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

Naghmeh Niroomand

Department of Economics

Eastern Mediterranean University, North Cyprus

naghmeh.niroomand@gmail.com

and

Glenn P. Jenkins

Queen's University, Canada,

and Eastern Mediterranean University, Mersin 10, Turkey

Address: Department of Economics,

Queen's University, Kingston, Ontario, Canada, K7L 3N6

E-mail: jenkins@econ.queensu.ca

Abstract

The incidence of fatality over the period 2010 to 2014 from automobile accidents in North Cyprus is 2.75 times greater than the average for the EU. With the prospect of North Cyprus entering the EU, many investments will need to be undertaken to improve road safety in order to reach EU benchmarks. 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 parameter values needed for the evaluation of the change in the expected incidence of automotive accidents and time savings brought about by such projects.

In this study we conducted a stated choice experiment to identify the preferences and tradeoffs 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. The estimates for the VSL range from €315,293 to €1,117,856 and the estimates of VI from € 5,603 to € 28,186. These values are consistent, after adjusting for differences in incomes, with the median results of similar studies done for EU countries.

Keywords: Willingness to pay; choice experiment; value of a statistical life; value of injury; road safety; automobile drivers

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 registered vehicles in the world (World Health Organization, 2013). 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, 2021). This study investigates the attitudes of the automotive drivers and passengers in the northern part of Cyprus to the risks of fatality and injury from road accidents. Estimates are made of the value of a statistical life (VSL) and the value of injury (VI) obtained through a choice experiment survey carried out on the population who live in this region.

Through the quantification of the benefits of improved road safety and the measurement of the willingness to pay (WTP) to reduce casualty risk, one can obtain a measure of the VSL (Andersson, 2007; Elvik et al., 2009). This parameter has traditionally been measured using contingent valuation, standard gamble, or chain method techniques, which basically express the risk of accidents as the probability of an accident occurring (Beattie et al., 1998; Carthy et al., 1998; Jones-Lee, 1994; Jones-Lee et al., 1993; Viscusi et al., 1991). These methods involve a monetary valuation of road safety that implies a tradeoff between money and risk, and have been criticized by specialists in human behavior (Fischhoff, 1991, 1997) and some economists (Diamond and Hausman, 1994; Hausman, 1993). They have pointed out that a common defect of contingent valuation studies arises from the embedded effect where people have a positive feeling or WTP about supporting an activity in general. Often the valuations people make of public goods are not consistent when they are asked to express their WTP for a series of interventions separately as compared to their valuation of the interventions when bundled together. Furthermore, in some cases the absence of direct market parallels affects the ability of the researcher to judge the quality of contingent valuation responses. This problem is at least partially solved in situations when one is able to observe direct expenditures made by individuals on averting or coping activities in order to alleviate the situation that is the focus of the contingent valuation. In the case of road safety, the actual decision that people make involves choosing between bundles of attributes that describe alternative routes. Hence, it is necessary to estimate the values of each of the attributes that can be bundled into different combinations to describe the services received from the various routes.

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 (Hensher et al., 2009; Iragüen and Ortúzar, 2004; Rizzi and Ortúzar, 2003, 2006; Svensson and Johansson, 2010). 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 (Louviere et al., 2000; McFadden, 1998).

In this study the SC experiment focuses on the preferences of Turkish-Cypriot drivers for travel times, travel costs, and improvements in safety for routes 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 to reduce their risk, 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; Hensher et al., 2005).

1.1 Road safety in North Cyprus

Cyprus is the third largest island in the Mediterranean. Turkish Cypriots live in the northern part of the island, which comprises about a third of the total land area of the island. According to the 2012 Census, North Cyprus had a population of 286,257. The average age of the population of North Cyprus in 2012 was 33, while the life expectancy at birth for males is 79.6 years and for females it is 83.1 years. The annual per capita gross national income (GNI) in 2014 was €10,989.[1] In 2014 the official minimum wage was TL1, 675 (€572) per month (€6864 per year). The gross domestic product (GDP) was derived heavily from tourism (21%) and higher education services (11.5%), with a further 12% coming from transportation and communications.

