European Research Studies Journal
Volume XXII, Issue 2, 2019

pp. 342-352

Estimating the Value of Risk Reduction for Car Occupants

Submitted 10/02/19, 1st revision 25/02/19, 2nd revision 12/03/19 accepted 14/04/19

Shahram Fattahi[1], Somayeh Azami[2], Amineh Naderi[3]

Abstract

Purpose: *The paper tries to estimate the willingness to pay the value of statistical life of drivers in Tabriz highways.*
Design/Methodology/Approach: *Data were obtained using a questionnaire whish was distributed among people who travel daily on Tabriz highways to study or work in 2017. Stated choice technique and the mixed logit model are used to estimate the individual's preferences to reduce the risk of fatality and injury.*
Findings: *The results indicated the effects of cost, trip time, number of fatalities and injuries, number of speed cameras and speed limits on choosing a driving route. In addition, investigation of interactive effects of demographic variables and indices shows that only the interactive effects of age, income with indices are statistically significant.*
Practical Implications: *Some policy implications to increase investment on highways and financimg road projects by road users including drivers.*
Originality/Value: *Goverment strategy on highways development is to eliminate or reduce the number of fatalities and injuries.*

Keywords: *Goverment strategy, highways development, number of fatalities, injuries.*

JEL code: *C25, C83, C93, R41.*

Paper type : *Research article.*

[1]*Razi University, Faculty of Social Sciences, Dept. of Economics, Corresponding Author,* sh_fatahi@yahoo.com
[2]*Razi University, Faculty of Social Sciences, Dept. of Economics.*
[3]*Razi University. Faculty of Social Sciences, Dept. of Economics.*

1. Introduction

Traffic costs account for 1-2 percent of gross national product at the global level and road accidents were the fifth cause of death in 2013. It is the leading cause of death among young people in the 15-29 age group. Traffic accidents in Iran with an annual incidence of 34.1 per 100,000 people are the second leading cause of death and the first cause of lost life in Iran. In general, the years of lost life in Iran as a result of traffic accidents is higher than that of other parts of world and Eastern Mediterranean region and this problem is one of the serious issues in Iran (Ainy *et al.,* 2014).

Hence, the road safety nowadays is one of the critical issues. Road accidents cause serious consequences at the economic and public health levels, including loss of production capacity and income or human resources. If we take damage to properties and medical care and related rehabilitation into consideration, the financial burden caused by the accidents is considerable (Haddak *et al.*, 2014). In addition to the suffering and pain which people incur, losing a key factor in the household or losing the family head due to accidents can lead to poverty. In addition to economic and public health problems, loss of efficiency, loss of income, and the burial costs of many victims of accidents are among the serious consequences of accidents (Gopalakarishnan, 2012). Reducing this great social problem requires the choice and considerable investment in road transport and safety. An important task is to choose these projects among those which may be implemented and justified through cost-effectiveness and cost-benefit analyses (Elvik *et al.*, 2009).

To do so, the method of value of statistical life in road traffic is an important indicator for assessing road safety projects. In fact, the interaction and trade-off between monetary wealth and fatal risks are stated as value of statistical life (VSL), which is widely used to assess public policies in the fields of medicine, environment and safety. A key issue for starting a discussion is the precise meaning of the value of statistical life, which might seem to be surprising. The fact is that we are ready to lose all our wealth to prevent loss of our lives. Therefore, there is no restriction in definition of the value of life. When we spend part of our wealth to avoid fatal risks or we are willing to receive some money in exchange for taking risks, we implicitly define trade-off between wealth and the risk of fatality. The ratio of wealth we are willing to change with a small change in the likelihood of death, expressed as monetary units (in Rials or Dollars), is often called as value of statistical life, which plays an important role in assessing road safety projects, prioritizing projects, and allocating funds in this area (Ashenfelter, 2006).

