Lost Output by Road Traffic Injuries in Iran, an Estimate Based on Disability-Adjusted Life Years Index

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Abstract:
The main objective of this study is to estimate a part of road traffic injury costs including costs due to fatality and disability, which are related to lost social products. Lost output consists of costs, which are related to losses of national product or lost-income in death, hospitalization or physical disabilities. In recent years, the Disability-Adjusted Life Years (DALYs) has been used as an appropriate criterion to measure mortality and disability burden from different diseases. The DALYs index for a definite disease is defined as total years of life lost due to a premature death (YLL) and the years lost due to disability (YLD) for the disease. The distribution of fatalities and disabilities in age intervals takes advantage of official references including Legal Medicine Organization reports on road fatalities and Harvard University surveys in road-crash-related disability dispersion in Iran. According to this distribution, life expectancy can be determined for the used age distribution in this study. This study indicates that the highest amount of the life years lost due to road fatalities belongs to the age range of 11-29 years old in Iran for whom, an average value of lost useful life is estimated more than 12 years. The total output value or lost product due to death or disabilities by traffic injuries is estimated approximately 1.4 Billion USD in 2011. As a social cumulative criterion, it stands for the second cost contributing factor after medical costs. The study has shown that the lost output is identified as the main part of costs imposed on each individual killed by a road traffic injury.

Keywords: Road traffic injuries, economic cost, lost output, gross domestic product.

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1. Introduction

Human Capital (HC) is the stock of competencies, knowledge, habits, social and personality attributes, including creativity, and cognitive abilities embodied in the ability to perform labor to produce economic value [Sheffrin, 2003]. It is an aggregate economic view of the human being acting within economies, which is an attempt to capture the social, biological, cultural and psychological complexity as they interact in explicit and/or economic transactions [Simkovic, 2013]. Lost output is used as a criterion in human capital approach, which is based on Gross Domestic Product (GDP).

The main objective of this study is to estimate a part of road traffic injury (RTI) costs including costs due to fatality and disability that is related to lost social products. For this purpose, lost output consists of costs, which are related to losses of national product or lost-income in death, hospitalization or physical disabilities. This cost refers to the amount of economic loss and wage interruption, which is imposed on families and society owing to victim's inactivity during the years affected by road traffic injuries. The two items of information that are required to estimate lost output are the amount of product per person and the time duration affected by traffic injury. In this study, the GDP per capita was estimated as a measure of average product for each individual in the society, and then the number of lost years due to traffic fatality or disability is calculated.

The GDP is a highly suitable basis to estimate average individual's gross product at national level. Since the majority of people involved in crashes in low income countries are poor people with low income, this method is not highly effective in poorer countries. However, in Iran, as a middle-income country according to the region definition of the World Health Organization (WHO) , this approach can create acceptable results. Asian Development Bank's guideline [ADB, 2003], however, recommended the simple estimation of life years lost as the difference between life expectancy and average age of fatality due to traffic injuries. In previous studies in Iran, Diya method based on court verdicts was used instead of the official approaches recommended by the WHO [Ayati, 2005; Ayati, 2008]. Ahadi and Razi-Ardakani [2015] have also used 'Court Award Method` to estimate the lost output due to road traffic injuries in Iran considering five explanations of permanently disabled, fatalities, serious injuries, slight injuries, and the other involved cases. This study estimates the lost output by Disability-Adjusted Life Years (DALYs) concept for the first time in Iran and shows more accurate results than the court verdict methods due to the variables and parameters considered in the equations. As described in next sections, the DALYs index for a definite disease is defined as the total years of life lost due to a premature death (YLL) and the years lost due to disability (YLD) for a given disease [Mathers et al, 2001].

