Eliciting road traffic injuries cost among Iranian drivers’ public vehicles using willingness to pay method

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ABSTRACT

Background and Aim: To allocate resources at the national level and ensure the safety level of roads with the aim of economic efficiency, cost calculation can help determine the size of the problem and demonstrate the economic benefits resulting from preventing such injuries. This study was carried out to elicit the cost of traffic injuries among Iranian drivers of public vehicles.

Materials and Methods: In a cross-sectional study, 410 drivers of public vehicles were randomly selected from all the drivers in city of Tehran, Iran. The research questionnaire was prepared based on the standard for willingness to pay (WTP) method (stated preference (SP), contingent value (CV), and revealed preference (RP) model). Data were collected along with a scenario for vehicle drivers. Inclusion criteria were having at least high school education and being in the age range of 18 to 65 years old. Final analysis of willingness to pay was carried out using Weibull model.

Results: Mean WTP was 3,337,130 IRR among drivers of public vehicles. Statistical value of life was estimated 118,222,552,601,648 IRR, for according to 4,694 dead drivers, which was equivalent to 3,940,751,753 $ based on the dollar free market rate of 30,000 IRR (purchase power parity). Injury cost was 108,376,366,437,500 IRR, equivalent to 3,612,545,548 $. In sum, injury and death cases came to 226,606,472,346,449 IRR, which was equivalent to 7,553,549,078 $. Moreover in 2013, cost of traffic injuries among the drivers of public vehicles constituted 1.25% of gross national income, which was 604,300,000,000$.

Conclusion: Cost of traffic injuries among drivers of public vehicles included 1.25% of gross national income, which was noticeable; minibus drivers had less perception of risk reduction than others.

Key Words: Contingent value, drivers of public vehicles, revealed preference, stated preference, willingness to pay

INTRODUCTION

Growing cost of fatalities and injuries is a major issue for managers, authorities, policy makers, and traffic police. Traffic injuries with the annual occurrence rate of 26.5 cases per 100,000 people are the second cause of fatality and first cause of year life lost in Iran. Generally, in Iran, the amount of year life lost as a result of traffic injuries is higher than that in the world and Eastern Mediterranean region; this problem is one of the serious issues of the country.[1] Causes of traffic accidents are drivers, highways, and motor vehicles and most of the road traffic injuries often involve drivers.[2-5] Tanzanian police has attributed 51.6% of the accidents to reckless/dangerous driving.[6] For precise resource allocation, cost calculation can help determine the size of the problem. Such calculation is more widely done using two methods: One method is human capital model and another is willingness to pay (WTP) method. In human capital method, computational components are
extracted from the information of police and forensics medicine organizations. Because this model is mostly focused on lost output and does not consider the elderly and children who do not have any revenue, it is usually accompanied by under-reporting. In contrast, willingness to pay method measures the benefit resulting from the prevention of death and injury caused by traffic injuries and thus its cost calculation is closer to the real figure of injury costs. There is lack of information about the cost of road traffic injuries among Iranian public transportation drivers. Thus, this study was conducted to calculate the cost of road traffic injuries among Iranian public transportation drivers in 2013 using WTP method for the first time.

**MATERIALS AND METHODS**

In a cross-sectional study on the costs resulting from traffic injuries, 410 drivers of public vehicles were randomly selected and investigated. The research questionnaire was prepared based on the standard for WTP method (stated preference (SP), contingent value (CV), revealed preference (RP) model) considering perceived risks, especially in Iran. The research questionnaire was collected along with a scenario for the drivers of public vehicles. Inclusion criteria were having at least high school education and being in the age range of 18 to 65 years old. For the precise implementation of the research, a briefing session was held for the questioners to get them familiar with how to fill out the questionnaire, interview, and use visual tools for risk understanding.

**Calculating process**

Fatality cost estimation (FC): Actual risk of death in traffic injuries in Iran was approximately 26.5 per 100,000 people. Nonetheless, a 50% reduction in risk was equivalent to the reduction of 13.25 per 100,000 people. To obtain the value of statistical life, the CV value (3,337,130 IRR) was multiplied by 100,000/13.25. Statistical value of life was estimated according to the Legal Forensic of Iran (LFI) which was 4694 deaths (estimated by the 2013 LFI with the total expenditure of 118,222,552,601,648 IRR, equivalent to 3,940,751,753 $, based on the dollar free market rate of 30,000 IRR (purchase power parity).

