

Estimating the Value of Life, Injury, and Travel Time Saved Using a Stated Preference Framework

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Abstract

The incidence of death and injury from automobile accidents in North Cyprus is 3.6 times greater than the average for the EU. With the prospect of North Cyprus entering the EU, many investments will need to be undertaken in order to reduce these figures and reach EU norms. A key task will be to select the investments that are justified on the basis of a cost–benefit or cost–effectiveness analysis and not to waste resources through poor project selection. The objective of this study is to provide local estimates of the value of a statistical life and injury along with the value of time savings. These are among the key parameters needed for the evaluation of the benefits of such projects.

In this study we conducted a stated choice experiment to identify the preferences and trade-offs of automobile drivers in North Cyprus for improved travel times, travel costs and safety. The choice of route was examined using mixed logit models to obtain the marginal utilities associated with each attribute of the routes that consumers choose. These estimates were used to assess the individuals' willingness to pay (WTP) to avoid fatalities and injuries and to save travel time. We then used the results to obtain community-wide estimates of the value of a statistical life (VSL) saved, the value of injury (VI) prevented, and the value per hour of travel time saved.

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1. Introduction

In 2014 there were 1.3 million fatalities on the world's roads. Approximately 92% of global traffic fatalities occurred in low- and middle-income countries. These countries contain 53% of the total number of registered vehicles in the world (WHO, 2013). North Cyprus, with a population of 286,257, had 41 fatal accidents, or 143 deaths per million (2011 Census). This incidence of death from automobile accidents is 3.6 times greater than the average for Western Europe (European Commission Road Safety Statistics website). Moreover, in North Cyprus the incidence of various non-fatal injuries is more than 30 times greater than the number of deaths. The main causes of traffic accidents in North Cyprus are speeding, alcohol, lack of attention, inadequate sleep, reckless driving, and bad driving habits. Young children and citizens aged 21–44 years are found to be the most vulnerable road users (Road Traffic Accident Prevention Association, 2014).

In addition to the direct pain and suffering incurred, traffic accidents can push victims' families into poverty through the loss of a key caregiver, loss of productivity, loss of income, cost of medical care, damage to property, rehabilitation, and burial costs. The large number of victims created by traffic accidents and the seriousness of the consequences represent a major economic and public health problem (Gopalakrishnan, 2012).

Reducing this major social problem will require the selection and implementation of many investments in the area of road transport and safety. The important task will be to select those projects, among the many possible ones proposed, that can be justified on the basis of cost–benefit or cost–effectiveness analysis. To conduct such appraisals, a number of key parameter values are required. Three such parameters are the value of time saved by individuals in travel, the value per life saved and the value of injury prevented through the reduction in traffic accidents. The objective of this paper is to obtain credible estimates of these parameters for North Cyprus.

Through the quantification of the benefits of road safety and the measurement of the willingness to pay (WTP) to prevent casualty risk, one can obtain a measure of valuation of a statistical life (Elvik et

al., 2009). This parameter has traditionally been measured using contingent valuation, standard gamble, or chain method techniques (Viscusi et al., 1991; Jones-Lee et al., 1993, Jones-Lee, 1994; Beattie et al., 1998; Carthy et al., 1998). These methods basically express the risk of accidents as the probability of an accident occurring and involve a monetary valuation of road safety that implies a tradeoff between money and risk. They are flawed, as the actual decision that people make involves choosing between bundles of attributes that describe alternative routes. These methods, however, have been criticized by specialists in human behavior (Fischhoff, 1991; 1997) and some economists (Hausman, 1993; Diamond and Hausman, 1994).

A number of recent studies on the valuation of road safety have used a different approach based on stated choice (SC) or conjoint analysis techniques (De Blaeij et al., 2003; Rizzi and Ortúzar, 2003, 2006; Iragüen and Ortúzar, 2004; Hojman et al., 2005; Hensher et al., 2009). An SC analysis is an experiment in which individuals are asked to choose between different alternative combinations and levels of alternative road attributes. Therefore, SC implicitly reveals the actual behavior of people and is a more appropriate technique for the valuation of intangibles (McFadden, 1998; Louviere et al., 2000).

In this study the SC experiment focuses on the preferences of Turkish-Cypriot drivers for travel times, travel costs, and safety on a route based on a bundle of attributes that is described in each choice set. In this way, an estimate of the ex ante WTP of drivers, and hence the value of risk reduction (VRR), can be made. This parameter value is a key piece of information in the evaluation of road safety and time-saving measures (Hensher, 1994; Louviere et al., 2000; Hensher et al., 2005).