2. Literature Review

Lost output is a term that is generally used in the context of ex-post Human Capital approach in estimating the economic burden of road traffic injuries. Owing to more consistent responses, developed countries have constantly favored to use the ex-ante Willingness-to-Pay approach, however, the HC methods, notably the lost output components, have always been an inherent issue of crash costing. Australia, as a lead country in RTI costing, has utilized the DALYs concept in the last decades as an alternative approach to measure the loss life quality used in the Australian Institute of Health and Welfare's (AIHW) study on the burden of disease and injury [Mathers, Vos & Stevenson, 1999; BTE Report, 2000; ATSB, 2004]. Potter-Forbes and Aisbett [2003] estimated the lost output and the value of avoiding lost life quality due to any given cause of mortality and morbidity by valuing in dollar terms and the estimated DALYs lost to all recorded injuries for each ten-year age-sex category plus an extra category for those under five year olds. The DALYs method in estimating lost output by diseases has favorably been practiced in the current decade. In the economic analysis of health sector interventions, the method could have been employed in cost-benefit analyses based on comparing a monetized value of a disability adjusted life year (DALY) with intervention cost [Fox-Rushby, 2012; Walby & Olive, 2013].

Lost output, as a typical component of road crash costs within Human Capital approach, has been widely used in developing countries, but rare studies have used DALYs as a quantity in estimating the lost output com-

ponent. The DALYs and Quality Adjusted Life Years (QALYs) measures were introduced in South Africa to quantify the number of years lost due to disability and early mortality by road crashes [Beer & Niekerk, 2004], but not used as a costing measure of the lost output. In Philippines, lost labor output was calculated as the average daily wage rate of each individual involved in the crash, multiplied by the number of off days, then added up for all the people involved in the crash. For fatalities and permanent disabilities, the calculation was performed over the rest of their expected productive working life and discounted to an equivalent present value [De Leon et al., 2005]. The cost of road traffic accident in Vietnam simply estimates amount of time lost due to accidents and average wages of casualties [Anh et al., 2005]. Ismail and Abdelmageed [2010] used a simple technique in estimating the lost output and they assumed an added 55 percent of the corresponding lost output as the family and community loss of a fatality or an injury. In a study carried out to estimate the economic burden of motorcycle accidents in Northern Ghana [Kudebong et al., 2011], value of lost output as a resource cost is estimated 20.6 percent of the total costs.

3. Methodology

This study estimates lost output due to all fatal road traffic injuries occurred in year 2011 in Iran. It includes all 20,089 fatalities reported by the Legal Medicine Organization (LMO) of Iran. For the case of disabilities, a proportion of all inpatients injured in road crashes in 2011 was considered in the analysis, which is described in Section 3.2 of this paper. The methods to distribute fatalities and disabilities in age ranges are explained in Sections 3.1 and 3.2, both of which take advantage of official references including the LMO reports on road fatalities and Harvard University surveys in road-crash-related disability dispersion in Iran [Bhalla et al., 2008]. The main instruments for the estimation process were the equations presented by the WHO known as the DALY index [Mathers et al, 2001]. Figure 1 displays the general plan to organize different analyses carried out in the present study. As shown in this figure, the estimations were carried out in two parts consisting of road fatality and disability related lost product. The process to estimate lost output considers the following assumptions:

• Lost output refers to only economic losses imposed

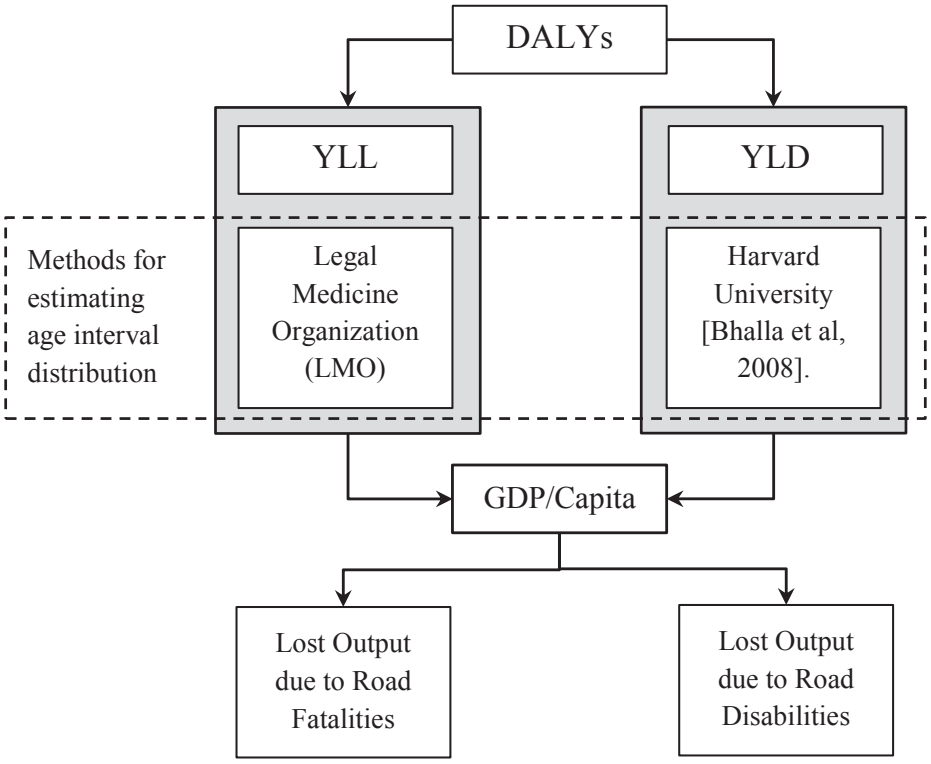

Figure 1. The analysis plan for estimating lost output due to road fatalities and disabilities

by premature deaths and permanent disabilities, but not to lowered functional capacity due to temporary and non-incapacitating road traffic injuries or indirect costs imposed by pain, grief, and suffering effects;

• The age intervals for both fatalities and disabilities can be fit into existing credible sources as shown in Tables 1 and 5;

• The GDP values for future years were extrapolated by a simple third order regression model;

Estimating lost output due to road traffic fatalities and disabilities using the DALY index is carried out in this study for the first time in Iran where the previous studies have estimated approximate amounts of the court awards by Diya method as mentioned in Section 1. This is an advantageous contribution to estimate road crash costs by Human Capital approach. To utilize this gain, we must be cautious by choosing the parameters affecting the estimation upshots, for example discount rates, age intervals, and disability weights.

In recent years, the DALY index has been used as an appropriate criterion to measure mortality and disability burden from different diseases. DALY index is a criterion to measure health gap in society that combines lost time due to premature death and time related to nonfatal condition [Mathers et al, 2001]. DALY index for a definite disease is defined as total years of life lost due to a premature death (YLL) and the years lost due to disability (YLD) for the disease:

$$DALY = YLL + YLD \quad (1)$$

Lost healthy life due to nonfatal status needs estimating incidence in a distinct period. Years lost due to premature death is a function of mortality rate and the duration of life lost due to death at each age. In the following context, the method of quantification related to each of two discussed sections is described in the DALY index. Projections show that road traffic injuries will be one of the three leading contributors to the global burden of disease as measured by DALYs lost over the next two decades [Mathers et al., 2008].

3.1 Estimating Years of Life Lost due to Premature Death (YLL)

To estimate the number of lost years due to premature death, it is recommended to use five-year age interval. Therefore it requires specifying appropriate age distribution for killed individuals in the considered year. The classification, which is shown in Table 1 is the only available and useable age distribution in this study. For fatalities in each age range, the calculation of YLL requires the estimation of average death age. Adding a half year to the calculated average age range is required to estimate the average death age. It should be taken into account that for example, deaths at the age 60 include deaths at the true ages between 60 and 60.99 years. Then, it is necessary to determine the average life expectancy for each age. The WHO calculated the life expectancy for each country and for different age ranges in 1990, 2000 and 2011. The result for Iran is shown in Table 2.

According to this distribution, life expectancy can be determined for the used age distribution in this study, which is shown in Table 1. The relation, who is used to calculate YLL for each age range is defined as follows [Mathers et al., 2001]:

$$YLL = NCe^{(ra)}/(\beta+r)^2\left[e^{-(\beta+r)(L+a)}\left[-(\beta+r)(L+a)-1\right]-e^{-(\beta+r)a}\left[-(\beta+r)a-1\right]\right] \quad (2)$$

Where:

N: The number of killed individuals in each age range

C= Age-weighting correction constant (standard value is 0.1658)

β = The parameter from the age-weighting function (standard value is 0.04)

r = Discount rate (standard value is 0.03)

L = Years of Life Lost due to premature death or disability.

a= The average age of victims for each age interval

The amount of discount rate in this equation can be considered equal to official useful amount in Iran. This rate