The rate of unemployment in 2014 was 8.3% (Economic and Social Indicators, 2014). Because North Cyprus is a small island country with eight universities serving both the local and the international markets, much of the unemployment consists of recent graduates who are seeking local professional employment and who often end up moving to Turkey or to other EU countries to find such jobs. At the same time more than 25,000 guest workers from Turkey were employed in virtually every occupation in North Cyprus (Economic and Social Indicators, 2014). Hence, unemployment is largely a function of young people not finding the quality of jobs they are looking for, given their option of working abroad, rather than the absence of available jobs. Owing to a strong extended family tradition and a generous social security system, the incidence of poverty among the Turkish Cypriots is quite low.

In North Cyprus, the available modes of transport are road, sea, and air, and there are no railways in the country. All inter-urban transport is by road. In 2012 there were 260,084 registered motor vehicles, while the number of driving licenses issued was 419,030 (2012 Census). Of the 7,000 km of roads in North Cyprus, about two-thirds are paved. The average distance between the five districts of Northern Cyprus is 47.68 km.

Over the period 2010 to 2014, North Cyprus experienced, on average, 40 road accident fatalities per year, or 140 fatalities per million population. The incidence of fatalities from automobile accidents is 2.75 times greater than the average for Western Europe over the same period. The incidence of various non-fatal injuries is about 30 times greater than the number of fatalities, averaging 1,067 injuries per year, or 3,727 injuries per million population (2012 Census; European Commission Road Safety

[1] The exchange rate between the Turkish Lira (TL) and the euro is 2.93TL/euro for 2014. This value is obtained using the average exchange rate of €1=TL2.93 for May 2014 and was taken from the Central Bank of the Republic of Turkey's website.

Statistics website, 2014; Road Traffic Accident Prevention Association, 2014). By comparison, the number of industrial accidental deaths in North Cyprus over the same period averaged five per year, with an average of 247 non-fatal accidents per year (Turkish Republic of Northern Cyprus, Ministry of Labor and Social Security, 2015). As a percentage of the labor force the annual rate of non-fatal accidents is 0.2% in North Cyprus, while for the average for the labor force in the EU it is 1.6% (Eurostat, 2015). While safety in the work place in North Cyprus appears to be relatively better than in the EU, the level of safety in automobile transportation is much worse.

The main cause of traffic accidents in North Cyprus is the behavior of drivers (80%), including speeding, alcohol, lack of attention, inadequate sleep, reckless driving, and non-compliance with the traffic signs. The second most important cause is the road environment (20%) or the road layout, including road bends, narrow carriageways, mud deposits, animals or other objects in the carriageway, poor and defective road surfaces, inadequate road signs or markings, and lack of traffic signals. On the other hand, driving licenses are issued without examination to foreigners who already have a driving license from elsewhere. This is particularly dangerous for a small country with an international university student population of over 50,000, and many long-term tourists from countries with lax driving regulations. There is not even an official handbook for learner drivers to study the rules for their written examination. Young children and citizens aged 21–44 years are found to be the most vulnerable road users (Road Traffic Accident Prevention Association, 2014).

Reducing this major social problem, which has economic consequences, will require the selection and implementation of many new investments in the areas of road transport, road safety, and driver education. While the road network is fairly extensive, it is generally of low quality. Highways between cities need to be widened with adequate road breakdown lanes; overpasses need to be built at important highway junctions; barriers are needed to separate traffic moving in opposite directions on high-volume expressways with lane dividers installed or improved on busy urban streets; and modern roundabouts need to be built to replace many existing small roundabouts or busy four-way stop junctions. The important task will be to select those projects, from the many possible ones proposed, that could 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 from road improvements, the value per life saved and the value of injury prevented through the reduction of traffic accidents as a result of improvements in road safety. The objective of this paper is to obtain credible estimates of these parameters for North Cyprus.