Viscusi played a key role in empirical literature of VSL (1993). The value of statistical life is calculated as sum of willingness to pay (WTP) for improving the safety or sum of willingness to accept individuals (WTA), to compensate increasing risk levels. The value of statistical life is based one of these two approaches. The WTP and WTA values show people trade-off expenditures to improve safety against other consumption alternatives. Thus, these values clearly reflect the preferences and attitudes of individuals toward risk. The WTP is defined as the maximum value of money which people are willing to pay to avoid the risk of fatalities or injuries due to hazard activities occur due to road traffic (Anderson and Treich, 2011).

As the reduction of fatality risk is not market-dependent, we apply a non-market estimate for VSL. One of the well-known techniques in estimating the value of statistical life is the stated choice technique. The SC method is a test in which individuals are asked to choose among different alternatives.

The aim of this paper is to estimate the willingness to pay the value of statistical life of drivers in Tabriz highways in 2017 using the stated choice technique and econometric models which help policy makers in assessing safety improvement projects.

2. Material and Method

Suppose a particular route is used by the user N and provides a certain level of satisfaction expressed by the indirect utility function of the person.

$$V = V(r, c, t) \tag{1}$$

R=risk of fatality or injury, C=trip cost, and t=trip time in a particular route.

The VSL estimate is equal to the value of avoiding premature fatality or victimization by the injury to a person in a time unit. As road is a public good, the value of VSL for society is equal to the sum of the substitution rates of individuals between the risk of fatality or injury and income to the N user plus the covariance between the substitution rates of individuals MRS_j and the risk reduction δr.

$$MRS_j = \frac{\partial V/\partial r}{\partial V/\partial c}{:}V=\bar{V} \tag{2}$$

$$VSL = \frac{1}{N}\sum_{j=1}^{N} MRS_j + N\,COV\,(MRS_j\,, |\delta r|) \tag{3}$$

$$COV\left(MRS_j\,, |\delta r|\right) = \sum_{j=1}^{N}\frac{MRS_j\,\delta r_j}{N} - \sum_{j=1}^{N}\frac{MRS_j}{N}\sum_{j=1}^{N}\frac{\delta r_j}{N} \tag{4}$$

If we assume that the reduction in risk δr is equal for all people, the covariance between the substitution rates of individuals MRS_j and the reduction in risk δr is zero and the equation 3 is expressed as:

$$VSL = \frac{1}{N}\sum_{j=1}^{N} MRS_j \tag{5}$$

In other words, the value of statistical life of avoiding fatality or injury can be calculated as a sum MRS of a set of people who travel on a specific route. In terms of functional form, MRS depends on perception of each individual of his or her risk. Similar investigation can be performed through fatality or injury rates, which can be understandable from the respondent point of view. Therefore, the equation 1 gives:

$$MRS_j = \frac{\partial V / \partial f}{\partial V / \partial c : V = \bar{V}} = \sum_{j=1}^{N} SVF_j \tag{6}$$

f indicates the number of accidents leading to fatality and the risk is calculated as the ratio of fatality to population (Niroomand and Jenkins, 2016).

$$r = \frac{f}{N} \tag{7}$$

MRS is interpreted as the implicit value of life, which gives VSL by averaging on individuals. The SVF is a subjective value of a fatal crash reduction and is interpreted as the Lindhal price or the Lindhal tax (Varian, 1992). Equation 3 represents the definition of community-wide willingness to pay (WTP) for public goods (road safety improvement). If we suppose that under hypothetical tax routes, operators are fully able to extract the consumer market, the SVF is the maximum amount of money which can be extracted by expressing an individual's willingness for safety improvement. The indirect utility function Vji for each route j and for each individual i is shown as follows:

$$V_{ji} = \alpha f_{ji} + \beta C_{ji} + \gamma t_{ji} \tag{8}$$

F is the number of accidents leading to fatality, c is cost, and t is trip time. We assume that utility function is linear and a function summed up of trip attributes. As the designer does not have all information required, one random component should be included in the utility function. Random utility is simply obtained by summing two random surface and component utility terms.

$$U_{jic} = V_{jic} + \varepsilon_{jic} \tag{9}$$

It is assumed that each alternative is probability of choosing which has the highest utility Ujic for the individual. If the error terms are i.i.d, the polynomial Logit model will be an appropriate estimate. However, it is not real to assume that people have the same preferences. To solve this problem, we use mixed Logit model which assumes that those who answer the questionnaire have non-homogeneous preferences (Veisten *et al.*, 2013; Niroomand and Jenkins, 2016).

