Using bayesian model to estimate the cost of traffic injuries in Iran in 2013

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ABSTRACT

Background and Aim: A significant social and economic burden inflicts by road traffic injuries (RTIs). We aimed to use Bayesian model, to present the precise method, and to estimate the cost of RTIs in Iran in 2013.

Materials and Methods: In a cross-sectional study on costs resulting from traffic injuries, 846 people per road user were randomly selected and investigated during 3 months (1st September–1st December) in 2013. The research questionnaire was prepared based on the standard for willingness to pay (WTP) method considering perceived risks, especially in Iran. Data were collected along with four scenarios for occupants, pedestrians, vehicle drivers, and motorcyclists. Inclusion criterion was having at least high school education and being in the age range of 18–65 years old; risk perception was an important factor to the study and measured by visual tool. Samples who did not have risk perception were excluded from the study. Main outcome measure was cost estimation of traffic injuries using WTP method.

Results: Mean WTP was 2,612,050 internal rate of return (IRR) among these road users. Statistical value of life was estimated according to 20,408 death cases 402,314,106,073,648 IRR, equivalent to 13,410,470,202$ based on the dollar free market rate of 30,000 IRR (purchase power parity). In sum, injury and death cases came to 1,171,450,232,238,648 IRR equivalents to 39,048,341,074$. Moreover, in 2013, costs of traffic accident constituted 6.46% of gross national income, which was 604,300,000,000$. WTP had a significant relationship with age, middle and high income, daily payment to injury reduction, more payment to time reduction, trip mileage, private cars drivers, bus, minibus vehicles, and occupants (P < 0.01).

Conclusion: Costs of traffic injuries included noticeable portion of gross national income. If policy-making and resource allocation are made based on the scientific pieces of evidence, an enormous amount of capital can be saved through reducing death and injury rates.

Key Words: Bayesian model, contingent value, cost, death, injured, revealed preference, road traffic injury, stated preference, willingness to pay

INTRODUCTION

Traffic injuries with the annual occurrence rate of 26.5 cases/100,000 people are the second cause of fatality and first cause of year life lost in Iran.[1,2] In general, in Iran, the amount of year life lost as a result of traffic injuries is higher than that in the other part of the world and Eastern Mediterranean region, and this problem is one of the serious issues of the country.[3] Death victims of road injuries are 3 people per 10,000 vehicles in the world, while in Iran, it is 7.3 people per 10,000 vehicles, which is unfortunately increasing every year.[4] Moreover, traffic injuries can put a pressure on the health-care system that is mostly due to the insufficiency of resources. Low- and

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middle-income countries (LIC-MIC) have a high amount of death burden related to traffic injuries.\cite{5} Further and depth research of the economic burden due to road traffic injuries (RTIs) and more probing about the relationship of the health system factors and RTIs burdens to prevention and intervention programs should be produced in LIC, MIC, and high-income countries (HIC).\cite{6} According to Transportation Research Center, Iran University of Science and Technology, cost of traffic injuries using the human capital method was estimated 180,000 billion internal rate of return (IRR) in 2012.\cite{7} Generally speaking, the human capital approach proposes a number which is less than the actual cost of injuries, because in this method, cost components including special damage, execution, lost work, medical services, human cost, underreporting by the police and forensic medicine organizations, intensity and degree of injury, underreporting by insurance company, social costs including lost time, consumable fuel, additional pollution, cost of pain accompanying the injury, or worsening life quality, elderly, children, or patients are not included or estimated in the analysis.\cite{8} In contrast, willingness to pay (WTP) method presents a more accurate figure for cost rate and is an appropriate way for increasing social welfare by reducing injury and death.\cite{8-12} Death of thousands Iranians during the past 10 years due to traffic injuries and also injury and disability of millions of people during this period of time can by themselves place the necessity for such estimation on the list of the most important health-related priorities in the country.\cite{13} In this study, to estimate the cost resulting from traffic injuries, WTP method (which is used in HIC) was used. Thus far, this method has been less applied in LIC and MIC due to the accuracy in collecting the required information. We aimed to use Bayesian model to estimate the cost of traffic injuries in Iran in 2013.

