ECONOMIC AND SOCIAL COSTS OF TRAFFIC CRASHES IN SAUDI ARABIA

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ABSTRACT

Road traffic crashes have a substantial social and economic impact on the individual, family and the society at large. In Saudi Arabia, road safety has become increasingly vital and many nationwide strategic objectives have been established to reduce road fatalities. Therefore, it is important to estimate the costs of road traffic crashes to understand the extent and magnitude of the safety problem and guide decision-makers to propose effective countermeasures that would improve road safety and are economically justified. Several related data were collected to estimate the direct costs of traffic crashes in addition to conducting a questionnaire survey to estimate the human costs based on the willingness-to-pay (WTP) approach. Also, an ordinal logistic regression model was developed to examine the socioeconomic factors that affects individuals' WTP to reduce risk of being in a crash. The results indicate that there were four significant underlying variables (education, income, year of the make of the vehicle and if the individuals' relatives experienced a crash). Regarding the costs of traffic crashes, the results show that the average cost of a fatal crash, considering production loss, medical, property damages, administrative and human costs, was SR 5,984,338 (US$ 1,595,823) . The costs of serious injury, minor injury and PDO crashes were $375,470, $24,421 and $5,732, respectively. Therefore, the total economic and social costs of road traffic crashes in KSA is estimated to be around $20.27 billion (59.25% of which is direct costs), and this is equivalent to 2.88% of the Gross Domestic Product (GDP) of Saudi Arabia in 2018.

Keywords: Cost of traffic crashes, Willingness-to-pay (WTP), Ordinal Logistic Regression, Saudi Arabia,

INTRODUCTION

Road traffic crashes is a primary cause of concern worldwide, and it has led to around 1.35 million deaths and 50 million injuries every year (*1*). Fatalities and injuries due to traffic crashes in developing countries contribute to over 85% of the total global fatalities and injuries (*1*). Road traffic crashes impose an economic burden on a nation's economy. In economic terms, the costs of traffic crashes usually vary from 0.4% to 4.1% of the Gross Domestic Product (GDP), based on a data from 31 European countries (*2*).

Saudi Arabia (KSA) has a total population of 34.2 million and a total area of 2.15 million square kilometers (*3*). It has been categorized as a high-income country, and it is part of the G20 group of countries. Generally, the design of road network and quality of roads meet the global standards. In KSA, traffic crashes are the second leading cause of death (*4*). The number of fatalities and serious injuries due to traffic crashes totaled over one million during the period 1970-2008 (*5*). Around 80% of all trauma admissions is due to traffic injuries, and 20% of hospital beds are occupied by traffic crashes victims (*6*, *7*). Therefore, traffic crashes place a major burden not only on the families and friends of the injured person but also on the economics of the country at large.

The costs of traffic crashes could be classified into tangible and intangible costs. Tangible (direct) costs include mainly medical and rehabilitation cost, property damage cost, and administrative costs (e.g. police and fire fighters' services). The intangible (indirect) costs contain lost productivity and human costs (*2*). Knowing the total costs of traffic crashes is important to comprehend the extent and magnitude of the traffic safety problem and it is useful to evaluate the economic effectiveness of implementing safety countermeasures using benefit-cost analysis. Also, it would encourage decision makers to allocate some resources on improving road safety in the country.

This study aims to estimate the total costs of traffic crashes in KSA and the cost of traffic crashes for the different severity levels using a comprehensive approach. It also aims to identify the effect of the socioeconomic factors of individuals on their WTP for fatality risk reduction in KSA.

PREVIOUS STUDIES

Researchers have used advanced approaches to estimate the comprehensive costs of traffic crashes. Those approaches include willingness-to-pay (WTP) approach, net output approach, human capital (HC) or gross output approach, life insurance approach, court award approach, and implicit public sector valuation approach (*8*). HC and WTP approaches are widely used for estimating the costs of traffic crashes. Generally, selecting the appropriate approach depends on the objective, data availability, and capacity of the country.

The WTP approach has been implemented to estimate the costs of traffic crashes in many countries, such as United states, Sweden, United Kingdom, Singapore, New Zealand, Netherland, and Iran (*9–11*). The second most popular approach in estimating the costs of

traffic crashes is HC, and it has been adopted in many countries, such as Egypt, Vietnam, Sudan, South Africa, and Kuwait (*8*, *12–15*). International guidelines recommend the use of WTP approach and it results in higher human costs (pain, suffering, and grief) (*9*). The human costs account for an average of 40% of the total costs of traffic crashes when they implement WTP approach, and it is much lesser when they implement alternative method to calculate human costs (*2*, *9*). Some studies recommend that human costs should be estimated through WTP approach, and production loss should be estimated through HC approach (*16*).