Although North Cyprus has experienced exceptionally high fatality and injury rates from car accidents, this is the first study to elicit the road safety preferences of car drivers. In this survey, car drivers were asked to choose among different alternative scenarios of types of roads and safety features. These choice sets varied according to statistical design in order to maximize the precision of the estimates.

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 provides the results, Section 6 contains the discussion of the results of the analysis, and Section 7 briefly presents our conclusion.

2. The value of fatality and injury risk reductions

This section describes the principles underlying the microeconomic theory of risk-reduction valuations in a road environment using discrete choice models, and also introduces the VRRs for fatalities and injuries using the standard economic models. The analysis measures the VRRs based on estimates of drivers' WTP for incremental or marginal improvements in road safety. This is not an estimate of the total value of road safety but an attempt to measure the economic welfare benefits arising from interventions that improve road safety on the margin.

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. Other attributes are also considered in the analysis that follows.

The estimated VRR is equal to the value of avoiding premature fatality per unit of time within the aggregating demand for this public good, in this case road safety (Drèze, 1962; Jones-Lee, 1974). Equation (1) measures the marginal rate of substitution between the risk of the fatality (or injury) and income on a specific trip.[2] This is expressed as:

$$MRS_j = \frac{\partial V_j/\partial r}{\partial V_j/\partial c}\bigg|_{V=\bar{V}} \qquad (1)$$

Because road safety is a public good, the value of improving road safety to society is equal to the marginal rate of substitution (MRS_j) between the risk of fatality (or injury) and income for each individual that is then summed over the entire population, plus a covariance that measures the strength of the correlation between the MRS_j and the reduced risk (δr_j).[3] To express this value as an average for each of the *N* members of the population, we need to divide this sum by *N*. This is expressed in equation (2) as:

$$VRR = \frac{1}{N}\sum_{j=1}^{N} MRS_j + N \operatorname{cov}\left(MRS_j , \left|\delta r_j\right| \right) \qquad (2)$$

It is typically assumed that the covariance between *MRS* and δr in equation (2) is zero. This assumption would be correct if δr were the same for all individuals. To adjust these concepts to our empirical work, *N* represents the total number of automobile drivers on a particular route in a given year and *WTP* is the marginal rate of substitution between the risk of fatality (or injury) and income (Hojman et al., 2005; Veisten et al., 2013).

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[2] The term $\partial V_j/\partial c\,|_{V=\bar{V}}$ is measuring the marginal utility that is lost when the cost of the service to individual *j* is changed. As costs are an allocation of the individual's income, this is commonly referred to as the marginal utility of income. This term in equation (1) converts the marginal utility from a unit of risk reduction into a monetary value.

[3] $\operatorname{cov}(MRS_j, \delta r_j) = \sum_j \frac{MRS_j \delta r_j}{N} - \sum_j \frac{MRS_j}{N} \sum_j \frac{\delta r_j}{N}$

Equation (2) would then simplify to equation (3).

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

In terms of the functional form of V_j, MRS depends on each individual's perception of his or her own risk. The same analysis can be carried out using the fatalities (or injuries), which are more understandable from a respondent's standpoint. Risk is now measured by the numbers of fatalities as proportion of the population ($r = f/N$), where the number of fatalities is denoted as f. Equation (1) can then be made a function of the changes in f and written as equation (4):

$$MRS_j = N\frac{\partial V_j/\partial f}{\partial V_j/\partial c_{|V=\bar{V}}} \quad (4)$$

Substituting equation (4) for MRS_j in equation (3) yields equation (5), which sums the MRS between the number of fatalities (or injuries) and income over all the road users.

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

where SVF_j is the subjective value, or WTP, for reducing the expected number of fatal car accidents by one event on a single trip.