**MATERIALS AND METHODS**

In a cross-sectional study on costs resulting from traffic injuries, 846 people per road user were randomly selected and investigated during 3 months (1st September–1st December) in 2013. Global report of road safety was reported for Iran 2013 in which the portions of pedestrians, two-wheeled motorcyclists, occupants of four-wheeled vehicles, and drivers of four-wheeled vehicles were 28%, 23%, 26%, and 23%, respectively. Totally, based on the mentioned percentages, 846 people per road user were randomly selected and investigated. The research questionnaire was prepared based on the standard for WTP method considering perceived risks, especially in Iran, and its validity was determined using content validity which gained 75% of the overall degree of agreement out of 10 domain experts (by determining validity index and content validity ratio of 0.79). Its reliability was specified using test–retest method as \( r = 0.88 \). The study questionnaires included three parts: The contingent value (CV) approach involved direct questions; participants were straight asked that how much they were willing to pay for fatality risk reduction. The stated preference (SP) involved hypothetical scenarios for all road users (public transport drivers, motorcyclist, pedestrians, and occupants). The revealed preference (RP) method elicits value from real evidence such as importance to vehicle safety based on his/her WTP to more safety to his/her family or added safety device to own vehicle. In addition, WTP approach was used to estimate the value of statistical life and cost of injuries. Inclusion criterion was having at least high school education and being in the age range of 18–65 years old. Risk perception was an important factor to the study and measured by visual tool. Samples who did not have risk perception were excluded from the study. After a brief explanation about the study, consent letter was obtained from the participants. The collected data were analyzed after their strict control. Final analysis of WTP was carried out using a Bayesian method using WinBUGS software (version 1-4-3) 2012, University of Cambridge, UK.

**Statistical approaches**

**Bayesian approach**

Here, we will use a Bayesian approach for estimating the parameters. In this method, hierarchical structure should be used to define the model. The following model is used for this purpose:

In which as before the model’s error has an extreme exponential distribution (and \( \varepsilon_i \) and \( i \) are the annual rate of WTP for person \( i \), in this model \( W_i \) has Weibull distribution).

To carry out Bayesian inference, specifying prior distributions for the unknown parameters is necessary; as usual we have location parameter.

In this structure, \( N_{18} (0,1000 I_{18}) \) refers to a multivariate normal distribution with zero mean and large variance. Furthermore, \( I_{18} \) refers to the 18 × 18 unit matrix. An exponential distribution with mean 1000 is also considered, as a prior distribution, for the scale parameter of the Weibull distribution. Using this structure, a noninformative structure is considered for modeling.

Therefore, the above-mentioned model leads us to the following hierarchical model:

**Methods to handle missing covariates**

**Bayesian approach**

Various approaches have been developed to deal with missing covariate problems in regression analysis when the data are missing at random. In the Bayesian
approach, missing values can be filled in using predictive distributions. In this approach, an appropriate distribution is used for modeling the covariates with missing values.

In our data set, daily payment for injury reduction, payment for time reduction, and distance were continuous variables, have missing values. The assumption of lognormal distribution with mean \( m \) and variances is used for modeling these missing values. Furthermore, a Bernoulli distribution with mean \( p \) was considered for “having accident” variable which has some missing values. Hence, the hierarchical structure was as follows:

Therefore, in the presence of these prior distributions, it is necessary to obtain posterior distributions for the unknown parameters; then, Bayesian inference is formed according to these posterior distributions. Again, two methods have been used for modeling. The first method uses the imputation of zero values for WTP with the amount of 500 and the second one uses the assumption of having a value <1000; results of both imputations are the same.

**Frequents approach**

We have used regression imputation for handling missing covariates. Regression imputation (also known as conditional mean imputation) replaces missing values with predicted scores from a regression equation. The basic idea behind this approach is intuitively appealing: use information from the complete variables to fill in the incomplete variables. Variables tend to be correlated, so it makes good sense to generate imputations that borrow information from the observed data. In fact, borrowing information from the observed data is a strategy that regression imputation shares with maximum likelihood and multiple imputation although the latter approaches do so in a more sophisticated manner. The first step of the imputation process is to estimate a set of regression equations that predict the incomplete variables from the complete variables. A complete-case analysis usually generates these estimates. The second step is to generate predicted values for the incomplete variables. These predicted scores fill in the missing values and produce a complete data set.

As mentioned before “Accident,” “Dis,” “PTR,” and “DPFR” are the covariates with missing values. The following regression model is used for the continuous covariates (“Dis”, “PTR,” and “DPFR”):

Where, for the binary covariate (Accident), a logistic model is used. After imputation of the missing values, a maximum likelihood approach is used to obtain the parameter estimates.