Thus, in contrast to homogeneous parameters in the normal Logit model, we assume that some parameters are not constant and we would have a certain coefficient for each individual and each option. Therefore, utility for the considered parameters is not determinable and random. However, the parameter β has distribution and its distribution has a constant parameter θ. In this case, in order to obtain the probability of the choice i, we should take an integral due to random variable of the coefficients, that is, an integral over Pjic. In this case, the probability of choosing option i would be as follows:

$$P_{jic} = \int \frac{e^{V_{jic}}}{\sum_{j=1} e^{V_{jic}}} \, g(\beta_n|\theta)\, d\beta \qquad (10)$$

$$E(P_{jic}(\beta)) = \frac{e^{V_{jic}(\beta)}}{\sum_{j=1} V_{jic}(\beta)} \qquad (11)$$

Where g (βn | θ) is the distribution function β with parameter θ. Vjic (β) is an observable and non-random part of the utility function, which its value depends on the coefficient β (Train, 2003). The probability of choosing a particular option depends on the random parameters with density function g (βn | θ). As random parameters are still unknown, a non-conditional probability is used in estimating the model. The following integral is calculated by the maximum simulated probability method (Niroomand and Jenkins, 2016).

$$P_{jic} = \int E\left(P_{jic}|\beta_n\right) g\left(\beta_n|\theta\right) d\beta \qquad (12)$$

In this research, the willingness to pay for a reduction in the risk of fatality and the risk of injury caused by accidents are calculated separately for all road users. Computational values show the value of risk reduction of fatality (VSL) and the value of risk reduction of injury (VI). As the focus of this study is on automobile drivers, the willingness to pay for individuals should be as high as the risk of a driver's population. Being exposed to risk is defined as the number of trips and kilometers traveled by each driver in the entire population. In fact, the willingness to pay is the average willingness to pay for each person and each trip. In order to obtain the amount of risk reduction of fatality and the risk of injury, the willingness to pay to reduce fatality and injury should be divided by the chance of dying in a car accident or the chance of being injured in a car accident. To estimate these relationships, the average number of fatalities or injuries and the average annual kilometers travelled in the last 5 years is required (Veisten *et al.*, 2013; Niroomand and Jenkins, 2016).

$$\mathrm{VRR_f} = \mathrm{VSL} = \frac{\mathrm{WTP_{per\ trip}}}{\mathrm{Trip\ kms}} \times \frac{\mathrm{AAVKM}}{\mathrm{\#\ Fatalities}} \qquad (13)$$

$$\mathrm{VRR_f} = \mathrm{VI} = \frac{\mathrm{WTP_{per\ trip}}}{\mathrm{Trip\ kms}} \times \frac{\mathrm{AAVKM}}{\mathrm{\#\ Injuries}} \qquad (14)$$

Thus, the chance of fatalities and injury is defined as relationship between risk, which is measured as the number of fatalities or injuries in one year, and being exposed, which is stated as average kilometers travelled in one year (AAVKM). The average annual travelled kilometers is measured as the amount of fuel consumed per year multiplied by efficiency value of the fuel (kilometers travelled per liter of fuel consumed).

To determine and choose the important influential attributes in designing questionnaire, previous studies were reviewed. Several initial questionnaires were examined by five groups of 50 people, and their views and suggestions on road safety, driving, accidents and accident history were evaluated to identify effective factors. The important indices and their levels were modified according to the feedback on the original design of the questionnaire. Finally, according to the literature and consulting with experts of traffic, six attributes were selected. An example of these attributes is shown in Table 1.

