A Comparison of Stated Preference Methods for the Valuation of Improvement in Road Safety

Naghmeh Niroomand

Cambridge Resources International
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

This paper presents an empirical comparison of the contingent valuation method (CVM) and choice experiment (CE) method in the estimation of the non-market value of road safety improvements. In this study we used both the CVM and the CE method to identify the preferences and tradeoffs of automobile drivers in North Cyprus for road safety improvements. Mixed logit and payment ladder approaches were used to assess the drivers' willingness to pay (WTP) for road safety improvements. Although the CVM yielded higher values than the CE, the differences between the estimates of WTP derived from these two methods were found to be statistically insignificant. The value of a statistical life (VSL) and the value of an injury (VI) were estimated for car accidents, and the value was found for the annual economic welfare loss from such deaths and injuries in North Cyprus. The point estimate of the value of a statistical life expressed in euros is €717,000, and the value of an injury is €16,885. The point estimate of the VSL for North Cyprus obtained from this study was below €1 million, which places it among the bottom 30% of the estimates made internationally for these parameters. When aggregated over the whole country for 2014, the total annual economic welfare burden was €46.7 million, which is equivalent to an economic welfare loss of 1.5% of the gross national product (GNP) in that year.

Keywords: willingness to pay; contingent value model; choice experiment; value risk reduction; road safety; car drivers

JEL Codes: D12, D61, Q50, R41, D12

1. Introduction

The measurement of non-market values in the improvement of specific environmental goods or services can be obtained by revealed and stated preference methods (Mitchell and Carson, 1989). For approximately 30 years, the stated preference approach most frequently employed has been the contingent valuation method (CVM). It basically expresses in monetary terms the change in economic welfare arising from a change in the quality or quantity of services. This approach typically involves the measurement of predefined changes in non-market services (Adamowicz et al., 1994; Diamond and Hausman, 1994; Hanemann, 1994; Beattie et al., 1998; Carthy et al., 1998; Morrison and Bennett, 2000; Morrison, 2001; Carson, 2000; Islam, 2002; Carlsson and Martinsson, 2006; Andersson, 2007, 2011, 2013; Halkos and Matsiori, 2018).

Another type of stated preference method is the choice experiment (CE) technique, which can elicit choice behavior by valuing non-market preferences (De Blaeij et al., 2003; Hensher, 2008; Windle and Rolfe, 2011; Niroomand and Jenkins, 2016, 2017). In CE analysis, individuals are asked to choose between alternative combinations and attributes and their levels. Therefore, CE relies on defining a set of choices that are hypothetical but realistic in the way the combination of attributes are specified in the choices. It is thought to result in fairly precise estimates of the value of intangibles (McFadden, 1998; Louviere et al., 2000).

This study estimates car drivers' WTP for road safety improvements in North Cyprus. The CVM and CE methods were used to estimate the welfare change for identical road safety improvements where different attributes were used in the utility functions as the basis for calculating welfare change estimates (Rizzi and Ortúzar, 2003, 2006; Iragüen and Ortúzar, 2004; Hensher, 2009; Svensson and Johansson, 2010). In the CVM survey, car drivers were asked directly to state their maximum WTP for the non-market value of road safety, in which demand is unobservable. In the CE survey, car drivers were asked to choose between different alternative scenarios of types of roads and safety features. These choice sets were varied according to a statistical design in order to maximize the precision of the estimates.

The paper is organized in five further sections. Section 2 analyzes the econometric method and specification, while Section 3 presents the CE and CVM design. Section 4 describes the econometric analysis. Section 5 provides the resulting model estimates, and Section 6 closes the paper with a discussion and briefly presents our conclusion.

2. Theoretical considerations

Stated preference approaches measure incremental or marginal improvements in the non-market value of individuals' preferences based on the hypothetical scenarios through surveys (Boxall et al., 1996; Adamowicz et al., 1998; Foster and Mourato, 2003; Hensher et al., 2005; Mogas et al., 2005, 2006). From the perspective of economic theory, the CVM and CE methods allow estimation of incremental marginal economic welfare benefits that improve non- market services. This section describes the principles underlying the microeconomic theory for the valuation of welfare changes using CVM and CE methods.