Costs of traffic crashes for a country is usually expressed as a proportion of the GDP. Wijnen and Stipdonk (*9*) provide an overview of the costs of traffic crashes for 17 countries (ten of which are high income countries and 7 are low- and middle- income countries). They identified that the costs in high income countries vary from 0.5% to 6% of the GDP, and it ranges from 1.1% to 2.9% of the GDP for low- and middle- income countries. However, none of the low- and middle- income countries included in this study have used a WTP approach when calculating human costs. Elvik (*17*) found that the costs of traffic crashes for 11 countries included in the study range from 0.5% to 5.7% of gross national product (GNP) with an average of 2.5% of GNP. For other countries, it was found that the costs of traffic crashes are about 6.64% of the GNP in Iran (*11*), 2.56% of the GDP in Thailand (*18*), 3.4% of the GDP in South Africa (*14*), and 2.25% of the GDP in Jordan (*19*).

Locally, there were few studies that attempted to estimate the costs of traffic crashes in KSA. First, in 1980, Khawashki have estimated the costs of traffic crashes in KSA and found it to be about SR 2.4 billion (US $ 651.83 million) (*20*). The study did not include administrative costs, production loss, and damages to public properties, which are main components of the total costs of traffic crashes. In 2002, ArRiyadh Development Authority (ADA) estimated the costs of traffic crashes in Riyadh city (capital of KSA) to be around 1.5% of the GDP (*21*). However, the cost for each crash severity level in ADA study was taken from the UK figures, and those are core numbers in calculating the total costs of traffic crashes. Then, the strategic national traffic safety plan in 2011 has estimated the costs of traffic crashes based on the numbers of the previous study with some adjustment based on the inflation rate (*22*). Lastly, Mohamed (*23*) estimated the total costs of traffic crashes in KSA through the estimation of value of statistical life (VoSL) in 2013. However, this study has many limitations. First, the sample size in the online survey was only 148 respondents, and this is not enough to get an estimate of the VoSL in KSA. Also, the study included only the calculation of the VoSL without the other main costs (direct costs) in order to get the total costs of traffic crashes. Moreover, there were many assumptions with respect to the percentages of serious and minor injuries from the total number of crashes.

To sum up, while previous national studies have not estimated the total costs (tangible and intangible) of traffic crashes using appropriate data or approaches, this study aims to estimate the total costs of traffic crashes using human capital cost and willingness-to-pay approach. In addition, it aims to explore the effect of the socioeconomic factors of individuals on their WTP to reduce the risk of being in a fatal crash in KSA.

DATA COLLECTION AND PREPARATION

In order to estimate the costs of traffic crashes in KSA, huge data is required from different sources to get the most complete and accurate results. The data in this study was collected from different sources, including the general directorate of traffic (GDT), the national company for insurance services (NAJM), ministry of health, red crescent authority, rehabilitation center at King Fahad Medical City (KFMC), general authority for statistics, and Saudi Authority for Accredited Valuers (TAQEEM). The rest of this section discusses in details the nature of the collected data from the above resources.

Crash Data

The Crash data has been obtained from GDT, and it includes the total number of fatal, injury and property damage only (PDO) crashes. In 2018, there were 304,703 traffic crashes in KSA, in which 5,787 were killed and another 30,579 were injured. Regarding the PDO crashes, NAJM, which is a private company, handles PDO crashes if any of the involved vehicles has a valid vehicle insurance. Therefore, the PDO crashes that are reported by NAJM was also obtained for the same year to get the most complete crash data. The total number of fatal, injury, and PDO crashes are 4,631, 17,252, and 1,319,750 (1,036,930 from NAJM and 282,820 from GDT), respectively.

There is a big difference in crash cost with respect to injury crash severity. Therefore, injury crashes have to be divided into serious and minor injury crashes. To do so, a sample of crashes were used to identify the proportion of each injury level. A sample of crash data from Riyadh city for the period between 2012 and 2016 was obtained, and the proportion of serious and minor injury crashes were found to be 20% and 80%, respectively. In addition, the crash data contains information related to the crash (i.e., crash severity, time, date, etc.), involved people (age, nationality, health status, etc.), and involved vehicles (i.e., vehicle type, vehicle year, etc.).