Table 1. *Levels of attributes*

Attributes	levels
Average speed in k/h in single-line or two-line roads	60, 80, 90, 100
The number of cameras controlling the speed in single-line or two-line roads	1, 0
Total time of trip	Less than 30 minutes 31 minutes to 1 hour
Number of injuries per year	Less than 10 people 10 people and more
Number fatalities per year	Less than 5 people 5 people and more
Rate of change in monthly costs of driving	5% more 10% more 15% more 20% more

For attributes 1 and 6, four levels are defined, and for other attributes, two levels are defined. In this research, the choice set has been created using the shifted design technique. The conventional approach to this work is the orthogonal design (Niroomand and Jenkins, 2016). If a full factorial design is used allowing for occurrence of all combinations of levels of attributes and the main effects and interactions, the set of choices allows for creation of 256 choices according to the 2 four-level attributes and 4 two-level attributes. Thus, orthogonal fractional factorial with 32 cases (8 choice sets) was extracted from a full factorial to reduce the choices. Moreover, as heterogeneity of preferences of individuals is taken into account in estimating the model, the orthogonal design is the best option for identifying the attributes and their levels (Louviere *et al.*, 2000).

The number of levels for each attribute was in squared form. In 32 profiles, each level is displayed 16 times in the case of two-level attributes, and each level is displayed 8 times in the case of 4-level attributes. The minimum overlap is created when the levels of attribute of the first hypothetical route (A) is shifted to create the second hypothetical route (B) and ensures that the levels of the attributes within the choice set are not overlapping. The balance of utility and the absence of a dominant relationship are ensured by reducing the utility gap between alternatives by replacing the dominant alternatives within each choice set (Carlsson and Martinsson, 2003).

To increase the realism of the decision-making and choice process, a current route option relates to the recent driving experience of the audience is added to each choice set (Louviere *et al.*, 2000). Thus, if two other options are attractive from the people point of views; they will choose the current route. Thus, designing a questionnaire for choosing the options for driving includes three alternatives. One option is to choose the current situation and two other options that are in front of the current option, indicating improvement in road safety indices. These two options do not have a specific name (in the design of the choice test related to brands, especial name is often used) and only show two hypothetical routes. An example of choice sets is given in the Table 2.

Table 2. *An example of choice sets*

Attributes	Route A	Route B	Current route
Average speed (km/h)	90	80	
The number of speed control cameras (in each line)	1	0	I prefer the current route
Total trip time (min)	Less than 30 minutes	31 minutes to 1 hour	
Number of injuries per year	10 people and more	Less than 10 people	
Number of fatalities per year	Less than 5 people	5 people and more	
Rate of change in monthly costs of driving	20% more	10% more	

The questionnaire was distributed among people who travel daily on highways to study or work in companies, schools, universities, offices, shopping centers and so on. The sample included people aged 18 to 65 years. The questionnaires were completed through a controlled interview in 2017. The number of completed questionnaires was 300 and, finally, the number of observations for the sample was 2400 based on the 8 choice sets. It is noted that the Cronbach's alpha was obtained 0.75 which confirms the reliability of questionnaire. The equations are specified as.

$$U(\text{rout1}) = ASC1 + \beta_c \times \ln(\text{cost}) + \beta_d \times \text{death} + \beta_i \times \text{injury} + \beta_t \times \text{travel time} + \beta_{nc} \times \text{num of camera} + \beta_{sl} + \text{speed limit} + \beta_{ci} \times \text{cost} \times \text{income} + \beta_{sa} \times \text{speed limit} \times \text{age} \quad (15)$$

$$U(rout2) = ASC1 + \beta_c \times \ln(cost) + \beta_d \times death + \beta_i \times injury + \beta_t \times travel\ time + \beta_{nc} \times num\ of\ camera + \beta_{sl} + speed\ limit + \beta_{ci} \times cost \times income + \beta_{sa} \times speed\ limit \times age \quad (16)$$

$$U(no\ travel) = 0 \quad (17)$$

The value of risk reduction in death and injury has been reported in Table 3. In order to estimate the risk of fatality and injury, based on equations 13 and 14, we divide the level of willingness to pay by the chance of fatality and injury. The chance of fatality and injury is calculated by the relationship between the risk of annual fatality and injury and the average number of kilometers traveled annually. Therefore, in order to obtain the average annual kilometers travelled in the highways of Tabriz, fuel efficiency coefficient (considered 8 liters per 100 kilometers inside the city) and the total fuel consumption of one year in Tabriz highways have been calculated.