Estimate value of avoided injury (VAI) was 108,376,366,437,500 IRR, equivalent to 3,612,545,548 $, which was estimated using the following formula:

\[
\text{VAI} = \text{DP} \times \text{IC} \times \text{DTV} \times \text{WD}
\]

\[
\text{DP} = \text{Daily payment for injury reduction; 19,010 IRR} \\
\text{IC} = \text{73,325 injured cases (by the 2013 Legal Forensic of Iran (LFI))} \\
\text{DTV} = \text{Daily traffic volume of 311 (estimated by the 2013 Road Maintenance and Transportation Organization, Iranian Ministry of Road and Urban Development)} \\
\text{WD} = 250 \text{ working days}
\]

The total estimated cost of injury and death cases was 226,606,472,346,449 IRR, equivalent to 7,553,549,078 $.

The collected data were analyzed after their strict control. Final analysis of willingness to pay was carried out using Weibull model and R software (ver. 2013-03-01) by Institute for Statistics and Mathematics, Vienna. The R package was used to obtain the maximum likelihood estimates for the regression parameters.

**Statistical models for drivers**

To model WTP for drivers, a Weibull model was used as follows:

\[
\log(W_i) = \mu_i + \epsilon_i, \quad i=1,2,...,n,
\]

in which

\[
\mu_i = \beta_0 + \beta_1 \text{Vehicle}_{1i} + \beta_2 \text{Vehicle}_{2i} + \beta_3 \text{Age}_{i} + \beta_4 \text{Gender}_{i} + \beta_5 \text{Edu}_{i} + \beta_6 \text{Familysize}_{i1} + \beta_7 \text{Income}_{i1} + \beta_8 \text{Income}_{i2} + \beta_9 \text{Accident}_{i} + \beta_{10} \text{log(Dis}_{i}) + \beta_{11} \text{log(DPFR}_{i}) + \beta_{12} \text{log(PTR}_{i}) + \beta_{13} \text{log(Prefertopay65}_{i}) + \beta_{14} \text{Howpercen}_{i} + \beta_{15} \text{Howoften}_{i} + \beta_{16} \text{H1}_{i} + \beta_{17} \text{H2}_{i}
\]

Where \( Wi \) is the annual willingness to pay for the \( i \)th person and \( \epsilon_i \) is the model error with extreme exponential distribution (the consequently lead us to have a Weibull distribution for \( W_i \)).

We defined dummy variables by assuming that a categorical variable has three levels (type of car). Thus, two indicator variables were constructed as follows:

\[
\text{Vehicle}_1 = \begin{cases} 1 & \text{Bus} \\ 0 & \text{o.w.} \end{cases}, \quad \text{Vehicle}_2 = \begin{cases} 1 & \text{Minibus} \\ 0 & \text{o.w.} \end{cases}
\]

If both indicator variables Vehicle, and Vehicle, have a value of zero, the fact that individual has the third type of vehicle (i.e., private car).

In the above model, age is a continuous variable and gender is specified as the following dummy variable.

\[
\text{Gender} = \begin{cases} 1 & \text{Male} \\ 0 & \text{Female} \end{cases}
\]

Edu is the indicator variable for education, so that

\[
\text{Edu} = \begin{cases} 1 & \text{High school and diploma} \\ 0 & \text{others} \end{cases}
\]

Familysize, and Familysize are dummy variables of the number of family members and were defined as:
Income₁ and Income₂ are dummy variables of income level, defined as follows:

\[
\text{Income}_1 = \begin{cases} 
1 & \text{Middle income} \\
0 & \text{o.w.}
\end{cases}, \\
\text{Income}_2 = \begin{cases} 
1 & \text{High income} \\
0 & \text{o.w.}
\end{cases}.
\]

Accident (accident history) is an indicator variable, so that

\[
\text{Accident} = \begin{cases} 
1 & \text{Having an accident experience} \\
0 & \text{others}
\end{cases}.
\]

Health status is defined as:

\[
H_1 = \begin{cases} 
1 & \text{Low health} \\
0 & \text{o.w.}
\end{cases}, \\
H_2 = \begin{cases} 
1 & \text{Middle health} \\
0 & \text{o.w.}
\end{cases}.
\]

Also, in this model Dis means the distance traveled by an individual (km), DPFR shows daily payment for reducing death risk, and PTR indicates payment for travel time reduction. The other covariates are the number of hours worked per day as a continuous variable and more pay to less traffic, more pay to free flowing traffic, percent of more pay to less traffic, and how often the seat belt was fastened.