Although North Cyprus has experienced an exceptionally high death and injury rate from car accidents, this is the first study to elicit the road safety preferences of car drivers. In this survey car drivers were questioned on the VRRs of premature death or injury from alternative scenarios of types of road and safety features. The remainder of the paper is structured as follows. Section 2 describes the theory and methodologies underlying choice experiments and the associated modeling issues in road safety. Section 3 describes the design of the SC experiment, while Section 4 provides a summary

of the basic statistics. Section 5 contains the discussion of the results of the analysis.

2. The value of fatality and injury risk reductions

In this section we describe the principle underlying the microeconomic theory of risk-reduction valuations in a road environment using discrete choice models. We also introduce the VRRs for fatalities and injuries using the standard economic models.

2.1 Modeling the VRR

Assume that a trip on a particular route which is used by N users gives a certain level of dissatisfaction as defined by the static indirect utility function $V = V(r, c, t)$, where r denotes the risk of being killed or injured, c the cost of traveling and t the travel time on a route. In real life the trip would have more attributes.

The estimated VRR is equal to the value of avoiding premature death or one injured victim per unit of time within the aggregating demand for this public good, in this case road safety (Drèze, 1962; Jones-Lee, 1974). Because road safety is a public good, its value to society is equal to the sum of the individual marginal rates of substitution (MRS_j) over the N road users between the risk of death or injury and income, plus a covariance that measures the strength of the correlation between the MRS_j and the reduced risk (δr_j).¹ The value is equivalent to:

$$MRS_j = \frac{\partial V / \partial r}{\partial V_j / \partial c \mid V=\bar{V}} \quad (1)$$

$$VRR = \frac{1}{N} \sum_{j=1}^N MRS_j + N \text{cov} (MRS, |\delta r|) \quad (2)$$

If it is assumed that the covariance between MRS and δr in equation (2) is zero, where δr is the same for every individual, then equation (2) would simplify to equation (3).

¹ $\text{cov} (MRS_j, \delta r_j) = \sum_j \frac{MRS_j \delta r_j}{N} - \sum_j \frac{MRS_j}{N} \sum_j \frac{\delta r_j}{N}$

$$VRR = \frac{1}{N} \sum_{j=1}^N MRS_j \quad (3)$$

In other words, the value of avoiding one statistical death or injury can be interpreted as the sum of the MRS of the population of individuals traveling on a particular route. In terms of the functional form of V_j , MRS depends on each individual's perception of their own risk. The same analysis can be carried out using the fatalities (or injuries), which are more understandable from a respondent's standpoint.² Then equation (1) can be represented by equation (4):

$$MRS_j = \frac{\partial V / \partial f}{\partial V_j / \partial c \mid V=\bar{v}} \quad (4)$$

Risk is measured by the numbers of fatalities as proportion of the population ($r = f/N$), where the number of fatal accidents is denoted as f . Equation (5) measures the WTP for road safety as the sum over all the road users of their MRS between the number of fatalities (or injuries) and income.

$$VRR = \sum_{j=1}^N \frac{\partial V / \partial f}{\partial V_j / \partial c \mid V=\bar{v}} = \sum_{j=1}^N SVF_j \quad (5)$$

where SVF is the subjective value or WTP of fatal crash reductions and is a Lindahl price (Varian, 1992, Ch. 23).

2.2 Making the model operational

We now turn to the above model within a discrete choice framework where the static indirect utility function, V_{ji} , is represented by the attributes of alternative routes j and the attributes of individual i :

$$V_{ji} = \alpha \cdot f_{ji} + \beta \cdot I_{ji} + \gamma \cdot t_{ji} \quad (6)$$

where f is the number of fatal accidents and I the number of injuries. We assume V_{ji} to be a linear and additive function of the attributes of the travel. As we cannot observe all the relevant information in the utility function, let U_{jic} denote the random utility function that individual j associates with alternative i in choice set c , which is expressed as a deterministic V_{jic} and a random component ε_{jic} :

² The MRS for the effects coded binary attributes is $MRS_j = 2 \frac{\partial V / \partial x}{\partial V_n / \partial c \mid V=\bar{v}}$ (Hu et al., 2004).

$$U_{jic} = V_{jic} + \varepsilon_{jic} \quad (7)$$

If the random component is distributed independently and identically (IID) with a type I extreme among alternatives and across individuals in choice set c , the standard multinomial logit model (MNL) is obtained and the probability of individual j associates with alternative i can be formulated as:

$$E [P_{jic}] = \frac{e^{V_{jic}}}{\sum_{j=1}^J e^{V_{jic}}} \quad (8)$$

Unlike the homogenous parameters in the MNL model, we assume that some of the parameters (β_n) vary between individuals. The expected probabilities of choosing a particular alternative, therefore, depend on the random parameters with a density function $f(\beta_n | \theta)$, where θ stands for the parameters of the distribution. Since the random parameters are not known, the unconditional choice probability is calculated and used in the model estimation. The integral was estimated with simulated maximum likelihood techniques.