Socioeconomic Data

The general authority for statistics periodically produces the socioeconomic data in KSA. The related data that was acquired include: average age for Saudi retirees, which was 58 years in 2018 and the average monthly salary of employed persons, for Saudi nationals and expatriates, which were SR 6,750 and SR 2,079, respectively. Also, the number and value of imported vehicles based on their classifications (i.e., buses, passenger cars and jeeps, and trucks) were acquired. Lastly, the economic growth rate (EGR) and discount rate were acquired, which are 2.43% and 5%, respectively. In terms of the nationality, the non-Saudi represents significant portion of the population, which is 37.8%.

Medical Data

The ministry of health provided the medical data for 2018 through King Saud Medical City (KSMC). The data contains rich information about the injured patients due to traffic crashes. It includes types and costs of treatments and/or operations. It also includes transport method (ambulance, private car), length of stay at hospital, patient's status after treatment (died,

discharged, or transferred to a rehabilitation center). In addition, it shows the injury severity score (ISS), which ranges from 1 to 75. Based on ISS, the cases have been categorized into died, serious injury (if ISS is more than 14), and minor injury (if ISS is equal or less than 14) (*10*). Moreover, the red crescent authority provided the cost of the medical and emergency services along with transportation cost. Lastly, the required data related to rehabilitation cost was obtained from the rehabilitation center at KFMC.

Property damage Data

Recently in KSA, a new authority which deals with valuing property damages (TAQEEM) was established. It estimates the value of repairing the damaged vehicle including the spare parts or estimating the market value of the vehicle before and after the traffic crash. A sample of over 280,000 vehicles were obtained. The data was used to get the cost of repairing the damaged vehicle based on the vehicle classification and linked to the crash data.

Administrative Data

The administrative data was mainly related to the GDT which includes average salary of the policemen who are responsible for handling traffic crashes. In addition, NAJM indicates that the average cost of handling each PDO crash is SR 300.

Willingness-to-pay (WTP) Survey

Traffic crashes have a social cost which is considered intangible cost to evaluate loss of a life. WTP approach can be used to measure the value of pain, suffering, and grief due to traffic crashes on individuals or their families. It can be done by asking people to what extend they are willing to pay for certain improvements in the road or their vehicles to avoid the risk of being killed or seriously injured.

WTP Survey Structure

The questionnaire consists of two parts; the first part relates to the respondents' socioeconomic information. The second part contains several questions related to the willingness to pay to avoid either being in a traffic crash or to reduce its risk. The first two questions were to ask the respondents on their willingness to pay in order to avoid being in fatal, serious injury, and minor injury crash. They were given five answers to measure their response from zero percent to 15%. The difference between these two questions is the percentage of reducing the risk of being involved in these crashes (i.e., 50% and 25%). The two questions formulated into two different ways. The purpose of the former questions is to determine the VoSL in matter of the investment in the vehicle safety to reduce the risk. The purpose of the latter question is to determine the VoSL from the people’s WTP out of their income in matter of road and infrastructure safety in return of risk reduction of a fatal or serious injury crashes. The last set of questions were to determine the investment that the people are willing to pay in matter of vehicle safety equipment without mentioning the risk reduction in order to determine the human cost of fatality and the pain of losing a family member. The question was "how much would you be willing to pay to get extra safety features, which will reduce risk of being in a

fatal crash when you're buying a new or used car for your immediate family?". They were given the answer of less than SR 1,000, 1,001-5,000, 5,001-10,000 and more than 10,000.

Pilot Survey

In the beginning, a pilot questionnaire was conducted to assess the reliability of the questionnaire. The results revealed that the Cronbach's alpha for the questionnaire items was between 84% to 94%, indicating that the items have a strong statistical reliability. Generally, a Cronbach's alpha of 70% and above is good (*24*).

Sample Size

The survey was carried out among people in the 13 provinces of KSA. This type of questions is new to the people in KSA. Therefore, it was decided to conduct the survey face-to-face. The sample size is 2,579 respondents whom aged more than 15 years old from the 13 regions of KSA. Figure 1 illustrates the distribution of the WTP questionnaires among regions of KSA.