2.1 Econometric method and specification

The random utility model (RUM) that forms the basis of the empirical analysis of limited dependent variables is the common theoretical framework for the CVM and CE methods (McFadden, 1973; Greene and Caracelli, 1997). Under the RUM framework, we cannot obtain perfect information, nor observe the complete information in the utility function. Thus, the random utility U_{ji} of alternative i perceived by individual j is partitioned into two components, a deterministic V_{ji} and a random component ε_{ji} as:

$$U_{ji} = V_{ji} + \varepsilon_{ji} \quad \text{where} \quad V_{ji} = \Sigma\ \beta_n X_{nji} \tag{1}$$

V_{ji} is estimated as the sum of the coefficients β_n times the level of each attribute X_{nji} and n identifies the particular attribute

In the CVM method, respondents are asked to choose between an improved state "i" and the current situation "k". Utilizing utility functions for two alternatives from equation (1) expressed in terms of the probabilities of an individual choosing alternative i is given as equation (2), and k as equation (3).

$$P_{ji} = P\,(\varepsilon_{ji} - \varepsilon_{jk} < V_{jk} - V_{ji}) \quad (2)$$

$$P_{jk} = P\,(\varepsilon_{jk} - \varepsilon_{ji} < V_{ji} - V_{jk}) \quad (3)$$

An assumption is made about the distribution of random errors. They are assumed to be independent and identically distributed (IID), and Extreme Value Type I distributed. The expected probabilities for an individual choosing alternative *i* can be formulated as:

$$P_{ji} = \frac{exp^{(V_{ji}-V_{jk})}}{1+ exp^{(V_{ji}-V_{jk})}} \quad (4)$$

In the CE model, the probability of utility that individual *j* associates with alternative *i* in choice set *h* when compared to an alternative *k* can be formulated as:

$$P_{jhi} = P\,(\varepsilon_{jhi} - \varepsilon_{jhk} \leq V_{jhk} - V_{jhi})$$
$$P_{jhk} = P\,(\varepsilon_{jhk} - \varepsilon_{jhi} \leq V_{jhi} - V_{jhk}) \quad (5)$$

Since the vector of coefficients (β_{n}) is not observed the unconditional probability is found by taking the integral of an expression. The integral is estimated by simulated maximum likelihood where values of β_{n} are randomly drawn from a specified distribution. Therefore, the expected probabilities of choosing a particular alternative are given as equation (6):

$$P_{jhi} = \int E\left[P_{jhi}\,|\beta_n\right] f\,(\beta_n|\theta)\;d\beta \quad (6)$$

In case of road safety, the indirect deterministic utility function in CVM is defined by $V = V\,(P_x, S, Y, A_j)$, where P_X denotes the price vector for all the other services (*X*) consumed by the automobile drivers, *S* is the level of safety in the road environment, *Y* is the individual's income, and A_j is the characteristic vector of individual *j*. In the CVM survey, the individuals are asked whether or not they are willing to incur an additional cost to secure an improvement in road safety.

In the CE model, it is assumed that a trip on a given route used by *N* users provides a certain level of dissatisfaction as defined by a deterministic indirect utility function $V = V\,(r, c, t)$, where *r* stands for the risk of being killed or injured, *c* the cost of traveling, and *t* the travel time on a route. Our analysis also considers other attributes. The model can now be made operational. The deterministic indirect utility function, $V_{ji,}$ of each available alternative i in choice set h perceived by individual j is:

$$V_{jhi} = \beta_1.f_{jhi} + \beta_2.I_{jhi} + \beta_3.c_{jhi} + \beta_4.t_{jhi} \quad (7)$$

In equation (7), f denotes the number of fatalities, I the number of injuries, c the cost of traveling, and t the travel time on a route

2.2 An illustration and comparison of stated preference techniques

Generally, the CVM represents the primarily discrete value for each individual; therefore, the mean of willingness to pay (WTP) estimated from the CVM approach corresponds to a discrete variation in the amount of good g, from g_1 to g_2. In contrast, the mean WTP yield in the CE model is defined as marginal changes in each attribute, that is, from g_1 to g_1+1. The marginal values are obtained from the ratio of attribute coefficients (where the coefficient on the cost variable is the denominator) in the CE study. The assumption of constant marginal values for all units will prevent the problem of scale parameter effects in discrete change value estimation (Hanley et al., 1998a). Based on this assumption, generally the CVM is more used for measuring discrete values and the CE for marginal values. However, it is possible to estimate discrete values from CE (Hanley et al., 1998b; Bateman et al., 2002; Alpizar et al. 2003).