$$P_{icn} = \int E [P_{icn} | \beta_n] f(\beta_n | \theta) d\beta \quad (9)$$

2.3 Estimating values of statistical lives and injuries

We calculate the summation of the WTP for a reduction in fatalities risk and injuries risk for all road users separately. The values are equivalent to the value of fatality risk reductions (VSL) and the value of injury risk reductions (VI). We have to convert the individual WTP to a driver population exposure risk measure because in this study we focus on car drivers. The exposure is defined as the number of trips and associated kilometers undertaken by each driver in the population. The trip kilometers associated with a single trip has to be scaled up to the relevant population, based on the number of times an individual in a sub-population is exposed to risk. Identifying the actual amount of trip activity is crucial in aggregating the average WTP per trip. The WTP is an average WTP per person per trip; the average number of fatalities or injuries is an average over the last 5 years; and the average annual vehicle kilometer on the route is also over the last 5 years. The formulas for each risk class are:

$$VRR_f = VSL \frac{\text{WTP per trip}}{\text{Trip kms}} \times \frac{\text{AAVKM}}{\# \text{ Fatalities}} \quad (10)$$

$$VRR_I = VI = \frac{\text{WTP per trip}}{\text{Trip kms}} \times \frac{\text{AAVKM}}{\# \text{ Injuries}} \quad (11)$$

The components of the estimation of VRR can be defined as WTP/chance, where chance is defined as the relationship between the risk, as measured by the number of fatalities or injuries per annum, and exposure, defined by the average annual vehicle kilometers on the route (AAVKM). The average annual vehicle kilometers traveled in North Cyprus is estimated by taking the values of the total amount of automobile fuel consumed per year and multiplying this value by the fuel efficiency of the automobiles (kilometers travelled per liter used).

3. Design of SC experiment

The SC experiment in the present study enables us to express the alternative service improvements in terms of combinations of different attributes at different levels, and to estimate the marginal WTP for each alternative attribute. In this way one can estimate the cost and time associated with the proposed service improvements (Hensher, 2004; Veisten et al., 2013). Applying the SC experiment required travelers to make choices between a pair of alternative routes and the current route. The SC experiment approach derives the independent contributions of each of the attributes of the different routes that allow for efficient and optimal experiments to be performed. In this study, a SC experiment is used to find car drivers' preferences for travel times, travel cost, and safety on a route, based on a bundle of attributes that is described for each alternative.

Different factors impact on the design of a hypothetical survey for estimating a WTP for improving road safety in order to avoid fatalities and injuries. We are dealing with issues such as the risk of a fatality, and the risk of injuries, disability, and distress that car accidents may cause.

In North Cyprus, although the risk is high in absolute terms compared to that in Western European, the probability of a fatality is low. The majority of people do not recognize the risk of a car accident

as an objective probability on each route they travel. Hence, it is difficult to explain to people the different levels of risk involved in traveling on routes in the survey, even when they have the same probability of occurrence. Suppose that a person faces exactly the same risk of death traveling by car as subjective risk or objective risk, and also that the individual is offered the same reduction in his or her risk probability for both situations. Will the individual pay the same for both? It is obvious that they will not. In the case of the car trip, individuals may feel that the subjective risk of an accident is completely under their control, so will not be willing to pay anything. On the other hand, as the subjective risk of an accident is out of the individual's control, he or she may be willing to pay a certain amount to reduce it. Because of this, it is necessary to define the same type of risk in both alternatives, which is adjusted for the difference between subjective risk and objective risk in the same direction for both alternatives (for instance, if a respondent believes he or she drives more safely than the average driver, he or she will think the same in both alternative cases).

In order to identify and select the most appropriate attributes on which to build an uncomplicated and representative choice experiment questionnaire on road safety improvements, we reviewed the literature relating to SC experiment studies on road traffic specifically in relation to the design objectives and the statistical efficiency of the design (Rizzi and Ortúzar, 2003; Hojman et al., 2005; Hensher et al., 2005, 2009). Several pilot questionnaires were completed with five focus groups. A total of 40 participants from the five districts of North Cyprus were interviewed by trained interviewers to discuss their opinions and suggestions on road safety, driving, and accident experience on the road, with the goal of revealing the significant attributes for which they are willing to pay for an improved service.

The identified attributes and their levels used in the initial design of the SC experiment were confirmed by the data collected through the pilot questionnaires. Some changes were made in the final questionnaires after considering the feedback from the focus groups in the pilot study. Final questionnaires had an introductory letter to the respondents explaining that the aim of the study was to improve road safety in order to avoid fatality and injury. The attributes in the choice sets section were also explained and respondents were advised to consider each choice set as an independent decision.