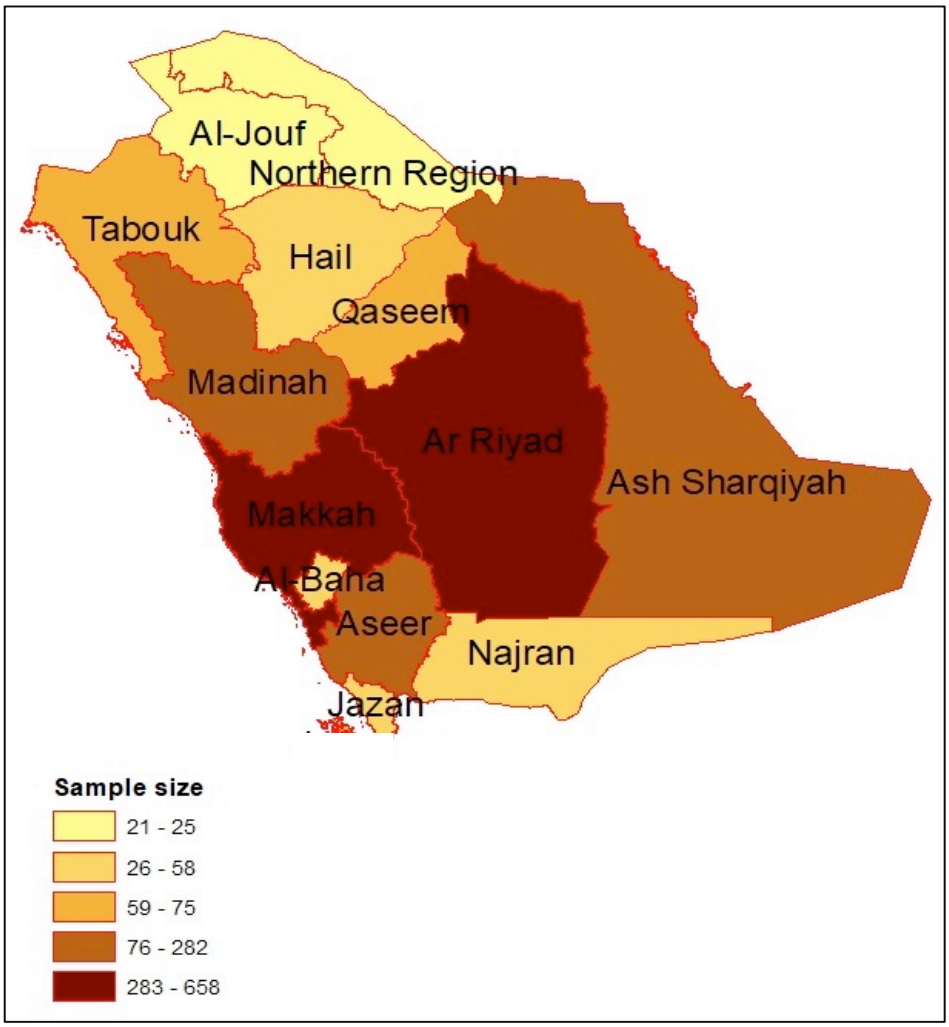

Figure 1: Distribution of the WTP Questionnaires among KSA Regions

RESEARCH METHODOLOGY

There are five main components of estimating costs of road traffic crashes, and those components are production loss, property damages, medical costs, human costs, and administrative costs. The human costs account for the loss of intangible assets, such as value of preventing premature death and pain, grief and suffering of the individuals and their families because of road crashes. All of these components were considered in this study to estimate the costs of traffic crashes. A similar framework for costing road crashes as a unit of crash severity levels that is suggested by (*25*) and extended by (*26*) was used in this study. The structure is as follows:

$$TC = \sum_{i=1}^{3} R_{ji} * PLC_i * TA_i + \sum_{i=1}^{3} R_{ji} * MC_i * TA_i + \sum_{i=1}^{3} R_{ji} * HC_i * TA_i + \sum_{i=1}^{4} R_{ki} * PDC_i * TA_i + \sum_{i=1}^{4} AdC_i * TA_i \quad (1)$$

Where TC is the total economic and social costs of road crashes. TA_i is the total number of crashes for each crash severity level *i*. R_{ji} represents the average number of individuals involved in each crash severity level *i* based on each health status *j* (died in the scene, died in the hospital, died when transport to the hospital, transport to the hospital and had treatment in the scene). R_{ki} represents the average number of vehicles involved in each crash severity level *i*. PLC_i refers to production loss costs of each severity levels *i* excluding PDO crashes. MC_i and HC_i represent the medical cost and human cost for each crash severity level *i* (excluding PDO crashes), respectively. PDC_i is the property damage costs a in the involved vehicles and public property. Lastly, AdC_i denotes the administrative costs.