There are a number of potential biases that have be taken into account with stated preference techniques (Fischhoff, 1991, 1997; Hausman, 1993; Diamond and Hausman, 1994) and careful attention has to be taken into the design of a study to minimize them. Over the years there have been many empirical experiments and suggestions incorporated in the methodologies to minimize the various errors or biases that could potentially affect the results (Whittington, 1998; Venkatachalam, 2004; Adamowicz and Boxall, 2001; Saelensminde, 2001).

3. North Cyprus and research design

Cyprus is one of the largest islands in the Eastern Basin of the Mediterranean Sea. The north-eastern portion of the island, with a population of 286,257, is populated by Turkish Cypriots. The average age of the population is 33 years (2013 Census). In North Cyprus, roads are the only available inter-urban mode of transport, and approximately 70% of these are paved. According to the 2013 Census, for every register motor vehicle (168,264), there were more than 2.5 driving licenses issued (432,055). Although the northern part accounts for a third of the island's land area, the distance between the five major parts is on average 47.68 km.[1]

The average incidence of fatalities and non-fatal injuries per year in the period 2010–2014 was about 40 and 1,067, respectively. Young people and adults between 21 and 44 years are the most involved in traffic accidents (2013 Census; European Commission Road Safety Statistics website, 2014; Road Traffic Accident Prevention Association, 2014). The top cause of traffic accidents in North Cyprus is the behavior of drivers and the second is road environment.

Surprisingly, foreigners can obtain a valid driving license for Cyprus without proper examination, simply by possessing a driving license from their own country. This raises concerns for a small island with a population of 50,000 international students and many long-term resident tourists from countries with poor driving standards.

There is a need to choose and implement various investments in the areas of transport, road safety, and driver education in order to alleviate this considerable social issue that has economic consequences. Among the many projects proposed, the key requirement is to select those that can be supported on the basis of cost–benefit analysis (CBA) or cost–effectiveness analysis (CEA). The public's WTP for increased road safety is one of the key parameters in such appraisals.

[1] Traffic Department, Traffic Accident Prevention and Road Safety Awareness Office. We obtained access to the complete North Cyprus distance and accident statistics data set. This data set is available via direct application to the Traffic Department.

Despite the fact that North Cyprus has endured levels of fatality and injury that are approximately three times higher than those in the EU over past five years, this is the first study to objectively assess the WTP of car drivers to avoid traffic accidents.

The questionnaire designed to ascertain the non-market value of road safety improvements included four parts. The first part focused on the recent trip in terms of transportation systems (status quo); the second was a CE question; the third included the CVM questions; and the last asked about the socio-demographic characteristics of the respondent.

3.1 Designing the choice experiment

The CE approach allows alternatives to be expressed in terms of combinations of different attributes at different levels, and the marginal WTP to be estimated for each alternative attribute. To generate the CE experiment, travelers were asked to make choices between two alternative routes offered and the current route. The CE approach derives the independent contributions of each of the attributes of the different routes.

In order to achieve realistic attributes and levels, after identifying and selecting from related literature with respect to design objectives and statistical efficiency, a number of pilot questionnaires were conducted. The attributes and their levels were confirmed by the outcomes of questionnaires, as shown in Table 1 (Hojman et al., 2005; Rizzi and Ortúzar, 2003, 2006; Hensher et al., 2009; Veisten et al., 2013; Hyman and Daly, 2014, Nguyen et al., 2015a, b). 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 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.

