B  | 85th        | median | Average      | Max   |
|               | Noise   |         |         |         | Speed       |        | Severance    |       |
| Haydon Bridge | 65dB(A) | 65dB(A) | 76dB(A) | 74dB(A) | 35mph       | 30mph  | 45"          | 1:30" |
| Rowlands Gill | 60dB(A) | 58dB(A) | 73dB(A) | 68dB(A) | 40mph       | 35mph  | 30"          | 1:10" |
| Seaton Sluice | 57dB(A) | 45dB(A) | 64dB(A) | 55dB(A) | 42mph       | 35mph  | 30"          | 50"   |

**Table 2. Conditional logit estimates,  $N = 3312$** 

| Parameter                  | Model I           | Model II          | Model III          | Model IV          | Model V            | Model VI           |
|----------------------------|-------------------|-------------------|--------------------|-------------------|--------------------|--------------------|
| Noise                      | -0.039<br>(0.003) | -0.031<br>(0.005) | -0.046<br>(0.000)  | -0.043<br>(0.006) | -0.048<br>(0.009)  | -0.044<br>(0.010)  |
| Speed                      | -0.009<br>(0.003) | -0.008<br>(0.003) | -0.024<br>(0.0002) | -0.023<br>(0.005) | 0.020<br>(0.012)   | 0.019<br>(0.012)   |
| Beauty                     | 0.010<br>(0.026)  | 0.019<br>(0.029)  | 0.234<br>(0.0190)  | 0.746<br>(0.170)  | -0.192<br>(0.217)  | -0.2660<br>(0.243) |
| Tax                        | -0.020<br>(0.003) | -0.021<br>(0.003) | -0.022<br>(0.002)  | -0.022<br>(0.003) | -0.023<br>(0.003)  | -0.022<br>(0.003)  |
| Wait                       | 0.075<br>(0.005)  | 0.071<br>(0.043)  | 0.062<br>(0.002)   | 0.060<br>(0.047)  | 0.054<br>(0.043)   | 0.053<br>(0.010)   |
| Dist × Noise               | —                 | —                 | 0.004<br>(0.000)   | 0.004<br>(0.002)  | 0.005<br>(0.009)   | 0.004<br>(0.010)   |
| Dist × Speed               | —                 | —                 | 0.009<br>(0.000)   | 0.008<br>(0.002)  | -0.041<br>(0.013)  | -0.040<br>(0.012)  |
| Dist × Beauty              | —                 | —                 | -0.067<br>(0.029)  | -0.192<br>(0.043) | 0.413<br>(0.233)   | 0.390<br>(0.224)   |
| Dist <sup>2</sup> × Noise  | —                 | —                 | —                  | —                 | -0.000<br>(0.002)  | -0.000<br>(0.002)  |
| Dist <sup>2</sup> × Speed  | —                 | —                 | —                  | —                 | 0.011<br>(0.003)   | 0.010<br>(0.003)   |
| Dist <sup>2</sup> × Beauty | —                 | —                 | —                  | —                 | -0.0951<br>(0.048) | -0.116<br>(0.045)  |
| Beauty × Visible           | —                 | 0.120<br>(0.056)  | —                  | -0.389<br>(0.118) | —                  | -0.426<br>(0.120)  |
| Noise × Audible            | —                 | -0.009<br>(0.004) | —                  | -0.004<br>(0.004) | —                  | -0.003<br>(0.004)  |
| Log $L$                    | -3529.3           | -3524.56          | -3491.97           | -3486.74          | -3469.62           | -3463.89           |

"Dist" coded as :

- 1 = less than 50 yards (1896 cases)
- 2 = between 50 and 100 yards (768 cases)
- 3 = between 100 and 200 yards (224 cases)
- 4 = more than 200 yards (424 cases)

" Visible " coded as :

- 0 = Main Road Not visible (2696 cases)
- 1 = Main Road visible (616 cases)

" Audible " coded as :