The questionnaire was organized into three main sections. The first asked about the current trip in terms of transportation systems, frequency of using major routes in general, travel times, travel costs, the purpose of trip and the people present in the car during the trip. Information on current road safety based on the routes used during the described trip and the respondents' perception of road safety and policy was also collected. The second part included the SC experiment followed by two different types of questions related to the experiences of the respondents or their friends/relatives of road accidents. The third part of the survey asked socioeconomic questions.

3.1 Statistical design of the choice experiment

The attributes and attribute levels included in the design of the SC experiment are shown in Table 1.

Table 1. Attribute levels

Attributes	Levels
Average speed limits per km/h posted on 1- and 2-lane each-way sections of route	60, 80, 90, 100
Number of speed cameras located on 1- and 2-lane each-way sections of route	1, 2
Total travel time	Less than 60 min 61 min to 2 hours
Number of injuries per year, representing the number of people who have been injured in car accidents using this road	Fewer than 20 people 20 people or more
Number of deaths per year, representing the number of people who have been killed in car accidents using this road	Fewer than 10 people, 10 people or more
Percentage change in monthly costs for the trip	5% higher than now 10% higher than now 15% higher than now 20% higher than now

Once the number of attributes and the number of attribute levels were determined, we constructed two unlabeled experiments in which the title of each alternative relates to two hypothetical routes. The choice sets were created by using a shifted design (Bunch et al., 1996). The conventional approach to shifted design is a straightforward extension of the orthogonal method. We used a full factorial design, which allows all possible treatments or attribute level combinations of main effects and higher-order interactions.

In our case we had six attributes, two with four levels, and four with two levels. The full factorial design would have implied that there would be 256 ($4^2 \times 2^4$) choice sets. The large number of scenarios is too much of a burden on the respondents. The orthogonal fractional factorial with 32 profiles (four 8-choice sets) was generated from this full factorial in order to reduce the number of choice sets to be used in the experiment. Therefore, each respondent saw only eight of the 32 profiles during the questionnaire process (Winer, 1971; Bunch et al., 1996; Louviere et al., 2000; Hensher et al., 2005).

In terms of efficient choice design, this design had four desirable properties, namely orthogonality, level balance, minimal overlap, and utility balance (Huber and Zwerina, 1996). In this way, orthogonality was satisfied when we allocated the attribute levels to the design correlation matrix in such a way that any two columns were uncorrelated with each other and therefore collinearity was minimized. Attribute level balance is satisfied when each level of an attribute appears an equal number of times in the profile sets. In this study, the numbers of levels for each attribute were designed to be a power of two. In the 32 profiles, each level appears 16 times in the case of the two-level attributes, and eight times in the case of the four-level attributes. Minimal overlap is satisfied by using modular arithmetic when the attribute levels of Route A are shifted to produce the levels of Route B and ensuring that within each choice set the attribute levels do not overlap. The last principle of design efficiency, utility balance, is satisfied when the utility gap between the alternatives is reduced by switching the dominating alternatives within each choice set (Carlsson and Martinsson, 2003).

Finally, to make the choice decision more realistic, a current route option that related to the respondent's recent trip experience was added to each choice set. Therefore, respondents had the option to stay with their current route in real life if they found the other two alternatives unattractive (Table 2).

Table 2. Typical card from SC sets

	Route A	Route B	Current Route
Speed camera (per lane)	1	2	Neither route A nor route B: I prefer to stay with my current route
Average speed limit (km/h)	90	80	
Travel time (min)	Less than 60 min	61 min to 2 hours	
Running costs (TL)	20%	10%	
Fatal crashes (per year)	Fewer than 10 people	10 people or more	
Injuries (per year)	20 people or more	Fewer than 20 people	

4. Data collection and preliminary analysis

A survey was made in the districts of Lefkoşa, Girne, Gazimağusa, Güzelyurt, and İskele using face-to-face interviews during the period February–May 2014. Of the 286,257 individuals in North Cyprus, 33.1% reside in Lefkoşa, 24.4% in Gazimağusa, 24.2% in Girne, 10.5% in Güzelyurt, and 7.9% in İskele (2011 Census). These percentages were used in distributing the targeted 389 interviews to each district. A total of 510 interviewees were recruited among individuals who drove on a regular weekday for any purpose, such as education, work, personal business, or bureaucratic purposes. From these, 15 respondents who were marked as protest bids were excluded from the econometric analysis as they might have had problems in understanding the choice scenario. Also, 121 respondents answered the choice experiments base on lexicographic decision-making rules, i.e. they picked an alternative that was uniquely better on one of the most important attributes. There were 54 lexicographic respondents for the cost attribute, 30 for the number of death and injuries attributes, and 37 for the travel time attribute. The data with this characteristic were removed as these respondents did not choose according to the model we aimed to analyze (Johnson et al., 2000; Saelensminde, 2001; Rizzi and Ortúzar, 2003). The final number of usable responses was 374, or 2,992 observations, as each respondent made eight choices.