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 a function of the attributes of alternative routes i and the attributes of individual j:

$$V_{ji} = \beta_1 . f_{ji} + \beta_2 . I_{ji} + \beta_3 . c_{ji} + \beta_4 . t_{ji} \quad (6)$$

In equation (6), f denotes the number of fatalities, I denotes the number of injuries, c denotes the cost of traveling and t refers to the travel time on a route. The SVF_j is equal to β_1/β_3 for fatalities for each individual, and β_2/β_3 is the SVI_j for injuries for each individual (Hojman et al., 2005). By computing β_4/β_3, we obtain the individual's subjective value of travel time (SVT_j) (Hensher et al., 2005).

We assume V_{ji} to be a linear and additive function of the attributes of the travel.[4] As we cannot observe all the relevant information in the utility function, let U_{jci} denote the random utility function of alternative *i* in choice set *c* perceived by individual *j*, which in turn is expressed as a deterministic V_{jci} and a random component ε_{jci}:

$$U_{jci} = V_{jci} + \varepsilon_{jci} \tag{7}$$

The standard multinomial logit (MNL) model assumes the independently, identically distributed (IID) random component ε is distributed extreme value type I (EVI) among alternatives and across individuals in choice set *c*. The MNL model is obtained and the probability that individual *j* associates with alternative *i* in choice set *c* can be formulated as:

$$E\left[P_{jci}\right] = \frac{\exp^{V_{jci}}}{\sum_{j=1}^{J} \exp^{V_{jci}}} \tag{8}$$

Unlike the homogeneous 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 $f(\beta_n \mid \theta)$, 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 is estimated with simulated maximum likelihood techniques.

$$P_{jci} = \int E\left[P_{jci} \mid \beta_n\right] f\left(\beta_n \mid \theta\right)\, d\beta \tag{9}$$

2.3 Estimating values of statistical lives and injuries

The WTP per trip for a reduction in fatalities risk and injuries risk is now calculated for automobile drivers. The values for SVF_j and SVI_j are estimated from equation (6) and then summed over all the drivers, as shown in equation (5), to calculate the average WTP of a driver to reduce the risk of a fatality or injury on a single trip by one event. The automobile driver population exposure to risk is measured

[4] Some studies report their relationship to be nonlinear (Rizzi and Ortúzar, 2003).

by the number of trips and associated kilometers per trip undertaken by each driver in the population. The average WTP per driver per trip to reduce fatalities or injuries will be determined by, among other things, the risk or chance of such an event occurring during the trip. The WTP per kilometer is found by dividing the WTP per trip by the number of kilometers per trip. The estimation of VRR can be derived as (WTP per km)/(chance per km). Chance per kilometer in this situation is measured by the number of fatalities or injuries per annum on the route divided annual average number of kilometers driven on the route (AAVKM). These relationships for each risk class can be expressed as shown in equations (10) and (11):

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

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

Identifying the actual amount of trip activity is crucial in aggregating the average WTP per trip. For the estimations carried out in this study for North Cyprus, the average annual vehicle kilometers traveled is estimated by multiplying the total amount of automobile fuel consumed per year by the fuel efficiency of the automobiles (kilometers traveled per liter used).

3. Designing the SC experiment

The SC experiment in the present study enables us to express the alternatives in terms of combinations of different attributes at different levels, and to estimate the marginal WTP for each alternative attribute. In this way we can estimate the improvement in road safety, travel costs, and travel times associated with the proposed routes (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. In this study, a SC experiment is used to find car drivers' preferences for travel times, travel costs, and safety on a route, based on a bundle of attributes that is described for each alternative.