Table 1. Attributes and levels used in the CE

Attributes	Levels
Average speed limits per km/h posted on one- and two-lane each-way sections of route.	60, 80, 90, 100
Number of speed cameras located on one- and two-lane each-way sections of route.	1, 2
Total travel time.	60 min or less 61 to 120 min
Number of injuries in the past 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 in the past 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

In each of the five districts of North Cyprus there is a main road that leads to either the capital, Lefkoşa, or to one of the larger towns. The benchmark number of injuries of 20 and deaths of 10 are hypothetical, but at the same time not unrealistic for the present level of safety on these main routes. The CE questions are related to a one-way trip along these various major routes.

Given the average length of the road used in this study of 47.68 km, the travel time used in the questionnaire was set at less than 60 minutes or more than 61. This reflects the present road conditions in the country. The current length of time it requires for the residents of North Cyprus to make their trips on these roads was measured in the survey and was quite close to the benchmark of 60 minutes used in the questionnaire.

After determining the number of attributes and their levels, we constructed two unlabeled experiments as two hypothetical routes. In our case the full factorial design would have implied that there would be 256 ($4^2 \times 2^4$) choice sets. Within each experiment, the 32 profiles were subsequently grouped into four versions of eight choice sets by using the orthogonal fractional factorial that was created from this full factorial in order to decrease the number of choice sets in the experiment. Thus, each respondent saw only eight CE screens during the experiment process. 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). Finally, the option of the current route (no improvements and no payment required) was included in each choice set (Table 2).

Table 2. Typical card from CE 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)	60 min or less	61 to 120 min	
Running costs (TL)	20%	10%	
Fatalities (per year)	Fewer than 10 people	10 people or more	
Injuries (per year)	20 people or more	Fewer than 20 people	

3.2 Designing the contingent valuation questions

The CVM section of the questionnaire considered a safety improvement on the road environment. The objective of the CVM was to estimate the maximum WTP for two specific route projects which is presented on the CE section (Route A and Route B) with a reduction of premature fatality and injury using a payment ladder format. Individuals were required to state their maximum WTP at the given price (bid) for a safety improvement, in addition to their current costs for the trip (Table 3). Respondents could choose whether or not to pay an additional cost to secure the improvement in road safety. The questionnaire contained a explanation (cheap talk) describing the aims of the study.

Table 3. Typical card from Willingness to pay for road safety improvement

Suppose you are to return to your home after spending a day in (neighboring city approximately 45 to 50 km away). The trip has the following characteristics:
You drive your car.
You pay for the total cost of the trip.
Your return trip takes more than an hour.
You have to choose between two routes for your return trip (both are similar to the current route), considering the following two factors: the cost and the number of injuries and fatal crashes on each route.

We now ask you to suppose that a road safety improvement has become available that will achieve a reduction in premature deaths or injury for the next decade by improving safety in road environments. The improvement will involve installation of more speed cameras, and will reduce running costs and travel time on each trip. How much money would you be willing to pay monthly to improve safety in order to decrease your own possibility of dying (injury) by five in one thousand?

"Note: Every driver has a different purpose for their trip and a different level of financial resources. Please respond to the questions on the basis of your own purpose for the trip and finances. You should also consider whether your family has more important things to spend its money on."

		Total monthly cost	
Put a tick next to the highest amount you are sure that you would pay per month for the next decade and a cross next to the first amount that you are sure that you would not pay for safety improvement program.	1.	Would not pay for improved road safety	[ ]
	2.	10 TL per month	[ ]
	3.	20 TL per month	[ ]
	4.	30 TL per month	[ ]
	5.	40 TL per month	[ ]
	6.	50 TL per month	[ ]
	7.	70 TL per month	[ ]
	8.	90 TL per month	[ ]
	9.	120 TL per month	[ ]
	10.	150 TL per month	[ ]
	11.	200 TL per month	[ ]
	12.	250 TL per month	[ ]
	13.	350 TL per month	[ ]
	14.	450 TL per month	[ ]
	15.	550 TL per month	[ ]
	16.	More than 550 YTL per month Min WTP _________TL per month Max WTP __________TL per month	[ ]

4. Data collection and preliminary analysis

The main survey was conducted from the beginning of February to the end of May 2014 using face-to-face interviews. The respondents were selected by using the exogenous stratified random sample (ESRS) method with five mutually exclusive groups based on the main districts in North Cyprus. The districts of North Cyprus are included, Lefkoşa (33.1% of the 286,257 total population), Gazimağusa (24.4%), Girne (24.2%), Güzelyurt (10.5%), and İskele (7.9%) (2013 Census).