There were 162 single and 191 married persons, the rest being separated or widowed. Some 70% of the families had children and of these, 67% had children younger than 18 years of age. The majority of respondents (344) had a college education. The median family income data was between TL7,000 (€2,389) and TL9,000 (€3,071) per month. In the case of family income, only 100 respondents were in

the highest range. Of the 64% of respondents who were working, 45.2% worked for the public sector and the rest in the private sector. Table 3 provides a summary of the age and gender distribution of the final sample. We also collected information on the driving experience of respondents who had been exposed to car accidents or knew someone who had died or been injured in a car accident (Table 4).

Table 3. Targeted number for each geographical and socioeconomic segment

Region	Trip length/age	Male			Female			Total
		18–30	31–60	61+	18–30	31–60	61+	
Lefkoşa	15–60 min	7	9	0	2	6	0	24
	61–120 min	33	38	0	12	21	0	104
Gazimağusa	15–60 min	11	19	3	9	8	0	50
	61–120 min	19	10	0	2	7	0	38
Girne	15–60 min	7	9	0	1	5	0	22
	61–120 min	15	25	0	11	17	0	68
İskele	15–60 min	12	11	0	2	7	0	32
	61–120 min	3	2	0	2	1	0	8
Güzelyurt	15–60 min	0	2	0	1	2	0	5
	61–120 min	6	9	0	1	7	0	23
Total		113	134	3	43	81	0	374

Table 4. Awareness of road accidents

	Died	Injured
Personally involved	-	92
Known someone	17	240

5. Results

The MNL model based on the limitation of heterogeneity in preferences of individuals is not capable of estimating both random and non-random parameters. The heterogeneity in preferences limitation may partly be removed by introducing a number of socioeconomic variables; however, the independence from irrelevant alternatives (IIA) axiom assumption of the error term is violated in our model. Therefore, the MNL results could be biased and unreliable (Hensher et al., 2005).

The distribution of random parameters in the mixed logit model allows for heterogeneity in preferences of individuals. Prior to estimating the model, we considered models in which the parameters and attributes enter the utility function with a linear specification or alternatively, as a linear-logarithmic specification. This is done for assessing the best model fit. The pseudo rho-square values in the range 0.2–0.4 represent extremely good model fits (Louviere et al., 2000). The mixed logit models with simulated maximum likelihood were estimated using the econometric software Limdep (Nlogit).

We specified all parameters to be from an unconstrained triangular distribution, but the mean and standard deviations of the majority of parameters were statistically insignificant. This confirms that the existence of preference heterogeneity is insufficient to be captured by an unconstrained distribution. Thus, we estimated all parameters based on a constrained triangular distribution, where the heterogeneity around the mean preserved the sign of parameters by imposing a constraint on the standard deviation over the entire distribution.

Those attributes with insignificant standard deviations for their distributions were respecified as fixed parameters in the utility function. To identify any statistically significant effect of socioeconomic characteristics in random parameters, we estimated all potential interactions and kept the significant interactions only (Birol and Villalba, 2006).

The final mixed logit model results with interactions are reported in Table 5.

Table 5. Mixed logit with interactions results

Attributes	Parameters	(t-ratio)
Random parameters		
Constraint triangular distribution		
Traffic speed limit (km/h)	−0.0757	(−4.72)
Speed cameras	−0.070	(−1.73)
Travel time (min)	−0.054	(−2.68)
Death	−0.131	(−6.45)
Injury	−0.083	(−4.67)
Non-random parameters		
Constant (ASC)	0.581	(3.27)
Cost (TL increase per month)	−0.188	(−4.06)
Traffic speed limits by age	0.001	(3.82)
Traffic speed limits by education	0.031	(3.84)
WTP (TL)		
Traffic speed limit (km/h)	0.402	(3.078)
Speed cameras	0.376	(1.564)
Travel time (min)	0.577	(2.236)
Death	1.40	(3.471)
Injury	0.885	(2.904)
Halton draws	1,000	
Number of observations	2,992	
LL(0)	−4,752.60	
LL(β)	−3,230.46	
ρ^2	0.32	
Trip distance (km)		
Average	47.68	
St. dev.	21.55	
Min.	10	
Max.	100	

The estimated utilities, using equations (12) and (13) that gave the highest values of ρ^2 even in the form of an additive utility function are those with the attributes of traffic speed limit, speed cameras, travel time, and total number of deaths and injuries in linear specification, and the change in monthly travel cost expressed in logarithmic form. Estimating the cost attribute as a fixed parameter implies

that the distribution of the marginal WTP for an attribute is equal to the distribution of that attribute's coefficient. Also, the logarithmic distribution in the fixed cost attribute with values close to zero could lead to exceptionally high marginal WTP measures for the other attributes (Revelt and Train, 1998).