Production Loss Cost

Production loss refers to the loss of the productive capacity from individuals who died or injured due to road crashes (*27*). The cost of the production loss varies depending on the crash severity levels, the ages of the persons involved in the crash and their income rates, as well as years of work. It can be calculated per unit of crashes (i.e., fatal, serious injury, and minor injury). As for property damage only (PDO) crashes, it is evident that there is no cost for the production loss, as there are no injuries resulting from it.

Regarding fatal crashes, the production loss can be estimated based on the average years of production loss which is the average ages of those died in crashes substituted from the average ages of retirees. It also accounts for, the average income, growth rate and discount rate to be adapted to the present values as shown on the following formula:

$$Production\ loss = \sum_{N=1}^{L} \frac{S(1+G)^N}{(1+D)^N} \quad (2)$$

Where the L represents the total years of production loss (N_s), S denotes the average annual income, G refers to the economic growth rate, D is the discount rate to discount the losses to the present value.

In addition, the production loss costs were weighted based on the nationality proportion and additional SR 4,000 was added as the cost of sending the body of the non-Saudi back to their countries according to the ministry of health.

The cost of production loss due to a serious injury is calculated based on the total lost output of those seriously injured during treatment and absence from work. It varies based on the severity of the injury which affects the number of non-working days and the average income. In addition, serious injury crashes may result in permanent disability due to injury in the spiral cord or the brain. This would affect individual's productivity after period of rehabilitation. Thus, this item will be added to production loss costs by identifying the average age of those who seriously injured and average age of retirement. Finally, the production loss due to minor injury crash was based on the lost output during the non-working days by determining the average number of non-working days and their average income.

Medial Cost

The injuries due to road crashes, of course, require medical intervention by providing all related services, such as ambulance services, treatment at the scene, and transportation to the hospital (if necessary). It also includes the presence of medical staff, medical devices, medicines, and perform the necessary surgeries in the hospital if needed.

The medical cost also varies, depending on the length of stay in the hospital and the required treatments. It is estimated by identifying the average medical cost that provided to the injured for each severity level. It also includes the provided services to died individuals from the scene until the case is registered as a death. Lastly, for those who are seriously injured, there might be an additional cost due to rehabilitation. The rehabilitation cost includes length of stay at the rehabilitation center, equipment cost, treatment cost, and re-entry cost at a later stage.

Property Damage Cost

In almost every crash there is a property damages to the involved vehicles on that crash. It may also result in public damages to the road infrastructure or its furniture, such as traffic signs, barriers, several types of panels, trees, and others. Although the cost of property damage in fatal or injury crashes may not be significant compared to other costs, the total cost of PDO crashes may constitute a large proportion of the total costs of road crashes due to the large number of PDO crashes (*27*). The cost of property damage to the involved vehicles is estimated based on the average cost of repairing that damage which varies based on type of the vehicle.

Administrative Cost

Significant part of the administrative costs is because of the traffic department costs since they are the main department to handle crashes. The administrative costs of the traffic department are estimated based on the average income of the policemen and officers who are in charge of reporting crashes and handle any related work to it, and the average amount of time allocated to each crash based on its severity (response time, time on scene, time to complete crash related work, etc.). In addition, the cost of operating/maintaining the buildings, equipment and vehicles assigned to traffic crashes related work.

In KSA, NAJM company is responsible for PDO crashes, when at least one of the involved vehicles has a valid insurance. Therefore, part of PDO crashes are handled by traffic department where none of the involved vehicle has a valid insurance, or the crash occurred outside the coverage area of NAJM company (currently NAJM operating in 32 cities only in KSA). Also, administrative costs include any costs related to the presence of civil defense and Saudi Red Crescent if needed. However, one of the limitations of this study is the lack of data related to the costs of civil defense.

Human Cost

WTP approach is commonly used in many countries to measure the value of risk reduction based on value of the drivers, their families, and the whole community. The WTP approach includes the determination of the value of statistical life (VoSL). One way is to conduct a questionnaire of the willingness to pay in order to improve road safety or investment in improving vehicle safety. This will help to calculate the cost of fatal, serious injury and minor injury crashes. The following equation is used to calculate the VoSL (*13*, *28*):

$$VoSL = \frac{\mathrm{WTP}_i}{\mathrm{R}_i} \qquad (3)$$

Where the WTPi is the willingness to pay to reduce risk of each crash based on each severity level i, Ri represents the risk of involvement in each crash based on each severity level i.