In the 2013 Census the total number of driving licenses issued in North Cyprus was 419,030. Of this total 44% were learner licenses that later might have been converted into regular license. A number of non-permanent residents, such as international university students and frequent holiday visitors have obtained driving license. The holiday visitors were excluded from the population surveyed.

Of the 510 car drivers who were asked to participate in this study, the number of usable responses was 374, or 2,992 observations, as each individual had eight choices. Of the remaining 136 responses, 11% were marked as protest bids. The others were answered on the basis of lexicographic decision-making rules (40% lexicographic respondents for the cost attribute, 22% for the fatality and injuries attributes, and 27% for the travel time attribute), and were excluded from the econometric analysis as the respondents might have had difficulty comprehending the choice scenario regarding the aim of our analysis (Johnson et al., 2000; Rizzi and Ortúzar, 2003).

The CVM survey was presented to the individuals of the same sample as used in the CE. Out of the 389 usable responses, 56 respondents (14.4%) who chose not to go for the improvement system were asked a follow up question and reasons for their choice. The 20 respondents who chose not to pay for the safety improvement and gave reasons were treated as protest responses, because such responses do not necessarily imply that the drivers put no value on the road safety improvement. In order to avoid a bias in estimation by including invalid zero bids, we removed the protest responses from the CVM analysis (Birol and Villalba, 2006).

Of the 374 respondents, 162(43%) were single and 191(51%) were married, with the remaining 21(6%) either separated or widowed. This is higher than the proportions of people in the 2013 Census, which were 42%, 54% and 4% respectively. About 70% of the families had children and, of these, two-thirds had children younger than 18 years of age. The average age of the individuals being interviewed was 36.7 (ranging from 20 to 61). From the 2013 Census, the weighted average age of the population between the ages of 20 to 61 was 32.1 years. Out of our sample of 374 about 35.5% had travel times below 60 minutes, while the remaining 64.5% had a travel time on average of greater than 61 minutes. The mean monthly family income according to the nine income ranges was TL6,010.58 (€2,051), ranging from TL5,501 (€1,877) to TL7,500 (€2,260) (Table 4).[2]

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

Table 4. 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
TL3,501–5,500	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

5. Results

5.1 The models

We estimated all parameters based on a constrained triangular distribution in the mixed logit model, where the heterogeneity around the mean preserved the sign of parameters by imposing a constraint on the standard deviation over the entire distribution.[3] We defined the standard deviation of the random parameters to be half 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 independent variables and their interaction with attributes and kept the significant interactions only (Briggs et al., 2015).[4] The mixed logit model with simulated maximum likelihood was estimated using the econometric software LIMDEP 9.0. The final mixed logit model results with interactions are reported in Table 5.

[3] Hensher and Greene (2011) suggest 'The empirical evidence offers an encouraging sign that constrained distributions on random parameters in preference space 'may' offer a suitable proxy for WTP estimates obtained in WTP space where such constraints are not imposed.'

[4] A number of social demographic variables were collected and considered as potential variables along with their interactions with the 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.

Table 5. Mixed logit with interaction results from CE application

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	(−4.67)***
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	(4.67)***
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)**
Fatality	1.40	(3.471)***
Injury	0.885	(2.904)***
Halton draws	1,000	
Number of observations	2,992	
LL (0)	−4, 753	
LL ([illegible])	−3, 230	
Pseudo-R^2	0.32	
Trip distance (km)		
Average	61.28	
St. dev.	27.05	
Min.	10	
Max.	101	