Form of the likelihood

The probability density function of the Weibull distribution with parameters \(\lambda\) and \(r\) is given by:

\[
f(w; \lambda, r) = \lambda w^{r-1} \exp\left(-\lambda w^r\right),
\]

Where \(\lambda\) is the scale parameter for the \(i\)th individual and \(r\) is the shape parameter.

In the Weibull regression model, \(\lambda_i\) is parameterized again in terms of predictor variables and regression parameters (or \(\mu\)) in the following way:

\[
\lambda_i = \exp(\mu_i),
\]

The mean of this model (mean WTP) is defined as follows:

\[
\mathbb{E}[W_i] = \exp(\mu_i) \Gamma\left(1 + \frac{1}{r}\right).
\]

Therefore, the observed likelihood function is as follows:

\[
L(\beta, r | w) = \prod_{i=1}^n f(w_i; \lambda_i, r) = \prod_{i=1}^n \left(\lambda_i r w_i^{r-1} \exp\left(-\lambda_i w_i^r\right)\right),
\]

Where \(f(.; \lambda_i, r)\) denotes the density function of the Weibull model with shape parameter and scale parameter \(\lambda\).

Presence of participants with zero willingness to pay: Approaches and likelihood

One problem in the analysis of the abovementioned data is the existence of 27 zeroes in the values of the WTP variable. Two solutions exist for this problem. The first method is to replace zero values with the midpoint of 0 and 1000 (10,000 IRR), i.e., 500 (5,000 IRR). If an indicator variable is defined as follows:

\[
Z_i = \begin{cases} 
1 & \text{zero willingness to pay} \\
0 & \text{o.w.}
\end{cases}.
\]

The likelihood function is as follows (assuming \(n\) as the total number of drivers):

\[
L(\beta, r | w) = \prod_{i=1}^n f(w_i; \lambda_i, r) \cdot (f(500; \lambda_i, r))^{z_i} = \prod_{i=1}^n \left(\lambda_i r w_i^{r-1} \exp\left(-\lambda_i w_i^r\right)\right)^{z_i}.
\]

Where \(z_i\) is the observed value of \(Z_i\).

The second approach for dealing with the zero points is to assume that these people’s WTP was less than the minimum value in the sample 1000 (10,000 IRR). In this case, the likelihood function is as follows (assuming \(n\) as the total number of drivers):

\[
L(\beta, r | w) = \prod_{i=1}^n f(w_i; \lambda_i, r) \cdot f(1000; \lambda_i, r)^{z_i} = \prod_{i=1}^n \left(\lambda_i r w_i^{r-1} \exp\left(-\lambda_i w_i^r\right)\right)^{z_i}.
\]

Where \(f(1000(10,000IRR))\) is the cumulating distribution function of Weibull evaluated of 1000(10,000IRR).

Findings

Out of all the collected samples, only 410 questionnaires were completely filled out. Given that one of the key questions of this research was risk perception, it was observed that 27 out of 410 people wrongly responded to risk understanding. Therefore, they were removed.
and data of 383 samples were analyzed. Mean age of the drivers was 36.1 ± 10.0. Men and women formed maximum and minimum gender percent by 89.3%, and 10.7%, respectively. Mean family size was 4.18. Moreover, 65.3% of the studied population was breadwinners. Employment status showed that the maximum number of people (47.3%) was self-employed, 62.7% owned houses, and 56.7% owned cars. Educational status revealed that maximum education percent was at diploma level (49.9%). Maximum percentage of monthly income was between 5 and 10 million IRR (49.3%). Maximum percentage in terms of trip purpose was business (81.7%). Moreover, maximum percentages of leaving and returning home were in the morning by 85.6% and at night and midnight by 61.1%, respectively. Mean of willingness to pay for more safety among the drivers was 6,697,260 IRR, which was higher than other items such as willingness to pay for risk reduction and daily willingness to pay. In the investigated population, value of one minute time in cars was higher by 3105 IRR and value of one minute time in buses was lower by 1523 IRR than those in other vehicles. Willingness to pay for having a safer vehicle was higher than that for risk reduction. And, 54.7% of the studied population was willing to pay for traffic reduction. People were willing to pay on average 14,500 IRR more than the trip cost in order to reduce 10 min of their total time of daily trips. Furthermore, 15.4% of people were willing to pay 10% more than the cost of daily trips in order to use less crowded vehicles. Statistical value of life was estimated according to 4694 death drivers 19,010 IRR for 250 working days). In sum, injury and death cases came to 226,606,472,346,449 IRR, equivalent to 7,553,549,078 $. In 2013, costs of traffic injuries among the drivers constituted 1.25% of gross national income. Willingness to pay was higher among those who had extra payment for reducing time, more daily payment, and more pay to less traffic. Willingness to pay also had a significant relationship with gender, and minibus drivers. More than four-fifths of the studied population traveled with business purposes. In line