- 0 = Main Road Not Audible (3072 cases)
- 1 = Main Road Audible (240 cases)

| Basic Variables | Units                       | Weightsin estimation | Expected sign |
|-----------------|-----------------------------|----------------------|---------------|
| Noise           | 60,70,80 (dB)               | 0.1                  | negative      |
| Speed           | 20,30 (mph)                 | 0.01                 | negative      |
| Beauty          | 0-1 dummy (1 = Improved)    | 0.01                 | positive      |
| Tax             | 10,20,30 (£/yr)             | 0.1                  | negative      |
| Wait            | 0-1 dummy (1= shorter wait) | 0.1                  | positive      |

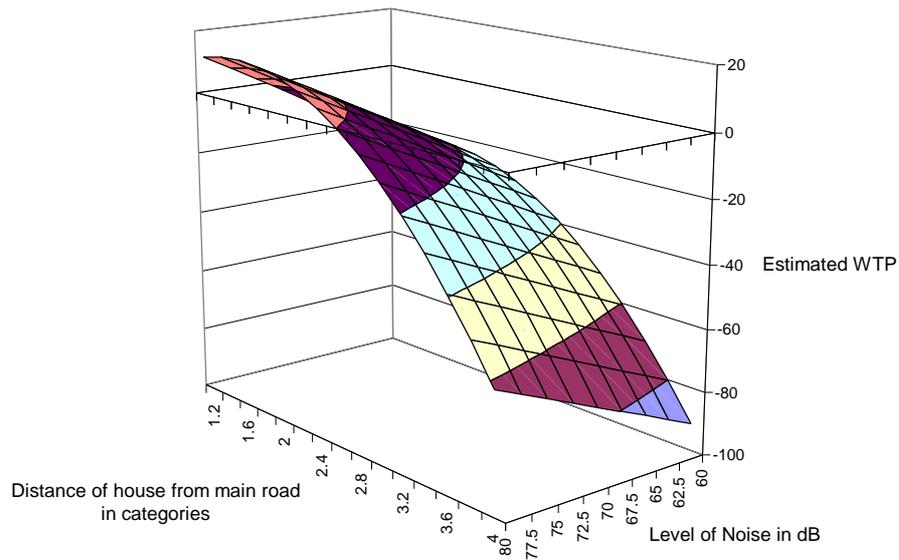
| Interaction Variables | Units                             | Weightsin estimation | Expected sign |
|-----------------------|-----------------------------------|----------------------|---------------|
| Speed × Noise         | (dB) × (mph)                      | 0.1 × 0.01           | negative      |
| Dist × Noise          | category (1,2,3,4) × (dB)         | 0.01                 | positive      |
| Dist × Speed          | category (1,2,3,4) × (mph)        | 0.01                 | positive      |
| Beauty × Visible      | dummy =1 only for " Visible " HHs | 0.1                  | positive      |
| Noise × Audible       | dummy =1 only for " Audible " HHs | 0.1                  | positive      |

**Table 3. *p*-values of the likelihood ratio tests.**

| Restricted<br>Unrestricted | Model 5  | Model 4  | Model 3  | Model 2  | Model 1  |
|----------------------------|----------|----------|----------|----------|----------|
| Model 6                    | 3.25E-03 | 6.55E-10 | 8.90E-26 | 1.62E-24 | 1.97E-24 |
| Model 5                    | —        | —        | 1.16E-23 | —        | 2.29E-23 |
| Model 4                    | —        | —        | 1.50E-02 | 3.75E-17 | 7.34E-17 |
| Model 3                    | —        | —        | —        | —        | 6.37E-17 |
| Model 2                    | —        | —        | —        | —        | 2.44E-02 |

**Figure 1. WTP surface in the Distance-Noise Space**

Baseline is a border of the road House, with ESL of 30 mph and 80 dB exposure  
 The proposed change is an increase in ESL to a 40 mph, ceteris paribus



**Figure 2. WTP surface in the speed-distance space.**

Baseline is a border of the road House, with an ESL of 20 mph and 60 dB noise exposure

The proposed change is a noise increase to 65 dB, ceteris paribus