** $p < 0.05$, *** $p < 0.01$

The estimated utility, using equation (8), gave the highest values of Pseudo-R^2 (0.32) in the form of an additive utility function. Equation (9) is estimated to obtain the utility obtained from the current route. To estimate the WTP for improved road safety the expected utility obtained from equation 8 is divided by the expected utility obtained from the estimation of equation 9. The result is that we find that ASC has become the default variable to explain the choice of an improved road safety option over the current situation. Furthermore, the Wald test was used to estimate the WTP for the attributes as reported in Table 5.

$$U\ (Route\ A,\ B) = ASC + \beta_{sl} \times speed\ limit + \beta_{sc} \times speed\ cameras + \beta_{t} \times travel\ time + \beta_{fatality} \times fatality + \beta_{inj} \times injury + \beta_{lc} \times \ln\ (cost) + \beta_{slage} \times speed\ limits \times age + \beta_{sledu} \times speed\ limits \times education \quad (8)$$

$$U\ (Current\ Route) = \beta_{sl} \times speed\ limit + \beta_{sc} \times speed\ cameras + \beta_{t} \times travel\ time + \beta_{fatality} \times fatality + \beta_{inj} \times injury + \beta_{lc} \times \ln\ (cost) + \beta_{slage} \times speed\ limits \times age + \beta_{sledu} \times speed\ limits \times education \quad (9)$$

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.[5] 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 help to explain the sources of heterogeneity in the preferences of individuals.

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). We might have expected greater speed to 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 and age, and traffic speed limits and education are positive (0.001 and 0.031, respectively). The

[5] 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 5.

interaction between traffic speed limits and age implies that as age increases, the marginal disutility of driving at a high speed declines. The interaction between traffic speed limits and education implies that the marginal disutility associated with 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 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.[6] 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), which is associated with the unobserved influences on the choice between a particular route, A and B.

The results of the analysis of the CVM are reported in Table 6. The model was estimated using binary logit models in which the socio-demographic variables were included. The dependent variable takes the value one if the respondent is willing to accept additional payment to improve road safety, and zero otherwise (Hanemann and Kanninen, 1999). The monetary payment and the respondents' socio-demographic characteristics were used as the independent variables in this model.

The coefficients of all the variables are statistically significant. The coefficient of cost was found to be negative (−0.0207), which implies that the probability of accepting payment of the proposed

[6] The MRS for the effects coded binary attributes is MRSj= 2 $\frac{\partial v_j/\partial x_j}{\partial v_j/\partial c}\Big|_{v=\bar{v}}$ (Hu et al., 2004), where x denotes the vector of attributes as viewed by individual j. These attribute 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 multiply the coefficients by 2 in order to measure the marginal WTP for a unit change in the variable.

amount for safety decreases as the cost increases. The result indicates that the older respondents who have a university degree and higher incomes are more likely to pay. The model chi-square statistic is significant at the 99% confidence interval.

Table 6. Logit model estimation from CVM application

Variables	Parameters	(z-ratio)
Constant (ASC)	−0.8767	(−2.19)***
Cost (TL increase per month)	−0.0207	(−4.14)***
Age	0.0242	(2.01)***
Income	6.42E-5	(2.10)***
Education	0.6475	(2.43)***
Maximum log likelihood	−239.725	
% of correct predictions	60%	
Chi-square	31.11	
Pseudo-R^2	0.06	
Number of observations	369	

*** $p < 0.01$

In terms of goodness of fit, Pseudo-R^2 for the CE model (0.32) has a better prediction for choices made by respondents than the Pseudo-R^2 for the CVM model (0.06). This is probably a result of the variations in attributes, respondents' socio-demographic characteristics, and the interactions between these variables, while the CVM model is restricted to estimating one variable (in our case, cost) and the demographic characteristics.

5.2 Welfare analysis

When the objective of improving road, safety is to decrease the number of traffic casualties, we would like to measure the economic welfare impact of such an improvement on road users, in units of money income, estimated by compensating variation (CV). This method is often referred to as the maximum an individual is willing to pay for quality improvement (Silberberg and Suen, 2001). It is defined as the amount that needs to be deducted from a person's overall income at the new level of safety (S^1) to keep them as well off as at the initial level of safety (S^0). In terms of the indirect utility function, this can be expressed as:

$$V(P^0, S^0, Y) = V(P^0, S^1, Y-CV) \quad (10)$$

where P^0 is the vector of prices and Y is the individual's income. In terms of expenditure, the function can be calculated as follows:

$$CV = e\ (P^0, S^0, U^0) - (P^0, S^1, U^0) \tag{11}$$

where U^0 is the respondent's level of utility with the current route of S^0.