Table 1. Age distribution of road traffic fatalities in 2011[1]

Age interval	Fatality rate (%)
≤ 10	8.4
11 - 17	6.0
18 - 29	30.3
30 - 49	28.7
≥ 50	26.7

[1] Source: Legal Medicine Organization of Iran

Table 2. Estimating life expectancy based on age classification used in this study

Age distribution and life expectancy by WHO classification			Age distribution and life expectancy classification in this study		
Age interval	Agerage age	Life expectancy	Age interval	Agerage age	Life expectancy
< 1	0.3	73.40			
1-4	2.6	73.98	≤ 10	5.5	71.78
5-9	7.5	70.27			
10-14	12.5	65.435			
			11 - 17	14.5	62.52
15-19	17.5	60.577			
20-24	22.5	55.86	18 - 29	23.5	54.94
25-29	27.5	51.24			
30-34	32.5	46.61			
35-39	37.5	41.95	30 - 49	39.5	40.09
40-44	42.5	37.31			
45-49	47.5	32.71			
50-54	52.5	28.24			
55-59	57.5	23.92			
60-64	62.5	19.73			
65-69	67.5	15.87			
70-74	72.5	12.52			
75-79	77.5	9.61	50 ≥	77.5	9.61
80-84	82.5	7.07			
85-89	87.5	5.10			
90-94	92.5	3.59			
95-99	97.5	2.55			
+100	102.5	1.90			

is recommended 12% for public investments in Iran [Management & Planning Organization, 2007].

Finally, the number of effective years of lost life can be obtained for each age range using this equation as shown in Table 3. It should be noted that the number of YLL for each victim at an early age (under 10 years) is less than the number of teens and young adults (11 to 30 years) obtained in this table and this is due to the less investment of community for children. Finally, it is observed that the total number of effective years of lost life for all ages and victims in traffic accident in Iran was 176,168 years in 2011.

3.2 Estimation of Years Lost due to Disability (YLD)

Lost output due to disabilities can be calculated as conducted for YLL; however, this loss is measured based on the weight of disability due to the occurrence of a particular disease. Accordingly, the equation to estimate YLD for all age ranges is defined as follows [Mathers et al., 2001]:

$$YLD = I \cdot DW \cdot C \cdot e^{(ra)} / (\beta + r)^2 \left[e^{-(\beta+r)(L+a)} \left[-(\beta + r)(L + a) - 1 \right] - e^{-(\beta+r)a} \left[-(\beta + r)a - 1 \right] \right] \quad (3)$$

In this equation, the parameters C, r, β and L are de-

Table 3. Estimated YLL index for road traffic fatalities in 2011

Age	Average age (a)	Lost years (L)	Number of Fatalities (N)	YLL	YLL/Fatality
≤ 10	5.5	71.78	1,686	16,474	9.77
11 - 17	14.5	62.52	1,204	14,492	12.04
18 - 29	23.5	54.94	6,081	73,199	12.04
30 - 49	39.5	40.09	5,760	56,074	9.74
≥ 50	77.5	9.61	5,358	15,930	2.97
	Total		**20,089**	**176,168**	**8.77**

fined as for YLL index. In the above-mentioned equation, represents the number of the incidence of disabilities due to diseases in a specified period and represents disability weight for that disease.

In the study carried out by Harvard University concerning traffic injuries in Iran in 2008 [Bhalla et al., 2008], the age distribution of traffic victims was obtained regarding inpatient and outpatient injuries and those treated at home separately.

Before establishing the related table to calculate the YLD index, it is necessary to acquire a disability weight for physical disabilities due to traffic injuries. Disability weight represents the burden of incapacitating and loss of health during which the related morbidity factor has not resulted in a death. This weight is defined as a coefficient between zero and one, so that zero represents complete health and ability and one represents a condition equivalent to death. For example, the WHO has determined 0.725 for long-term weight disability related to spinal cord problems [Mathers et al. 2008]. The title of injuries due to long-term disabilities and the related disability weight is ranked according to Table 4 [Mathers et al., 2001].