The other attributes were estimated as random parameters assuming constrained triangular distributions. The derived standard deviation of the parameters suggests that a significant level of preference heterogeneity resides within all sampled individuals. Therefore, a single parameter is insufficient to represent the population. Among the interactions between age, gender, education, and personal income with random parameters we found that only two significant interactions can explain the sources of heterogeneity in the preferences of individuals.

$$U(\text{Route A}) = ASC1 + \beta_{sl} \times \text{speed limit} + \beta_{sc} \times \text{speed cameras} + \beta_t \times \text{travel time} + \beta_{death} \times \text{deaths} + \beta_{inj} \times \text{injuries} + \beta_{lc} \times \ln(\text{cost}) + \beta_{sl} \times \text{speed limits} \times \text{age} + \beta_{sl} \times \text{speed limits} \times \text{education} \quad (12)$$

$$U(\text{Route B}) = ASC2 + \beta_{sl} \times \text{speed limit} + \beta_{sc} \times \text{speed cameras} + \beta_t \times \text{travel time} + \beta_{death} \times \text{deaths} + \beta_{inj} \times \text{injuries} + \beta_{lc} \times \ln(\text{cost}) + \beta_{sl} \times \text{speed limits} \times \text{age} + \beta_{sl} \times \text{speed limits} \times \text{education} \quad (13)$$

$$U(\text{no travel}) = 0 \quad (14)$$

The mean and standard deviation of all the attribute coefficients are statistically significant except speed cameras. With respect to the signs of the parameters, all the coefficients are of the expected signs except traffic speed limits. The interaction parameters have no prior expected signs.

We observed that the value of the coefficient on the mean of the random parameter distribution for the number of deaths is higher than the coefficient on the mean of the number of injuries. This suggests that the individuals have a greater marginal utility for avoiding fatalities than for avoiding injuries.

As can be seen, the interactions between traffic speed limits by age and traffic speed limits by education are positive. The first result implies that as age increases, the marginal disutility of driving at a high speed declines. The second result implies that marginal disutility associated with the higher

speed is lower for drivers who do not have a university degree. However, the effect of age and education as the socioeconomic characteristics is small compare to the overall impact of the traffic speed limits attribute across all individuals.

Furthermore, the negative mean of the total travel time parameter implies that travel time saving is preferred. The value of travel time saving (VTTS) for individual trips at the mean of the unconditional estimates was TL34.62 (€11.81) per person hour. Thus, route choice within the sample data was determined by a tradeoff between travel time and cost.

As expected, the marginal utility of travel costs was found to be negative for all individuals. Also, the alternative specific constant (ASC) had a positive mean that is associated with the unobserved influences on the choice between a particular route A or B, in contrast with the option “not to travel”.

5.1 Deriving the economic welfare impacts of road improvements

The economic welfare impact of improving road safety is public good, in units of money income, on the road users of a particular route and is estimated by the compensating variation (CV) which measures the individual’s maximum WTP for quality improvement (Hanemann, 1991; Silberberg and Suen, 2001). It is the amount that needs to be taken away from the individual’s income at the new level of safety (S^1) to make him or her as well off as at the initial level of safety (S^0). In terms of the indirect utility function, this can be represented as:

$$V(P^0, S^0, Y) = V(P^0, S^1, Y - CV) \quad (15)$$

where P^0 is the vector of prices and Y is the individual’s income.

In our models, the change in monthly travel cost is specified in natural logarithmic form.³ Therefore, the economic welfare impact of a road improvement on an average respondent under the different scenarios, as compared with keeping the respondent at his or her current utility level, was calculated as follows:

³ To avoid having $\ln(0)$ as a presence of zero observations in monthly cost data we add the value of 1 before taking their natural logs (Moeltner and Layton, 2002).

$$CV = \exp\left(\frac{1}{\beta_{lct}} \left[V^0 - V^1_{|chcost=0} \right] - 1\right) \quad (16)$$

where V^0 and V^1 stand for the respondent's utilities with the current route and with the route improvement, respectively.