When the probability of risk is low, individuals have difficulty in accurately assessing it (Kahneman and Tversky, 1979). Most people do not recognize the risk of an automobile fatality or injury according to the actual objective probability that exists on each route they travel, but have a subjective risk that is usually quite different (Jones-Lee et al., 1993; Rizzi and Ortúzar, 2003). Objective risk can be described as the actual losses or risk of fatalities or injuries in a given period, while subjective risk is the feeling or perception of risk by individuals using a route. Hence, it is difficult to explain to people the different levels of risk to which they are exposed when traveling on the routes in the survey. In the case of a 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, if individuals feel that the subjective risk of an accident is out of their control, they 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 the case of both alternative routes. This is done by informing the respondent of the actual incidence of fatalities and injuries on the routes.

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 (Hensher et al., 2005, 2009; Hojman et al., 2005; Rizzi and Ortúzar, 2003, 2006; Veisten et al., 2013). 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.

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 included an introductory letter to the respondents explaining that the aim of the study was to improve road safety in order to avoid fatalities and injuries. 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 was also collected on current road safety based on the routes used during the described trip and the respondents' perception of road safety and policy. The second part included the SC experiment followed by two different types of questions relating 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	60 min or less 61 to 120 min
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 fatalities 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 related 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 (Hensher et al., 2005; Louviere et al., 2000; Winer, 1971).

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 2. 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
Average speed limit (km/h)	90	80	nor route B:
Travel time (min)	60 min or less	61 to 120 min	I prefer to stay
Running costs (TL)	20%	10%	with my current
Fatalities (per year)	Fewer than 10 people	10 people or more	route
Injuries (per year)	20 people or more	Fewer than 20 people	

4. Data collection and preliminary analysis

A survey using face-to-face interviews was conducted in the districts of Lefkoşa, Girne, Gazimağusa, Güzelyurt, and İskele 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 (2012 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 based 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 fatality 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 average age of respondents was 36.7 (ranging from 20 to 61). The majority of respondents (344) had completed high school, and 263 had a university degree. The mean monthly family income according to the nine income ranges was TL6010.58 (€2,051) with a range, as reported in Table 3, from TL5, 501 (€1,877) to TL7, 500 (€2,260). In the case of family income, only 100 respondents were in the highest range.

Of the 64% of respondents who were working, 68.4% worked for the public sector and the remaining 31.5% in the private sector. The 36% who were not in the labor force were retired people (7%), property owners and those undertaking household duties (13.5%), and foreign students with family support (79.5%). Of the working respondents, 89% were employees, 6.2% employers, and 4.7% self-employed. Owing to the underrepresentation of retired individuals in our survey (2.5% of the survey population versus 15% of the actual population receiving a retirement pension, with some also working), the proportion of working population in the survey (68.4%) was higher than the 57% reported in the 2012 Census. Table 4 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 personally involved in car accidents resulting in injury, or knew someone close (friend or relative) who had died or been injured in a car accident (Table 5).

Table 3. Household income (per month)

	Frequency	Percentage

Less than TL1, 500	22	5.9
TL1, 501–2,000	24	6.4
TL2, 001–2,500	17	4.5
TL2, 501–3,000	28	7.5
TL3, 001–3,500	26	7.0
TL3, 501–5500	13	3.5
TL5, 501–7,500	49	13.1
TL7, 501–12,000	95	25.4
More than TL12, 000	100	26.7
Total	374	100

Table 4. Number of respondents targeted for each geographical and socioeconomic segment

		Male (age group)			Female (age group)			Total
		18–30	31–60	61+	18–30	31–60	61+	
Region	Trip length							
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 5. Awareness of road accidents

	Died	Injured
Personally involved	-	92
Someone close (friend/relative)	17	240

5. Modeling 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 to assess the best model fit between the other discrete choice models. 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. We defined the standard deviation of the random parameters to be half of the absolute value of the mean parameter estimates.

Those attributes with insignificant standard deviations for their distributions were specified as fixed parameters in the utility function. To identify any statistically significant effect of socioeconomic characteristics in the random parameters, we estimated all potential interactions and kept the significant interactions only (Birol and Villalba, 2006).[5]

The final mixed logit model results with interactions are reported in Table 6.