Thus, by combining the related information of disability weight and age distribution of injuries, the accurate estimation of the YLD amount related to different injuries due to traffic trauma can be obtained. The calculations related to this index are presented in Table 5. Here by considering the constants C=0.1658, β= 0.04 and r=0.12, the number of years lost due to disability is calculated according to the disability level for each injury in every age range. Finally, it is noted that the total value of the YLD index for disability due to all types of injuries is equal to 143,411 years. In addition, the highest proportion of the lost life years is related to skull fracture in different parts that is caused by the multiplicity of casualties in this group of injuries.

4. Results

To estimate the lost product, the monetary value of this product in lost life years should be considered. For this purpose, the estimation of victims and disabled individuals is carried out in two steps so that the personal value of YLL and YLD was considered for each age group and by considering the duration of these years, the value of GDP per capita for every year was considered. It should be noted that the value of GDP per capita for every year in future should be discounted to the value of 2011. In following, first, the lost product due to death was estimated and then the lost product of physical disabilities was calculated.

Table 4. Disability weight for lifelong disabling injuries (Mathers et al, 2001)

Rank order of importance	Nature of injury	Disability weight	Disability duration
1	Spinal cord lesion	0.725	Lifelong
2	Brain injury	0.35	Lifelong (5% of incident cases)
3	Burns to >60% of body surface	0.255	Lifelong
4	Burns to 20–60% of body surface	0.255	Lifelong
5	Fractured skull	0.35	Lifelong (15% of incident cases)
6	Fractured femur	0.272	Lifelong (5% of incident cases)
7	Nerve injuries	0.064	Lifelong

Table 5. Total YLD estimated for disabilities due to RTIs in 2011

Age	Average age (a)	Duration of disability (L)	Spinal cord lesion	Brain injury	Burns	Fractured skull	Fractured femur	Nerve injuries	Total YLD
< 1	0.3	73.4	47	59	7	211	22	6	352
1-4	2.6	73.98	272	339	39	1,221	127	37	2,034
5-14	10	67.86	2,193	2,736	317	9,851	1,021	300	16,418
15-24	20	58.22	9,102	11,357	1,315	40,884	4,237	1,243	68,138
25-34	30	48.92	4,241	5,291	613	19,049	1,974	579	31,748
35-44	40	39.63	1,682	2,099	243	7,557	783	230	12,594
45-54	50	30.47	980	1,222	142	4,400	456	134	7,332
55-64	60	21.82	412	514	60	1,850	192	56	3,084
65-74	70	14.19	179	224	26	805	83	24	1,342
75-84	80	8.34	45	56	7	202	21	6	337
+85	90	4.34	4	5	1	18	2	1	30
Total			**19,158**	**23,902**	**2,768**	**86,049**	**8,917**	**2,617**	**143,411**

As noted above, the total amount of lost product was calculated for the sum of different age ranges and in each range, the sum of present value for the lost product in future years should be obtained. The purpose of future years in this estimation is the number of lost life years due to premature death that was obtained as a specific value for each age range. Considering that the annual GDP per capita values must be discounted to the amounts for the year 2011. According to this explanation, the equation to estimate the cost of the lost output due to traffic deaths in 2011 can be written as following:

$$C_{LOF} = \sum_{i=1}^{5}\left(N_{Fi} \times \sum_{j=0}^{YLL_{0i}} \frac{GDPpc_{2011+j}}{(1+r)^{j}} \right) \quad (4)$$

Where:

C_{LOF} = The cost related to lost output due to death

i = The number attributed to each five age groups in Table 2

N_{fi} = Number of fatalities in each age group

YLL_{oi} = The number of lost life years due to death for each fatality in each interval i.

$GDPpc_{2011+j}$ = The amount of GDP per capita in 2011 and every year after that

r = The discount rate, which is considered 12 percent according to the pervious explanation in this study.