ANALYSES AND RESULTS

This section shows the results of the study in two parts. The first part shows the calculations of each of the cost components and the total costs of traffic crashes in KSA. Section two presents the effect of the socioeconomic factors of individuals on their WTP for fatality risk reduction.

Production Loss Cost

In order to calculate the production loss cost due to fatal crashes, first, the average age of people who died due to traffic crashes has been identified from ministry of health data, and it was 31 for Saudi people and 36 for non-Saudi people. Also, the percentage of non-Saudi of the population is 37.8%. In addition, the average age for Saudi retirees, which was 58 years, and the average monthly salary of employed persons, which was SR 6,750 for Saudi and SR 2,079 for non-Saudi. Lastly, the average number of years staying in KSA for non-Saudi, average age at arrival to KSA, and the cost of sending the body of the non-Saudi back to their countries have been used to calculate the production loss for non-Saudi. Based on the previous equation,

the production loss has been calculated for each year, and it was SR 1,574,848 for Saudi people. Therefore, the lost productivity cost due to a death from a fatal crash is as follows:

(1,574,848*0.622) + ((7-(38-35)) *2,079*12) +4000) *0.378) = SR 1,018,143.

Secondly, calculating the production loss due to a serious injury needs many information, which are percentages of Saudi and non-Saudi of the population, average monthly income for both, average non-working days due to the serious injury, percentage and average age of people who needs to rehabilitation. The average non-working days due to serious injury crash is 34 days except for those who needs rehabilitation, and the average non-working days for the people who has spinal cord and brain injuries are 252 and 184 days, respectively. The percentage of people who have spinal cord and brain injuries are 7% and 22% out of the serious injured people. Lastly, based on the sample size, it was found that the average age of patients who needed rehabilitation is 32.2 years old. Based on the above information, it was found that the production loss for a seriously injured person is SR 214,167.

Lastly, to finalize the calculations of this component, we need to calculate the production loss due to minor injuries. In order to calculate this item, the average number of non-working days and the average monthly income are needed. The average number of non-working days due to a minor injury is 6 days based on the data from the ministry of health. Therefore, the production loss cost for a person who has a minor injury is SR 1,326.

Based on the above, we calculated the total production loss due to traffic crashes in 2018 knowing the average number of involved people for each crash severity level. It was found that the production loss due to a fatal, serious injury, and minor injury crash is SR 1,219,425, SR 293,204, and SR 1,412, respectively. Therefore, the total production loss due to traffic crashes in 2018 is SR 9,698,718,895 ($ 2,586,325,039).

Medical Cost

The medical cot has been estimated based on a data from KSMC for 2018. It was found that the average medical cost for a patient who has a minor injury is SR 19,000. With respect to people with serious injuries, we should keep in mind that 30% of them need rehabilitation. The cost for each patient with spinal cord and brain injury is SR 979,440 and SR 706,860, respectively. Therefore, the average cost of a serious injured patient is SR 382,482. Lastly, the average cost for a died patient due to traffic crashes is SR 78,500.

Based on the above, the average medical cost for each fatal, serious injury, and minor injury crash considering the average number of people involved in the traffic crash is SR 168,583, SR 373,467, and SR 20,325 respectively. Therefore, the total medical cost due to traffic crashes in 2018 is SR 6,145,225,048 ($ 1,638,726,679).

Property Damage Cost

In order to calculate the property damage cost, we have to have the average number of involved vehicles for each crash severity level, the number of imported vehicles based on their classifications, and the average cost of repairing property damage for each crash severity level and vehicle classification. The average cost of repairing property damage was estimated for each vehicle classification since the sample does not represent the actual percentage of those vehicles on the road. Therefore, the number of imported vehicles to KSA was used as a proxy to estimate the actual percentages of those vehicle classifications using weighted average. In addition, there is a lack of data with respect to the damages in public properties due to crashes, it was assumed that it represents 10% of the total property damage cost (*2*). The property damage cost for a vehicle involved in a fatal, serious injury, minor injury, and PDO crash is SR 14,541, SR 11,078, SR 8,614, and SR 7,534, respectively.

Based the average number of involved vehicles for each crash severity level and the added 10% as a damages on the road infrastructure and roadside objects and building, the property damage cost for a fatal, serious injury, minor injury, and PDO crash is SR 39,274, SR 28,911, SR 26,963, and SR 21,195, respectively. Therefore, the total property damage cost due to traffic crashes in 2018 is SR 28,646,329,783 ($ 7,639,021,275).