Since both methods are based on RUM theory, the welfare estimates of improving road safety can be estimated and compared. In the CVM case, change was examined by using the welfare measures outlined by Hanemann (1984). The mean WTP was determined using the formula:

$$Mean\ WTP = -\frac{\delta}{\beta} \tag{12}$$

where β is the value of the coefficient of the cost variable in the estimated logit equation, and δ is the sum of all other terms in the equation evaluated at the mean values of the independent variables.

For the CE case, the economic welfare impact, CV, for an average respondent under the different hypotheses was determined by the following equation:

$$Mean\ WTP = -\frac{1}{\beta_n}\left\{ ln\left[\sum_{h=1}^{h}\left(\sum_{i=1}^{I_c} e^{\frac{V_{hi}^{1}}{\beta_{nh}}}\right)^{\beta_{nh}}\right] - ln\left[\sum_{h=1}^{h}\left(\sum_{i=1}^{I_c} e^{\frac{V_{hi}^{0}}{\beta_{nh}}}\right)^{\beta_{nh}}\right]\right\} \tag{13}$$

where V^0 is the utility of the current situation, V^1 the utility with road safety improvement, h choice sets, i the number of alternatives, and β_n the coefficient of each attribute.

The WTPs for improvements in road safety are reported in Table 7, column 1. The results imply that the mean welfare measure obtained from the CVM is higher than that from the CE, but this estimation has a higher standard error than the estimate for the CVM (Table 7, column 2). As a consequence, the 95% confidence intervals in the CE estimate cover the entire 95% confidence interval of the CVM estimates (Table 7, column 3).

The maximum welfare impact of an improvement in road safety under different scenarios happens for 25 one-way trips per month taking 60 min or less, with one speed camera, a speed limit of 80km/h, and with fewer than 10 deaths and 20 injuries from automobile accidents per year. The WTP for this scenario was equivalent to a TL34.30 (€11.70) per month in CE. For the CVM the estimates of the WTP are 44.86 (€15.31) per month as measured by the increase in the monthly travel cost the car driver is willing to pay.

Table 7. Willingness to pay for road safety improvement from CE and CVM

	WTP TL/month	SE TL/month	95% confidence interval TL/month	
			Lower bound	Upper bound
CE	34.30 (€11.70)	13.95 (€4.76)	6.96 (€2.37)	61.64 (€21.03)
CVM	44.86 (€15.31)	5.21 (€1.77)	34.64(€11.82)	55.09(€18.80)

Delta method used to obtain confidence intervals in CE application (Greene, 2011) and bootstrap method with 1,000 draws in CVM application (Krinsky and Robb, 1986).

5.3 Tests for equivalence between methods

To assess the equality of the WTP for road safety improvement obtained through different approaches, we employed the empirical numeric procedure known as the convolution test (Poe et al., 2005). We chose this test because it does not require the assumption of a linear distribution between parameters and does not overstate the significance using non-overlapping confidence intervals (Park et al., 1991). In making a comparison of the CVM and CE welfare estimates, we proposed the null and alternative hypotheses as:

$$H_0: WTP_{CVM} - WTP_{CE} = 0$$
$$H_1: WTP_{CVM} - WTP_{CE} \neq 0 \quad (14)$$

The result of the consistency of hypotheses is presented in Table 8. We observed that the mean WTP estimates obtained with the help of CE and CVM have a statistically insignificant difference at the 95% confidence interval. [7]

Table 8. Results of hypothesis tests for equivalence between CE and CVM

	95% confidence intervals ($WTP_{CE} - WTP_{CVM}$) TL/month	Significance level ($WTP_{CE} - WTP_{CVM}$)
Convolution result	(−5.76, 66.15) (€1.96, €22.57)	0.178

[7] To increase efficiency, we also have estimated a pooled model, allowing for correlation among responses from the same respondent across the two surveys.