The maximum welfare impact of a road improvement under different scenarios was equivalent to a TL34.30 increase in the monthly travel cost with regard to the level of preference of each individual. This happens for 25 one-way trips per month taking less than 60 minutes, with one speed camera each way, a speed limit of 85km/h, and with fewer than 10 deaths and 20 injuries from automobile accidents per year. This is approximately equivalent to a 10% increase in the driver's monthly travel costs (Table 6). The average welfare impact values are estimated per month. Thus, it is necessary to convert the result from a per-month to a per-car-trip basis, given that the exposure rate relates to trips. Therefore, the welfare impact for an average of 25 one-way car trips per month is calculated as a TL1.37 increase in travel costs per car trip.

Table 6 . Confidence intervals for CV estimates – delta method

CV TL/month	SE TL/month	95% confidence interval	
		TL/month	
		Lower bound	Upper bound
34.30	13.95	6.96	61.64

Delta method used to obtain standard errors (Greene, 2000).

5.2 Deriving the VRR

Table 7 shows the primary results for average WTP based on the number of deaths and injuries as random parameters for avoiding fatalities and injuries on roads. The average WTP for a reduction in deaths, TL1.40 per car trip, is systematically higher than the WTP for a reduction in the number of injuries, TL0.88 per car trip.

Table 7. Willingness to pay (TL/trip/driver)

Attribute	Average (TL per car trip)	Std. dev.
Death	1.40	0.40
Injury	0.88	0.30

To estimate the average VRR according to equation (5), we need to estimate the WTP parameters for deaths and injuries per person per kilometer and divide this value by the incidence of death and injury separately, using equations (10) and (11). The chance of death or injury is measured by the relationship between the risk of deaths or injuries per annum and the average annual number of vehicle kilometers on the route. The results are presented in Table 7.

We estimated the average annual vehicle kilometers traveled in North Cyprus by multiplying the total amount of automobile fuel consumed by the fuel efficiency of automobiles. The average fuel efficiency of the fleet of automobiles in North Cyprus was estimated to be 10 liters/100km.⁴

The data used to calculate the chance of death or injury was collected from the Road Safety Branch of the Road and Traffic Authority (RTA) of North Cyprus and the State Planning Organization. These data cover the number of fatalities. A fatality is defined as a person who dies within 30 days of an accident as a result of injuries received in that accident. The number of injuries is measured by the number of non-fatal crashes in which at least one person was injured. The final estimated values of the chance of fatality or injuries and VRR, using equations (10) and (11), are reported in Table 8.

Table 8. The chance of fatality and injuries and the VRR

Number of casualties		Exposure AAVKM	Chance of		VRR (TL) per	
Fatalities	Injuries		Fatality	Injury	Fatality	Injury
41	1067	2.86×10^9	1.40×10^{-8}	3.73×10^{-7}	2,099,563	49,474

⁴ The European Union Automotive Fuel Economy Policy (UNEP) approved a fuel consumption of around 5.6 liters/100km of petrol or 4.9 liters/100km of diesel. However, the average fuel consumption is ‘combined’ 8.9 l, ‘urban’ 12.5 l, and ‘extra-urban’ 6.9 l per 100km. In North Cyprus, average fuel consumption for car travel is 12.5 liters/100km in city traffic. If truck traffic is also included, a reasonable estimate would be 10 liters/100km (http://en.wikipedia.org/wiki/Fuel_economy_in_automobiles, <http://www.eea.europa.eu/data-and-maps/figures/growth-in-private-car-travel>, <http://www.fueleconomy.gov/feg/findacar.htm>).

5.3 Discussion and conclusion

We compared our results with those in other studies that used similar methodology and that are reported in the research literature on the valuation of road safety. First we converted our results to euros using a conversion rate of €1=TL2.93.⁵ The VRR that automobile drivers place on the reduction of one fatality is TL 2,099,563 and of one injury TL49,474. Considering these results, the point estimate VSL is €717,000, with the 95% confidence interval from €315,293 to €1,117,856, and the VI €16,885, with the 95% confidence interval from €5,603 to €28,186.

According to the results reported by De Blaeij et al. (2003) from 30 studies conducted in the USA, Europe and New Zealand, the VSL for road safety was estimated within a wide range from around €200,000 to more than €10 million.⁶ Of these 30 studies, 18 presented lower and higher estimates and 12 gave single point estimates; 11 of the 30 studies reported values below €1 million, 15 reported values in the range €1 million to €10 million, and the values in the remaining studies were over €10 million.