Table 6. Mixed logit with interactions results

Attributes	Parameters	(*t*-ratio)
Random parameters		
Constrained triangular distribution		
Traffic speed limit (km/h)	−0.0757	(−4.72)
Speed cameras	−0.070	(−1.73)
Travel time (min)	−0.054	(−2.68)
Fatality	−0.131	(−6.45)
Injury	−0.083	(−4.067)
Derived standard deviations of parameter distributions		
Traffic speed limit (km/h)	0.0378	(4.72)
Speed cameras	0.0354	(1.73)
Travel time (min)	0.0271	(2.68)
Fatality	0.0658	(6.45)
Injury	0.0416	(4.067)
Non-random parameters		
Constant (ASC)	0.581	(3.27)

[5] A number of social demographic variables were collected and considered as interaction attributes in the analysis. These variables included age, education, income, gender, district, married status, occupation, car ownership, purpose of trips, number of passengers in vehicle, and concern about the safety of other drivers. Only age and education were independent variables that also had a significant impact.

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)
Fatality	1.40	(3.471)
Injury	0.885	(2.904)
Halton draws	1,000	
Number of observations	2,992	
LL (0)	−4, 753	
LL (β)	−3, 230	
Pseudo R^2	0.32	
Trip distance (km)		
Average	61.28	
St. dev.	27.05	
Min.	10	
Max.	101	

The estimated utility, using equation (12), gave the highest values of pseudo R^2 (0.32) in the form of an additive utility function. The attributes included are traffic speed limit, speed cameras, travel time, and total number of fatalities and injuries in linear specification, and the change in monthly travel cost expressed in logarithmic form.[6] 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.

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

[6] The value of the coefficient on the logarithm of cost variable must be multiplied by the mean of the costs in order to arrive at the marginal utility of cost as reported in Table 6.

heterogeneity in the preferences of individuals.

$$U \text{ (Route A, B)} = ASC + \beta_{sl} \times \text{speed limit} + \beta_{sc} \times \text{speed cameras} + \beta_{t} \times \text{travel time} + \beta_{fatality} \times \text{fatality} + \beta_{inj} \times \text{injury} + \beta_{lc} \times \ln(\text{cost}) + \beta_{slage} \times \text{speed limits} \times \text{age} + \beta_{sledu} \times \text{speed limits} \times \text{education} \quad (12)$$

The mean and standard deviation of all the attribute coefficients are statistically significant except speed cameras (–1.73). With respect to the signs of the parameters, all the coefficients are of the expected signs, including traffic speed limits (–0.075). It might have been expected that greater speed would increase utility because it would reduce travel time. However, once the travel time effect is accounted for in the estimation of utility, it is reasonable that people in general would prefer to experience less tension and drive at lower speeds.

The interaction parameters have no prior expected signs. The interactions between traffic speed limits by age and traffic speed limits by education are positive (0.001 and 0.031, respectively). The interaction between traffic speed limits by age implies that as age increases, the marginal disutility of driving at a high speed declines. The interaction between traffic speed limits by education implies that the marginal disutility associated with the higher speed is lower for drivers who do not have a university degree. However, when evaluated across all individuals, the interaction effect of age and education on utility is small as compared to the overall impact of the traffic speed limits.

We observed that the value of the coefficient on the mean of the random parameter distribution for the number of fatalities (–0.131) is larger than the coefficient on the mean of the number of injuries (–0.083). This suggests that the individuals have a greater marginal utility for avoiding fatalities than for avoiding injuries.

Furthermore, the negative mean of the total travel time parameter (–0.54) implies that travel time saving is preferred. The subjective value of travel time (SVT) for individual trips at the mean of the unconditional estimates was TL34.62 (€11.81) per person hour.[7] 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 (–0.188) for all individuals. Also, the alternative specific constant (ASC) had a positive mean (0.581) that is associated with the unobserved influences on the choice between a particular route, A or B.