Hence, we used the empirical findings of the CE method presented in Table 5 on the WTP to avoid fatality and injury on roads to estimate the average value of risk reduction (VRR) for fatalities and injuries as follows:

$$VRR_f = VSL = \frac{\text{WTP}_{\text{fatalities}} \text{ per trip}}{\text{Trip km}} \times \frac{\text{AAVKM}}{\text{\# Fatalities}} \quad (15)$$

$$VRR_I = VI = \frac{\text{WTP}_{\text{Injuries}} \text{ per trip}}{\text{Trip km}} \times \frac{\text{AAVKM}}{\text{\# Injuries}} \quad (16)$$

According to equations (15) and (16), we need to convert the WTP parameters for fatalities and injuries from per trip to per person per kilometer and divide the value obtained by the chance. The chance of fatality or injury is defined by the relationship between the risk of fatality or injury per annum and the average annual number of vehicle kilometers on the route (AAVKM). The results are shown in Table 9.

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

Average Number of			Exposure	Chance of		VRR (TL) per	
Fatalities	Injuries	Average 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 km per liter.[8]

The final value of a statistical life (VSL) and value of injury (VI) per person are TL2,099,563 and TL49,474, respectively. Taking these results into consideration, the VSL converted into euros (€1=TL2.93) is €717,000, with the 95% confidence interval between €315,293 and €1,117,856, and the VI is €16,885, with the 95% confidence interval from €5,603 to €28,186.

[8] 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).

6. Discussion and conclusion

We compared our results with those in other studies that used similar methodology and that are reported in the literature on the valuation of road safety. 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.[9] 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.[10]

At the EU level, the VSL most frequently used is €1 million (European Transport Safety Council, 2007). The VSL 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 every death prevented there will also be a reduction in the number of accidents in which injuries and property damage occur (Wesemann, 2000). However, the point estimate of the VSL for North Cyprus derived from this study was below €1 million, which places it among the bottom 30% of the estimates reported by De Blaeij et al. (2003).

In this paper, estimates have been made for the value placed on road safety improvements by the residents of North Cyprus, employing both the CVM and the CE method. Using the convolution test, we found that the two estimates are not significantly different from each other. Given the closeness of the values obtained using these two methods, they can be employed with some confidence to estimate the VRR from road safety improvements. Using the lower mean values obtained from the CE results; the VRRs for fatalities and injury from automotive accidents are estimated.

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[9] 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).

[10] 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).

The estimate of the WTP of North Cyprus residents to reduce fatalities and injuries can be used to evaluate the feasibility of alternative policies of improving road safety through the CBA of road projects that not only reduce travel times and running costs but have also been proved to be effective in decreasing the number of traffic accidents.

In the period 2010–2014, the number of driving licenses issued in North Cyprus rose rapidly, and more investment has been allocated to the installation of speed cameras as a result. This investment has dramatically reduced the role of speed as a cause of accidents. However, the incidence of road fatalities and injuries in 2014 has not varied significantly from the situation in 2010. Furthermore, 30–50% of all accidents still occur at junctions. One important task will be to select projects to remove numerous minor roundabouts or congested four-way stop junctions and instead install modern roundabouts to reduce the incidence of accidents in these areas.

To gain a better appreciation of the total burden of road fatalities and injuries on the economic welfare of North Cyprus, we multiplied the number of lives lost and injuries that occurred in 2014 from automobile accidents by the VSL and VI, as reported in Table 9. As there were 40 fatalities and 1,067 injuries caused by traffic accidents in 2014, the total annual economic welfare burden was €46.7 million, which is equivalent to 1.5% of the gross national product (GNP) of North Cyprus in that year (Economic and Social Indicators, 2014).

This is a large annual loss of economic wellbeing, and is largely preventable. With such a loss in economic welfare, many worthwhile investments in road safety are likely to be justified. The values of the parameters estimated in this study for the VSL and VI are key parameters required to carry out the necessary cost–benefit analysis for the selection of such investments.

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