Administrative Cost

NAJM company has an average cost of SR 300 to handle each PDO crash. With respect to GDT, it was concluded that the average cost of handling fatal, serious injury, and minor injury crash is SR 2300, SR 2300, and SR 1045, respectively. Based on the total number of each crash severity level, it was found that the total administrative cost is SR 441,925,648 ($ 117,846,840).

Human Cost

The WTP results show that the people are willing to pay 6 to 10% of the vehicle's price to enhance safety features on the vehicle to reduce the risk of being involved in a fatal or serious injury crash by 50%. This percentage is lower (1-5%) to reduce the risk of being involved in a moderate injury crash. Also, the people are willing to pay overall 5-7% of their monthly income to reduce the risk of being in a fatal or serious injury crash by 25%.

Several information is needed in order to estimate the human cost. First, the WTP results show that the people are willing to pay additional 5,001 to 10,000 of the vehicle's price to enhance safety features on the vehicle to reduce the risk of being any of their family involved in a fatal crash. Then, it is assumed that the average vehicle life is 11 years (*29*), and based on that it was found that the people are willing to pay on average SR 682 per year for improvements on the safety of their vehicles. Second, the road fatality rate in KSA is 18 per 100,000 capita. Therefore, the human cost due to a fatality using previous equation to determine the VoSL is SR 3,937,024. In order to estimate the human cost due to serious and minor injury crashes, it was assumed that the human cost for a serious injury crash is 13% of the human cost for fatal crash, and it is 1% for a minor crash (*30*). Therefore, the costs are SR 511,813 and SR 39,370 for persons who have a serious injury and minor injury respectively. The human cost for a fatal, serious injury, minor injury crash is SR 4,551,334, SR 701,114, and SR 41,926, respectively.

Total Costs of Traffic Crashes

The following table indicates that the total economic and social costs of traffic crashes in KSA in 2018 is around 76 billion Saudi riyals (equivalent to 20.22 billion US dollar). It falls between the most countries traffic crashes cost which is usually cost 1% to 3% of the GDP. The GDP in KSA in 2018 was 2,631,091,000,000 which means that the costs of road crashes in KSA is around 2.88% of the GDP.

Table 1: Total Costs of Traffic Crashes in KSA, in Saudi Riyals (SR).

Name	Crash severity				Total
	Fatal	Serious injury	Minor injury	PDO	
Direct cost/crash	1,433,004	706,897	49,654	21,495	2,211,050
Indirect cost/crash	4,551,334	701,114	41,926	-	5,294,374
Total cost/crash	5,984,338	1,408,011	91,580	21,495	7,505,424
Total direct cost	6,636,242,997	9,756,310,598	171,326,952	28,368,318,827	44,932,199,374
Total indirect cost	21,077,226,893	9,676,489,764	144,661,864	-	30,898,378,611
Total cost	27,713,469,979	19,432,800,362	315,988,816	28,368,318,827	75,830,577,985
Total	75,830,577,985				

WTP Questionnaire

The data of the first part were used as explanatory variables to the response variable which is the WTP to reduce risk of fatal crashes for their family. The serious crash (i.e., fatal or serious injury crashes) causes a pain for individuals or their families. This pain can be captured on the survey using the following question " Do you have (a friend/a family member) had a serious injury or death due to a traffic crash during the past year or this year".

Ordinal logistic regression model was developed using SAS software, and all of the significant predictors with p-value <0.05 are included in the final model. Prior to model estimation, Pearson and Spearman correlation tests in addition to the Variance Inflation Factors (VIF) were employed to check for multicollinearity which occurs in a model when two or more independent variables are highly correlated with one another. There was a high correlation between age variable and income variable (r=0.58454 and p=value<.0001). Therefore, only one of them kept in the model.

Table 2 shows the model's fit statistics and the estimates of the predictors of the model. The final model showed better performance compared to the intercept only model based on the measure of goodness-of-fit Akaike Information Criterion (AIC) (i.e., 6608.592 compared to 6899.628). There were 3 responses for the model since we have four intervals of the WTP values. There were four predictors that were significantly associated with the outcome variables (i.e., willingness to pay to reduce risk of fatal crash to a family member) at the alpha level of 0.05. Interpretation of the ordinal logistic regression is based on the odds ratio for the estimates with p-value<0.05. the results show that the respondents who had older vehicles are less likely to pay compared to respondents who had newer vehicles. Also, respondents with high income and high education are more likely to pay. Lastly, people who had a died or injured relative in a crash is more likely to pay more than people who had no relative injured in a crash to reduce the risk of being involved in fatal crash.