**RESULTS**

Out of all the collected samples, only 846 questionnaires were completely filled out. Given that, one of the key questions of this research was risk perception; it was observed that 64 out of 846 people wrongly responded to risk perception. Therefore, they were removed and data of 782 samples were analyzed. Mean age of the studied people was 33.4 ± 9.9. Men and women formed maximum and minimum gender percent by 89.3% and 10.7%, respectively. Employment status showed that the maximum number of people (45.8%) was self-employed, 64.2% owned houses, and 57.3% owned cars. Moreover, maximum percentages of leaving and returning home were in the morning by 88.4% and at night and midnight by 51%, respectively. The value of statistical life for one death was estimated to be 19,713,584,609 IRR based on mean WTP among road users 2,612,050 IRR and based on reduction rate of death risk from 26.5/100,000 people to 13.25/100,000 people. For total death cases in 2013 based on 20,408 death cases or 26.5 death cases per 100,000 people, 402,314,106,073,648 IRR which was equivalents to 13,410,470,202$ based on the dollar free market rate of 30,000 IRR with purchase power parity was obtained. Injury cost was 769,136,126,165,000 IRR equivalents to 25,637,870,872$ (considering annual traffic volume 113,518: Daily traffic volume 311 in 2013 × the mean of daily payment 31,030 IRR × 250 working days × 318,802 injured people in 2013). In sum, injury and death cases came to 1,171,450,232,238,648 IRR equivalents to 390,048,341,074$.

Findings in Table 1, results of Bayesian estimation using 500 Toman (one of the Iranian currencies) or 5,000 IRR for zero values and regression imputation for missing values showed that WTP had a significant relationship with age, middle and high income, daily payment to injury reduction, more payment to time reduction, trip mileage, private cars drivers, bus, minibus vehicles, and occupants [Table 1].

Findings in Table 2, results of Bayesian estimation using 1,000 Toman or 10,000 IRR for zero values and regression imputation for missing values showed that WTP had a significant relationship with age, middle and high income, daily payment to injury reduction, more payment to time reduction, trip mileage, private cars drivers, bus, minibus vehicles, and occupants [Table 2].

**DISCUSSION**

Results showed that value of statistical life for a death case was 19,713,584,906 IRR. WTP was higher among the people who had middle and high income compared with those with low income. It also had a significant relationship with age, trip mileage, and all road users
except pedestrians. In Bhattacharya’s study, value of statistical life in Delhi was estimated to be 150,000$. Rate of WTP grew with income and risk reduction. In Henry’s study, real value of accident cost was estimated using a method that reflected willingness of the society to pay. Pitel also calculated the number and cost of injuries caused by traffic injuries using the WTP method in Canada. Cost of the injuries was also estimated to be 2,062,000,000$.

Calculating value of statistical life is one of the most important components in determining the value of risk reduction. León showed that calculating value of statistical life is a key component in general policy-makings, which is used in the frequent evaluation of efficiency in environmental projects and field making which are effective in death. His results showed that social profit of survival would be 9.54 lives/year with the value of 5.5 million dollars.

| Variable                        | Mean ± SD    | Median | Lower limit | Upper limit |
|---------------------------------|--------------|--------|-------------|-------------|
| Intercept                       | 8.891 ± 0.483| 8.891  | 7.884       | 9.859       |
| Age                             | 0.012 ± 0.004| 0.012  | 0.004       | 0.019       |
| Education (high school and diploma) | 0.131 ± 0.080| 0.129  | −0.028      | 0.288       |
| Family size: 4 and more         | 0.041 ± 0.926| 0.038  | −0.225      | 0.137       |
| Income                          |              |        |             |             |
| Middle income                   | 0.444 ± 0.183| 0.465  | 0.071       | 0.785       |
| High income                     | 0.624 ± 0.205| 0.631  | 0.210       | 1.014       |
| Has had an accident experience  | −0.055 ± 0.074| −0.056 | −0.203      | −0.085      |
| Log (kilometer moving)          | −0.14 ± 0.005| −0.014 | −0.023      | −0.004      |
| Log (daily payment to injury reduction) | 0.248 ± 0.043| 0.248  | 0.158       | 0.327       |
| Log (payment to time reduction) | 0.005 ± 0.003| 0.006  | 0.000       | 0.112       |
| Health                          |              |        |             |             |
| Low                             | 0.031 ± 0.112| 0.030  | −0.192      | 0.246       |
| Middle                          | 0.041 ± 0.087| 0.043  | −0.132      | 0.208       |
| Road users                      |              |        |             |             |
| Bus                             | 0.792 ± 0.132| 0.791  | 0.530       | 1.049       |
| Minibus                         | 0.641 ± 0.124| 0.642  | 0.398       | 0.883       |
| Car                             | 1.259 ± 0.161| 1.261  | 0.944       | 1.571       |
| Occupants                       | 0.582 ± 0.149| 0.586  | 0.279       | 0.870       |
| Pedestrian                      | 0.101 ± 0.138| 0.104  | −0.175      | 0.365       |
| r                               | 0.942 ± 0.027| 0.941  | 0.895       | 0.998       |