Another source of evidence on VSL is Veisten et al. (2013), who used risk as one of the attributes of a trip in a SC survey for the valuation of casualty risk reduction in Norway. They estimated the VSL to be in the range €7.3 million to €19.2 million based on responses from people who considered risk as numbers of fatalities and serious injuries rather than the probability of risks.⁷

At the EU level, the value of human life most frequently used is €1 million. This is referred to as the ‘one-million-euro rule’ for the cost–benefit analyses of safety-enhancing interventions (Despontin et al., 1998; European Transport Safety Council, 2007). The value of life is estimated as the economic damage of a death. This amount is used as a benchmark for deciding which safety-enhancing intervention to select. In the EU, for every €1 million spent on a road safety measure, at least one death should be prevented (Despontin et al., 1998). This is based on the statistical relationship that for

⁵ This value is an average of the conversion rate for May 2014 and was taken from the Central Bank of the Republic of Turkey’s website.

⁶ The values reported by De Blaeij et al. (2003) are in 1997 USD. These values were adjusted for US inflation between 1997 and 2014 (42%, see inflation calculator on Federal Reserve Bank of Minneapolis website) and converted to euros using an exchange rate of €1=\$1.36 for May 2014 (US Federal Reserve Board website).

⁷ We adjusted values using an inflation calculator and converted to euros using an exchange rate of €1=NOK8.1533 for May 2014 (Central Bank of Norway website).

every death prevented there will also be a reduction in the number of accidents in which injuries and property damage occur (Wesemann, 2000).

The point estimate of the VSL for North Cyprus obtained from this study was below €1 million, which places it in among the bottom 30% of the estimates reported by De Blaeij et al. (2003). An important consideration is that North Cypriot households have a significantly lower income than the European average. Evidence suggests that the income elasticity of the VSL is equal to or greater than one in lower-income populations, implying that the VSL is a luxury good (Hammitt and Robinson, 2011). Under the standard assumption that a high degree of risk aversion usually implies high values for the income elasticity of the VSL (Andersson and Treich, 2011), it could also be that a lower value of VSL implies that the people of a given community have a lower degree of risk aversion.

To check the consistency of our results with those of European countries, we adjusted our results for the differences between the levels of income in North Cyprus and in European countries. We used our estimate to extrapolate the benefit transfer for Europe based on per capita gross national income (GNI) and with reasonable assumptions of the income elasticity of VSL. In 2014, GNI was about €10,989 in North Cyprus, compared to €26,282 in the European Union.⁸ If the income elasticity was 1, the benefit transfer function would be about € 1,714,841 [$VSL_{\text{Europe}} = 717,000 (GNI_{\text{Europe}} / GNI_{\text{Cyprus}})^1$], and if the elasticity was 1.2 it would be € 2,041,572 [$VSL_{\text{Europe}} = 717,000 (GNI_{\text{Europe}} / GNI_{\text{Cyprus}})^{1.2}$]. The higher elasticity leads to WTP estimates that are an increasing fraction of income for high-income countries. We found that these adjusted estimates are at least 50% higher than the value of €1 million per human life used by the EU in the cost–benefit studies of safety enhancement interventions. They are also close to the median of the other reported estimates of the value of VSL, but below the means for the USA, Europe and New Zealand.

⁸ These values are reported by the World Bank (EU data on World Bank website) and Turkish Republic of Northern Cyprus State Planning Organization. We adjusted the value for the EU using an inflation calculator (HICP table on Eurostat website) and converted to euros using an exchange rate of €1=\$1.36 for May 2014 (US Federal Reserve Board website). The value for North Cyprus is an average of the conversion rate for May 2014 and was taken from the Central Bank of the Republic of Turkey's website.

To summarize, we developed a new empirical estimate in the transport field of the WTP of North Cyprus residents to reduce fatalities, €717,000, and to avoid injuries, €16,885. We also estimated the value that drivers in North Cyprus place on the time saved in road travel at €11.85 per person hour.

Given the very high incidence of road deaths and injuries in North Cyprus as compared with that in the rest of the Western world, many investments in this area need to be undertaken to reduce current the level of casualties. The important task will be to select those projects, among the many possible ones, that can be justified on the basis of cost–benefit or cost–effectiveness analysis (Jenkins et al., 2014). In terms of policy tools, our findings provide a set of information that should be used as a benchmark for ex ante appraisals of such road improvement projects that not only reduce travel times but have also been shown from experience to be effective in reducing highway deaths and injuries.

With the prospect of North Cyprus entering the EU in the near future, many such investments must be initiated in order to achieve EU norms for road quality and safety. Given these estimates of the value of reductions in death and injury and time savings, project planners and analysts should strive to find those interventions that are the most cost-effective. Given the lower level of income in North Cyprus, the benchmarks used in the EU for the evaluation of such programs might initially be slightly too high for project selection in North Cyprus. At the same time, given the current poor road safety record in North Cyprus, it is likely that many sound investments are available that would be justified using these three key parameter values for the appraisal of such projects.

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