Figure 1 shows the WTP (panel a) and logarithm of WTP (panel b) for car drivers as a one sample of procedure. This figure illustrates the severe skewness of the observations. Panel (b) of this figure shows that some people have zero willingness to pay. The same patterns are found for other road users [Figure 1].

Table 1 contain results of maximum likelihood using a value less than 1000 (10,000 IRR) for zero values and regression imputation for missing values, shows that WTP had a significant relationship with daily payment for risk reduction, payment for time reduction, more pay to less traffic.

Table 2 contain results of maximum likelihood using 500 (5,000 IRR) for zero values and regression imputation for missing values, shows that WTP was significantly associated with gender, daily payment for risk reduction, payment for time reduction, more pay to less traffic and among minibus drivers.

### DISCUSSION

Mean willingness to pay was 3,337,130 IRR among drivers of public vehicles. In sum, injury and death cost was 226,606,472,346,449 IRR, equivalent to 7,553,549,078 $. Moreover in 2013, costs of traffic injuries among the drivers of public vehicles constituted 1.25% of gross national income. Willingness to pay was higher among those who had extra payment for reducing time, more daily payment, and more pay to less traffic. Willingness to pay also had a significant relationship with gender, and minibus drivers. More than four-fifths of the studied population traveled with business purposes. In line
with the current findings, Chhotu’s study showed that willingness to pay for reducing accidents per year was 2.6 Rupee per km. Coefficient rate of trip time to trip cost was 2, representing that users were willing to pay 2 Rupee more than usual in order to reduce their trip time. Also, people were willing to pay 0.08 Rupee per km in order to have more comfortable trips.[12] Antoniou’s study showed perceived difference in prevention value; to avoid unrealistic estimation, he noted attention to the population heterogeneity as an important aspect. These points should be considered that most people are in the middle class of the society and traffic density implies trip delays because of the interference of vehicles on a path. Density cost is a better method than other urban transportation costs. This method with over- or under-estimation can be used in close-to-ideal transportation policies and decision makings.[13] In the current study, injury cost was estimated according to annual traffic volume and based on daily traffic volume and daily payment during 250 working days considering the number of injuries. Litman represented traffic density as the biggest problem of urban transportation, the reduction of which would lead to maximum efficiency. He noted that calculation of density cost had a great effect on planning.[14] Results showed that people tended to reduce their trip time and use less crowded vehicles; thus, they were willing to pay more for this purpose. In line with other studies, this study showed the importance of reducing trip time, less traffic, and less crowded vehicles in the considered population. Transportation Research Center, Iran University of Science and Technology, estimated cost of traffic injuries using human capital approach as 180,000 billion IRR in 2012.[15] Statistics used in this method was taken from the police and forensics medicine organizations and thus may be under-reported. Cost of road traffic injury among the drivers of public vehicles was more than the estimation by Transportation Research Center, Iran University of Science and Technology. Real value of injury cost was estimated using a method that reflected willingness of the society to pay. Safety level can be different in various parts. In WTP method, in order for risk reduction of the value of statistical life, concentration should be made on the difference between not only vehicles, but also accident types. The current study used revealed preference method in addition to the cases investigated in Henry’s study. The studied population was more willing to pay in order to increase safety than reduce risk. It is worth noting that the studied population was more willing to pay in the cases, in which family safety was guaranteed, than the cases, in which the government had to interfere for problem solving. A theoretical terms, WTP is