Table 2 also displays the odds ratio estimates of the significant predictors. The odds ratio for those education is bachelor's degree and master/Ph.D. degree versus for their corresponding who is their education is high school are 1.583 and 1.445, respectively. That can be interpreted as the odds of having a higher likelihood of the willingness to pay are 1.583 times greater for those education is bachelor's degree compared to those with high school. Similarly, the odds of having a higher category of the outcome variable are 1.445 times greater for those education is master/Ph.D. degree compared to those with high school. Regarding the variable pain, the odds of having a higher likelihood of the willingness to pay are 1.239 times greater for those relatives had serious injury crash compared to those relative had no serious injury crash.

Table 2: Ordinal Logistic Regression Model Estimates and Fit Statistics for WTP of Respondent to his Family

Model estimate					Odd ratio				
Parameter	Level	Estimate	St. Er.	P-value	Effect		Estimate	95% C. L.	
Intercept	3	-1.1654	0.1221	<.0001					
Intercept	2	0.0924	0.1197	0.4405			-		
Intercept	1	1.6979	0.1262	<.0001					
Education	0	-0.0135	0.3872	0.9721	Education	0 vs 1	0.987	0.462	2.107
Education	2	0.4593	0.0821	<.0001	Education	2 vs 1	1.583	1.348	1.859
Education	3	0.3682	0.1735	0.0338	Education	3 vs 1	1.445	1.029	2.030
Education	4	-0.2870	0.2810	0.3071	Education	4 vs 1	0.751	0.433	1.302
Income	1	-0.0740	0.1037	0.4756	Income 1 vs 0		0.929	0.758	1.138
Income	2	0.3243	0.1090	0.0029	Income 2 vs 0		1.383	1.117	1.712
Income	3	1.1013	0.1387	<.0001	Income 3 vs 0		3.008	2.292	3.948
Income	4	1.2862	0.2089	<.0001	Income 4 vs 0		3.619	2.403	5.450
Vehicle year	0	-0.3036	0.3337	0.3628	Vehicle year	0 vs 4	0.738	0.384	1.420
Vehicle year	1	-0.3363	0.2011	0.0945	Vehicle year	1 vs 4	0.714	0.482	1.060
Vehicle year	2	-0.6062	0.1207	<.0001	Vehicle year	2 vs 4	0.545	0.431	0.691
Vehicle year	3	-0.3995	0.0838	<.0001	Vehicle year	3 vs 4	0.671	0.569	0.790
Pain	0	0.2145	0.0759	0.0047	Pain	0 vs 1	1.239	1.068	1.438
AIC (Intercept only)		6899.628							
AIC (Full model)		6608.592							

CONCLUSION

In this study, the costs of road crashes have been estimated based on five main components, and those are production loss, medical costs, property damage costs, administrative costs, and human costs. Human costs account for the pain, grief, and suffering of individuals and their families due to road crashes, and it has been estimated using WTP approach. Different data from related sources have been acquired to estimate direct costs of traffic crashes based on crash severity levels, which are fatal, serious injury, minor injury, and PDO crashes.

With respect to the human costs, a face-to-face questionnaire interview has been conducted on 2,579 subjects covered all regions of KSA. In addition, an ordinal logistic model was developed to identify the factors that affect individuals their willingness to pay in order to reduction the risk of being in a traffic crash. The results revealed that the statistically significant factors were education, income, year of the vehicle and the if the individuals had any relatives who had a crash.

In addition, the results of the cost components show that the average of direct costs of a fatal crash was SR 1,433,004 considering the average number of involved individuals and vehicles in the crash. The average direct cost of the serious injury, minor injury, and PDO crashes were SR 706,608, SR 49,385 and SR 21,283 respectively. Also, the average indirect costs for fatal, serious injury and minor injury were SR 4,551,334, SR 701,114 and SR 41,926, respectively. Therefore, the average cost of a fatal, serious injury, minor injury, and PDO crash were SR 5,984,338, SR 1,408,011, SR 91,580 and SR 21,495, respectively. Lastly, the total economic and social costs of road crashes in KSA was approximately SR 76 billion which is equivalent to 2.88% of the GDP.

Overall, this study provides a better understanding of the traffic safety problem in KSA. There is a big concern in KSA regarding road safety improvements and such study would help to evaluate economic effectiveness of implementing safety countermeasures. Decision-makers at related departments can implement appropriate effective countermeasures based on the benefit-cost analysis. It is vital that all related department work together to overcome the limitations of this study and update the results based on larger data.

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