Table 3. *Results of estimating VSL and VI*

VI	VSL	AAVKM	Number of injured people	Number of loses
762620	59139600	3478800000	333	5

3. Empirical Analysis

To estimate the individuals' willingness to pay to reduce the risk of fatality and injury using the choice technique, the mixed logit model was estimated using software R. The distribution of random parameters in the mixed logit model makes the heterogeneity in the preferences of individuals possible. To achieve the appropriate model, the parameters and indices have been entered into the utility function in linear or logarithmic form. The pseudo rho-square value represents the model with very appropriate fit (Louviere *et al.*, 2000). As triangular distribution is very suitable for the estimation of willingness to pay (Hensher and Greene, 2005), the distribution of all random parameters was first determined as a finite triangular distribution. However, the mean and standard deviation of many parameters became statistically non-significant. This indicates that this distribution is not able to cover heterogeneity in preferences. Thus, all random parameters were estimated based on a finite triangular distribution. To determine any significant effect of socio-economic variables on random parameters, all potential interactive effects were estimated and only significant effects remained in the model (Birol and Villalba, 2006). The mean and standard deviation of the coefficients of all indices are significant and all coefficients, except for coefficient of speed limitation variable have the expected sign. Among the demographic variables, only the interactive effect of the variables of age, income, and education with random variables was statistically significant.

Based on the results, the variables cost of trip, trip time, and number of fatalities, number of injured people, speed limit, and number of speed control cameras are factors affecting the people choice of driving route. Nirromand and Jenkins (2016) emphasized these factors as the ones affecting the choice of drivers' routes. However, they found the number of cameras is insignificant. Hensher *et al.* (2011) concluded that only indices cost, fatality, serious and partial injury, and trip time are important. Veisten *et al.* (2013) showed that indices time, cost, and fatality are significant. As shown in Table 4, the willingness to pay for reducing the time (hours) is 336 Rials. Moreover, the willingness to pay by vehicle drivers to reduce fatalities caused by accidents is 8.5 Rials and it is 7.3 Rials for reducing the number of injuries. Based on the results, the willingness to pay to reduce fatality is greater than that of injuries. This result is in line with the results of Hajman *et al.* (2005), Hensher *et al.* (2011), Haddak *et al.* (2014) and Niroomand and Jenkins (2016).

Table 4. *Results of mixed logit model*

Variables	parameters		T ratio
Random variables (with limited triangular distributions)			
cost	-0.23	random	-2.01
Fatality	-0.27	random	-2.76
injuries	-0.17	random	-3.09
Trip time	-0.13	random	-5.78
Number of camera	-0.08	random	-0.59
Speed limit	-0.1	random	-2.01
Non random variables			
Intercept	0.17	fixed	3.27
Income × cost	0.007	fixed	3.39
Age and speed	0.001	fixed	2.43
Halton draws	1000		
Willingness to pay			
Fatality	0.85		3.32
injuries	0.73		2.23
Trip time	0.56		2.02
Number of camera	0.34		4.03
Speed limit	0.43		3.50
Number of observations	576		
Pseudo R2	0.31		

Moreover, the interactive effect between income and cost and age and the speed is positive. The positive effect of income and cost reflects the final utility of income and the final utility of incomes of rich people is lower. Therefore, if a toll system is implemented on highways, it is expected that rich people to pay more money to improve the safety of highways. In addition, there is a positive effect between age and speed. As higher speeds are usually desirable on highways, it is expected that people with higher age and higher income to choose the highway route for driving and have high willing to pay more to improve the safety of highways. Finally, the value of statistical life and injury is 591396000 and 7626200 Rials, respectively, which is equivalent to 14685 and 191 dollars, respectively.