### Table 2: Results of maximum likelihood estimation using 500 (5,000 IRR) for zero values and regression imputation for missing values

| Variable                          | Est.       | S.E.       | Z value | P value | Est.       | S.E.       | Z value | P value |
|-----------------------------------|------------|------------|---------|---------|------------|------------|---------|---------|
| Intercept                         | 7.21844    | 0.72162    | 10.0031 | <0.001  | 7.20167    | 0.73138    | 9.8467  | <0.001  |
| Vehicle type                      |            |            |         |         |            |            |         |         |
| Bus                               | -0.06372   | 0.22191    | -0.2871 | NS      | -0.06347   | 0.22498    | -0.2821 | NS      |
| Minibus                           | -0.48615   | 0.18047    | -2.6937 | <0.01   | -0.48727   | 0.18305    | -2.6619 | <0.01   |
| Age                               | 0.00658    | 0.00632    | 1.0412  | NS      | 0.00653    | 0.0064    | 1.0197  | NS      |
| Gender (male)                     | -0.42823   | 0.18223    | -2.35   | <0.01   | -0.42853   | 0.18471    | -2.32   | <0.01   |
| Education (High school and diploma)| 0.20881    | 0.13374    | 1.5612  | NS      | 0.20716    | 0.1355    | 1.5288  | NS      |
| Family size                       |            |            |         |         |            |            |         |         |
| Less than 4                       | 0.00318    | 0.13829    | 0.023   | NS      | 0.00343    | 0.14022    | 0.0245  | NS      |
| Equal to 4                        | 0.02754    | 0.1318     | 0.2089  | NS      | 0.0258     | 0.13356    | 0.1932  | NS      |
| Income                            |            |            |         |         |            |            |         |         |
| Middle income                     | 0.38461    | 0.30924    | 1.2437  | NS      | 0.38456    | 0.31348    | 1.2267  | NS      |
| High income                       | 0.53137    | 0.33827    | 1.5708  | NS      | 0.53258    | 0.34286    | 1.5633  | NS      |
| Has an accident experience        | 0.03195    | 0.1043     | 0.3063  | NS      | 0.03013    | 0.10572    | 0.285   | NS      |
| Log (kilometer moving)            | -0.05372   | 0.09687    | -0.593  | NS      | -0.03319   | 0.06768    | -0.5753 | NS      |
| Log (daily payment to fatal reduction) | 0.49871    | 0.06221    | 8.0169  | <0.001  | 0.50025    | 0.06305    | 7.9343  | <0.001  |
| Log (more pay to time reduction)  | 0.08549    | 0.01899    | 4.5024  | <0.001  | 0.0859     | 0.01927    | 4.4582  | <0.001  |
| Log (more pay to less traffic)    | 0.3064     | 0.07733    | 3.9621  | <0.001  | 0.30761    | 0.07842    | 3.9226  | <0.001  |
| Health                            |            |            |         |         |            |            |         |         |
| Low                               | -0.09569   | 0.16048    | -0.5963 | NS      | -0.09816   | 0.16262    | -0.5913 | NS      |
| Middle                            | 0.11611    | 0.12876    | 0.9017  | NS      | 0.1168     | 0.13047    | 0.8952  | NS      |
| Log (scale)                       | -0.02826   | 0.04114    | -0.6869 | NS      | -0.0143    | 0.04233    | -0.3377 | NS      |
| n                                 | -5150.8    | 383        | -4664.4 |         | 383        | 383        |         |         |

IRR = Iranian rial’s
improving the sub-structure considering the limitation of resources based on prioritization. People are willing to pay significantly more for the lower chance of getting cancer that for not having traffic injuries, house burning, and aviation. Also, willingness to pay for traffic injuries is 5% more than aviation and 3% more than house burning.

Using the three methods of contingent valuation, stated preference, and revealed preference can be considered an innovation in this study. Also, Weibull models were used for modeling the data of willingness to pay. In this study, three different methods were applied for the imputation of missing values (median, regression, and mean imputation methods). Results showed that the missing values were random. In similar studies, missing values and the way of dealing with them have not been mentioned.

CONCLUSION

Willingness to pay was affected by gender, daily payment for reducing injury risk, payment for reducing trip time, more pay to less traffic, and drivers of minibuses. Costs of traffic injuries included 1.25% of gross national income. The presented statistics showed that this rate was high among drivers of public vehicles. Thus, it is essential to plan for improving the knowledge of minibus drivers about risk. The studied population was more willing to pay in the cases, in which family safety was guaranteed, than the cases, in which the government had to interfere for problem solving. Building trust in the society by the government seems to be a necessity. Considering the community’s opinion, the value of one minute for car was higher than other vehicles; hence, a serious alteration should be implemented in the kind of public transportation for promoting the safety of the community.

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