The calculation of this cost based on the above-mentioned equation requires the cost formulation in each age range. For this purpose, the present value of GDP was calculated by the discount rate of 12% annually as displayed in Table 6 and related information to estimate the product during the lost life years is classified as in Table 7. It should be noted that the present value of GDP per capita in Table 7 is calculated until the number of the YLL years and its decimal value is considered in the last year. For example, for the age range of 10 years old and smaller, the value of YLL for each fatality is equal to 9.77 years. The total present value of GDP per capita is calculated as follows:

$$PV_{0-10} = 72.10 + 90.27 + 113.00 + 141.47 + 177.11 + 221.72 + 347.49 + 435.02 + 0.77 \times 544.61 = 1206.57$$

Table 7 and Figure 2 display the results of the total cost by the lost output due to traffic fatalities equal to 22822.181 Billion RLS in 2011. Therefore, regarding the total fatalities in this year, which is 20089, the lost output for each killed individual achieves 1136.05 Million RLS. Now, the value of the lost output for physical disabilities due to traffic accidents can be also obtained using the above approach. For this purpose, it is necessary to estimate the value of GDP over the lost years due to physical disability for all disabled people in 2011 using the results of calculating the YLD index for different age ranges. According to this and similar to what was described for traffic fatalities, the following equation can be defined to estimate the lost output due to disability:

$$C_{LOD} = \sum_{i=1}^{11}\left(N_{Di} \times \sum_{j=0}^{YLD_{0i}} \frac{GDPpc_{2011+j}}{(1+r)^{j}} \right) \quad (5)$$

Table 6. GDP/capita equivalent value estimated for 2011

Year	Annual specific GDP/capita (Million Rials)[1]	GDP/capita discounted to values in 2011 (Million Rials)	Year	Annual specific GDP/capita (Million Rials)	GDP/capita discounted to values in 2011 (Million Rials)
2011	72.10	72.10	2018	347.49	157.19
2012	90.27	80.60	2019	435.02	175.70
2013	113.00	90.08	2020	544.61	196.39
2014	141.47	100.70	2021	681.79	219.52
2015	177.11	112.56	2022	853.54	245.37
2016	221.72	125.81	2023	1068.54	274.27
2017	277.57	140.63	2024	1337.71	306.57

[1] One Million Rials = 40 US Dollars

Where:

C_{LOD} = The cost of lost output due to disability

i = The Number attributed to each 11 age ranges in Table 5.12

N_{Di} = The number of victims with a degree of disability in age range i

YLD_{oi} = The number of lost life years due to disability for each individual in age range i

The parameters related to GDP per capita and discount rate is defined as similar to what mentioned for traffic fatalities. Here, it is necessary to determine the current value of GDP per capita for the years after 2011 consistent with what obtained in Table 6. Table 8 and Figure 3 show the result of the calculation for all age ranges. These calculations show that the lost output due to physical disabilities is equivalent to 12,175 Billion RLS for 39,641 incapacitating injuries. This number results in the average equal to 307.13 Million RLS for the lost output due to disability for each individual.

It should be noted that in both Tables 7 and 8, the summed amount of the present value of GDP, shows the per capita value of product lost due to death or disability for all age

Table 7. Lost output estimated for road traffic fatalities in 2011

Age	Number of fatalities	Average YLL (years)	Total present value of GDP/capita (Million Rials)	Lost output due to fatalities (Billion Rials)
≤ 10	1686	9.77	1206.57	2034.277
11-17	1204	12.04	1727.61	2080.042
18-29	6081	12.04	1727.61	10505.596
30-49	5760	9.74	1200.68	6915.917
50 ≥	5358	2.97	240.08	1286.349
	Total			**22822.181**

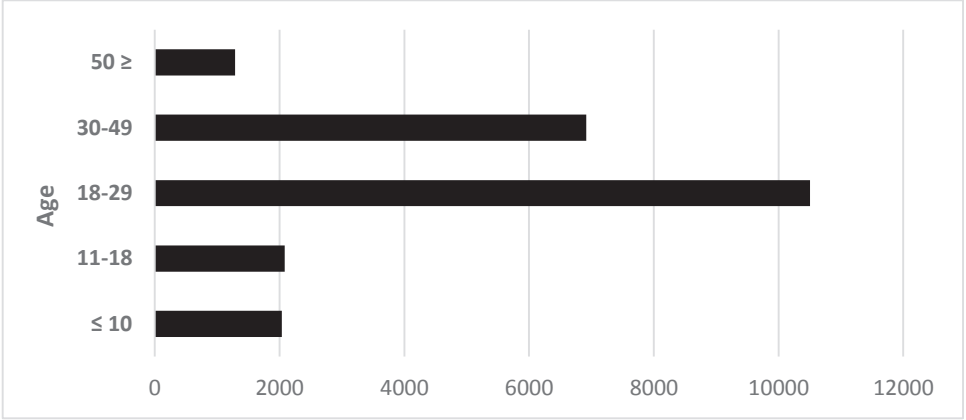

Figure 2. Lost output due to fatalities (Billion Rials)