4. Conclusions and Some Policy Implications

In the present study, the stated choice technique and the mixed logit model were used to estimate the individual's preferences on reducing the risk of fatality and injury. The results indicated the effects of indices cost, trip time, number of fatalities and injuries, number of cameras and speed limits on choosing a driving route. In addition, investigation of interactive effects of demographic variables and indices showed that only the interactive effects of age, income with the indices are significant. The value of statistical life and the statistical value of injury were estimated to be 591.396.000 and 7.626.200 Rials, respectively. Considering the number of fatalities and injuries in Tabriz highways, investment in improving the safety of city streets is necessary. Since the interactive effects of the cost index with the income variables is positive, rich people have more willingness to pay for improving the road safety. On the other hand, the interactive effects of age and speed have shown that older people have more willingness to increase speed and reduce driving time. Thus, in order to improve the safety of Tabriz highways and reduce fatalities and injuries, economic investments are recommended. One solution is to assign these tasks to private companies and financing road projects by road users including drivers. The outcome of accidents is fatalities, injuries, and financial loses.

The risk of fatality and injury and accidents is not solely due to human errors, but road and its safety are critical in reducing or increasing fatalities. Therefore, investment in improving road safety is an important part of reducing fatality around the world. However, investment projects to reduce fatalities and injuries should be investigated in terms of cost-benefit in order to prevent the loss of resources of the country.

References:

Ainy, E, Soori, H, Ganjali, M and Baghfalaki, T. 2014. Road Traffic Injury Cost Estimation by Willingness to Pay Method. Journal of Safety Promotion and Injury Prevention, 2(3), 215-225

Anderson, H and Treich, N. 2011. The Value of Statistical Life. Transport Economics, 1-36.

Ashenfelter, O. 2006. Measuring the Value of Statistical Life: Problems and Prospects. Institute for the Study, of Labor, IZA Discussion Paper, No.1911, 1-32.

Barro, R. 1991. Economic growth in a cross-section of countries. Quarterly Journal of Economics, 106, 407-443.

Birol, E and Villalba, E.R. 2006. Estimating Mexican Farmer's Valuation of Milpa Diversity and Genetically Modified Maize: A Choice Experiment Approach. Environmental Economy and Policy Research. Working Paper, University of Cambridge, Department of Land Economics.

Carlsson, F and Martinsson, P. 2003. Design Techniques for Stated Preferences Methods in Health Economics. Health Economics, 12(4), 281-294.

Elvik, R., Hoye, A., Vaa, T. and Sorensen, M. 2009. The Handbook of Road Safety Measures (2nd ed). Emerald, Bingley, UK.

Gopalakarishnan, S. 2012. A Public Health Perspective of Road Traffic Accidents. J. Fam. Med. Prim. Care, 1(2), 144-150.

Haddak, M., Havet, N. and Lefevre, M. 2014. Willingness to Pay for Road Safety Improvement. Gate. Working Paper 06, 1-18.

Hensher, D.A. and Greene, W.H. 2001. The Mixed Logit Model: The State of Practice and Warnings. The Unwary, 1-39.

Hensher, D.A., Rose, J.M., Ortuzar, J.D. and Rizzi, L. 2011. Estimating the Value of Risk Reduction for Pedestrains in the Road Environment: An Exploratory Analysis. Journal of Choice Modeling, 4(2), 70-94.

Louviere, J.J., Hensher, D.A. and Swait. 2000. Stated Choice Methods: Analysis and Applications. Cambridge University Press.

Niroomand, N. and Jenkins, G.P. 2016. Estimating the Value of life. Injury and Travel Time Saved: Using a Stated Preferences FrameWork. Accident Analysis and Prevention, 91, 216-225.

SWOV fact sheet. 2012. The Valuation of Human Losses of Road Deaths, 1-5.

Train, K. 2003. Discrete Choice Methods With Simulation. Cambridge UK: Cambridge University Press.

Varian, H.R. 1992. Microeconomic Analysis (3rd edition). Norton and Company INC, New York.

Veisten, K., Flugel, S., Rizzi, L., Ortuzar, J. and Elvik, R. 2013. Valuing Casualty Risk Reductions from Estimated Baseline Risk. Research in Transportation Economics, 43, 50-61.