5.1 Deriving the economic welfare impacts of improved road safety

The economic welfare impact of improved road safety is a public good, in units of money income, for the road users of a particular route and is estimated by the compensating variation (CV), which measures the individual's maximum WTP for improved road safety (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:

$$V(P^0, S^0, Y) = V(P^0, S^1, Y - CV) \quad (13)$$

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.[8] Therefore, the economic welfare impact, CV, of an improvement in road safety for an average respondent under the different scenarios, as compared with keeping the respondent at his or her current utility level, was calculated as follows[9]:

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[7] The MRS for the effects coded binary attributes is $MRS_j = 2\frac{\partial V_j/\partial x_j}{\partial V_j/\partial c_{|V=\bar{V}}}$ (Hu et al., 2004) where x denotes the vector of attributes as viewed by individual j. These attributes variables are effects coded as –1 and 1 (a difference of 2), instead of as a dummy variable (0,1). Hence, the estimated coefficient will be half as large as it would be if it were coded as 0,1. To adjust for this, we must multiply the coefficients by two in order to measure the marginal WTP for a unit change in the variable.

[8] To avoid having ln (0) for the zero value observations in monthly cost data, we add the value of 1 before taking their natural logs (Moeltner and Layton, 2002).

[9] The derivation of equation 14 from equations 12 and 13 is as follows:
The change in utility due to the route improvement is
$V^1 \mid_{chcost=0} - V^0$
The CV is the increase in the monthly running cost amount that will keep the respondent at his or her current utility level, $\ln(cost)^1 = \ln(1 + CV)$. The utility with road safety improvement and an increase in monthly running cost is estimated by,

$$CV = \exp\left(\frac{1}{\beta_{lct}}\left[V^0 - V^1_{|chcost=0}\right] - 1\right) \quad (14)$$

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 an improvement in road safety under different scenarios was equivalent to a TL34.30 (€11.70) 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 60 minutes or less, with one speed camera each way, a speed limit of 85km/h, and with fewer than 10 fatalities and fewer than 20 injuries from automobile accidents per year. This is approximately equivalent to a 10% increase in the driver's monthly travel costs (Table 7). 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 (€0.47) increase in travel costs per car trip.

Table 7. Confidence intervals for CV estimates – delta method

CV TL/month	SE TL/month	95% confidence interval TL/month	
		Lower bound	Upper bound
34.30 (€11.70)	13.95 (€4.76)	6.96 (€2.37)	61.64 (€21.03)

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

5.2 Deriving the value of the risk reduction

Table 8 shows the primary results for average WTP based on the number of fatalities and injuries as random parameters for avoiding fatalities and injuries on roads. The average WTP for a reduction in

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$V^1 = V^1 \big|_{chcost=0} + \beta lct * \ln(\text{cost})^1$
$V^1 = V^1 \big|_{chcost=0} + \beta lct * \ln(1 + CV)$
From the definition of CV,
$V^1 - V^0 = 0$.
Hence, $[V^1 \big|_{chcost=0} + \beta lct * \ln(1+CV)] - V^0 = 0$. Solving for CV yields equation 14.

fatalities, TL1.40 (€0.48) per car trip, is systematically higher than the WTP for a reduction in the number of injuries, TL0.88 (€0.30) per car trip.

Table 8. Willingness to pay (TL/trip/driver)

Attribute	Average (TL per car trip)	Std. dev.
Fatalities	1.40 (€0.48)	0.40
Injuries	0.88 (€0.30)	0.30

To estimate the average VRR according to equation (5), we need to estimate the WTP parameters for fatalities and injuries per person per kilometer and divide this value by the incidence of fatality and injury separately, using equations (10) and (11). The chance of fatality or injury is measured by the relationship between the risk of fatality or injury per annum and the average annual number of vehicle kilometers on the route. The results are presented in Table 9.