CIs: Confidence interval, SD: Standard deviation

| Variable                        | Mean ± SD    | Median | Lower limit | Upper limit |
|---------------------------------|--------------|--------|-------------|-------------|
| Intercept                       | 8.979 ± 0.435| 8.110  | 7.884       | 9.859       |
| Age                             | 0.011 ± 0.004| 0.011  | 0.003       | 0.020       |
| Education (high school and diploma) | 0.128 ± 0.081| 0.126  | −0.032      | 0.280       |
| Family size: 4 and more         | −0.013 ± 0.095| −0.015 | −0.200      | 0.170       |
| Income                          |              |        |             |             |
| Middle income                   | 0.447 ± 0.171| 0.453  | 0.085       | 0.766       |
| High income                     | 0.622 ± 0.194| 0.622  | 0.243       | 0.988       |
| Has had an accident experience  | −0.045 ± 0.076| −0.044 | −0.194      | 0.111       |
| Log (kilometer moving)          | −0.014 ± 0.004| −0.015 | −0.023      | −0.005      |
| Log (daily payment to injury reduction) | 0.240 ± 0.040| 0.247  | 0.152       | 0.308       |
| Log (payment to time reduction) | 0.005 ± 0.002| 0.005  | −0.000      | 0.010       |
| Health                          |              |        |             |             |
| Low                             | 0.034 ± 0.106| 0.032  | −0.170      | 0.253       |
| Middle                          | 0.036 ± 0.093| 0.035  | −0.124      | 0.198       |
| Road users                      |              |        |             |             |
| Bus                             | 0.814 ± 0.133| 0.813  | 0.549       | 1.074       |
| Minibus                         | 0.658 ± 0.118| 0.658  | 0.427       | 0.892       |
| Car                             | 1.288 ± 0.157| 1.287  | 0.983       | 1.590       |
| Occupants                       | 0.601 ± 0.144| 0.601  | 0.324       | 0.899       |
| Pedestrian                      | 0.116 ± 0.135| 0.113  | −0.149      | 0.382       |
| r                               | 0.939 ± 0.028| 0.941  | 0.876       | 0.989       |

CIs: Confidence interval, SD: Standard deviation
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sum, injury and death cases came to 1,171,450,232,38,648 IRR equivalents to 390,048,341,0748. Transportation Research Center of Iran University of Science and Technology estimated that cost of traffic injuries using human capital approach to be 180,000 billion IRR in 2012.[6] Statistics used in this method which is taken from the police and forensics medicine organizations are usually underreported. In human capital method, value of hypothetical income for those with no production and the retired people is equal to zero. Financial estimation in human capital approach is less than its real value.[18]

Considering the accuracy of WTP method, in this study, cost of traffic injuries was approximately 6.5 times of the fortune reported by Iran University of Science and Technology. During the two recent decades, many countries have used the WTP approach. WTP is the value considered by people for social death reduction. Other studies have emphasized the accuracy of this method.[17] If WTP is considered to aim at reduced risk, a sign for value of statistical life would be obtained.[19] Value of risk change or WTP is based on fundamental assumptions and shows that the adopted decisions on resource allocation in the governmental sector should reflect citizens’ demands and preferences. The value allocated for improving road safety (risk reduction) is the total amount paid by people for preparation.[16,18,19,20,21]

Hensher showed value of statistical life as an efficient method for the economic analysis of safety benefit and promotion of road environment.[22] Other studies have demonstrated that preference expression studies may be valuable in the field of policy-making.[14,22-24] New approaches are being implemented for calculating value of statistical life. However, no improvement has been made in calculation methods for lost output, medical costs, and other costs (human capital model).[18,23]

The presented statistics showed that this rate was much higher than the global statistics. It seems that the undertaken measures have not been efficient in terms of reducing traffic injuries, or priorities of resource allocation have not been correctly detected, and thus, the made investments have been spent in less effective areas, the result of which has been high traffic volume in the country. The mentioned capital can be spent in the related departments such as traffic police, road police, and other concerned organizations to improve traffic status and promote road monitoring in the country.

Using the three methods of CV, SP, and RP can be considered the innovation of this study. Study on specific age group 18–65 years old and certain education at least high school education were the study’s limitations. Bayesian approach in analysis allows us to combine prior knowledge with observations to make predictions about the phenomenon under study. In Bayesian inference, all unknowns in a system are modeled by probability distributions that are updated using Bayes’ theorem as evidence accumulates. We show that the use of Bayesian models opens new possibilities for cross-sectional research.

CONCLUSION

Costs of traffic injuries included noticeable portion of gross national income. If policy-making and resource allocation are made based on the scientific pieces of evidence, an enormous amount of capital can be saved through reducing death and injury rates.

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Conflicts of interest
There are no conflicts of interest.

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