Table 9. The chance of fatality and injury, and the estimation of VRR

Number of			Exposure	Chance of		VRR (TL) per	
Fatalities	Injuries	Trip lengths (km)	AAVKM	Fatality	Injury	Fatality	Injury
40	1,067	47.68	2.86×10^{9}	1.40×10^{-8}	3.73×10^{-7}	2,099,563	49,474

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.[10]

The data used to calculate the chance of fatality 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 automobile accident as a result of injuries sustained in that accident. The number of injuries is the number of people who are severely injured, are hospitalized, or suffer minor injuries resulting from automobile accidents. The final estimated values of the chance of fatality or injury and VRR, using equations (10) and (11), are reported in Table 9.

6. Discussion

We compared our results with those from other studies that used similar methodologies and that are reported in the literature on the valuation of road safety. The VRR that automobile drivers place on the reduction of one fatality is TL2,099,563 and of one injury TL49, 474. Considering these results, the point estimate expressed of the VSL expressed in euros 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.[11] 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

[10] 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).

[11] 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).

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 an 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.[12]

At the EU level, the VSL 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 VSL is estimated as the economic damage of a fatality. 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 fatality should be prevented (Despontin et al., 1998). This is based on the statistical relationship that for every fatality 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 1 in lower-income populations, implying that the VSL is a luxury good (Hammitt and Robinson, 2011; Milligan et al., 2014). 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

[12] 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).

estimate to extrapolate the benefit transfer for Europe based on GNI and with reasonable assumptions of the income elasticity of VSL. In 2014, GNI was about €10,989 in North Cyprus, compared to €26,262 in the European Union.[13] If the income elasticity was 1, the benefit transfer function would be about €1,714,841 $\left[VSL_{Europe} = 717{,}000\ (GNI_{Europe}\ /\ GNI_{\ Cyprus})\hat{}\ 1\right]$, and if the elasticity was 1.2 it would be €2,041,572 $\left[VSL_{Europe} = 717{,}000\ (GNI_{Europe}\ /\ GNI_{\ Cyprus})\hat{}\ 1.2\right]$. 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.

7. Conclusions

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 fatalities 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 the current 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 analysis (Jenkins et al., 2014). In terms of policy tools, our findings provide a set of information on the VRR that is useful in the ex ante appraisals of road projects that not only reduce travel times and vehicle operating costs but that also have been shown to be effective in reducing highway fatality and injuries.

With the prospect of North Cyprus entering the EU in the near future, many such investments must be

[13] These values are reported by the World Bank (EU data on World Bank website) and the 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).

initiated in order to achieve EU benchmarks for road quality and safety. Given the limited public investment budget of North Cyprus, such investment interventions will need to be subject to a professional appraisal where the economic benefits are compared with the economic costs. The potential for choosing ineffective and wasteful projects is very much present.

An area of future research should be to distinguish the routes in North Cyprus between those with a high risk of fatalities and injuries and those with moderate levels of risk. Other researchers have found that the VSL and VI vary considerably with the level of risk and traffic volumes (Rizzi and Ortúzar 2003, 2006). The North Cyprus road network includes extremes of mountain pass roads with both high and low traffic volumes that cross between the north and south zones. They are relatively expensive to improve, in contrast with roads on the inland plains. The levels of risk are also likely to be quite different across these different types of routes. Hence, a more finely calibrated set of estimates of the VSL and VI would improve the measurement of the benefits of road safety improvements in the cost–benefit analysis of such interventions compared with the two single estimates for the whole country produced by this study.

A further area of potentially fruitful research would be to differentiate the injuries by type (non- severe, permanent, hospitalized). Although this information is not collected at present, it could be gathered in the future for each route in this small region. Furthermore, as the number of injured people who move away from the region is rather low, North Cyprus is likely to be a very good place to measure the lifetime cost of such injuries.

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