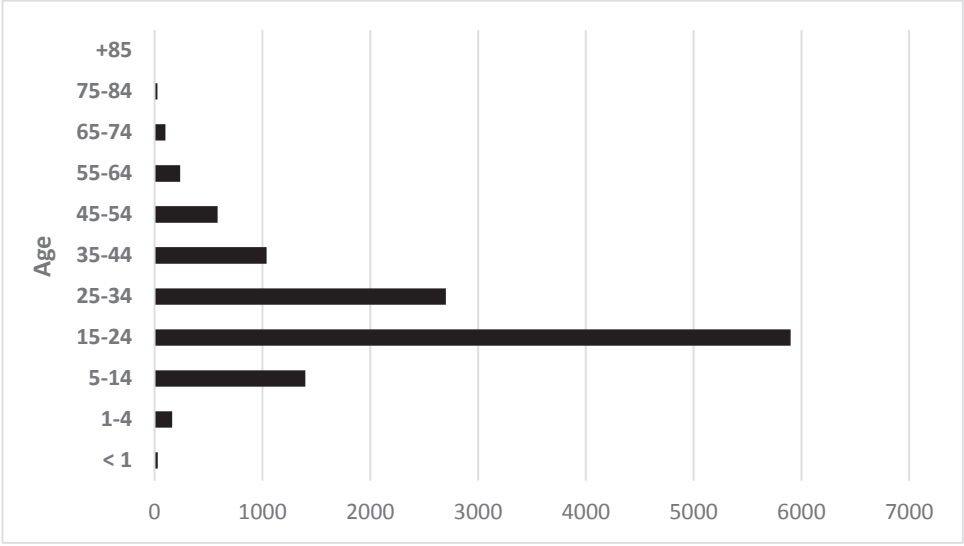

Figure 3. Lost output due to disabilities (Billion Rials)

Table 8. Lost output due to disabilities in 2011

Age	Number of disabilities	Average YLD (years)	Total present value for GDP/capita (Million Rials)	Lost output due to disabilities (Billion Rials)
< 1	156	2.26	176.12	27.47472
1-4	730	2.79	223.86	163.4178
5-14	4,312	3.81	324.35	1398.597
15-24	16,530	4.12	356.99	5901.045
25-34	8,326	3.81	324.35	2700.538
35-44	3,871	3.25	267.96	1037.273
45-54	2,788	2.63	209.45	583.9466
55-64	1,530	2.02	154.5	236.385
65-74	943	1.42	105.95	99.91085
75-84	386	0.87	62.73	24.21378
+85	69	0.44	31.72	2.18868
		Total		**12174.991**

ranges. It should be regarded that with considering the special values of personal YLL and YLD, which are obtained in this study, the obtained values for death or disabilities are allocated to 2011 and are not applicable for other years. Finally, the total output value or lost product due to death or disabilities by traffic injuries is estimated approximately 1.4 Billion USD (34,997 Billion Rials) in 2011, which includes 0.91 Billion USD for fatalities and 0.49 Billion USD for disabilities. It must be noted that this value is displayed only as the lost product and does not include the effects of pain, grief and suffering.

5. Discussion

Studies in Iran [Mehregan et al. 2013] show that a relation exists between economic growth and traffic fatalities so that traffic fatalities have increased along with economic growth until reaching to a critical point, and after that they will reduce. Iran is located at the first stage yet, hence, the increase in economic growth (i.e. the increase in GDP) above the growth of road traffic fatalities would intensify the value of lost outputs. By utilizing a small proportion of the lost output cost in road safety projects and programs, we can successfully prevent the occurrence of traffic injuries and also can contribute to economic growth by preventing this cost. In other words, a small investment in improving road safety in Iran will lead to a significant investment. By focusing on the health burden of traffic injuries in Iran, this study seeks to quantify the amounts of the economic burden of lost output (product) due to road traffic injuries in Iran. Lost output is defined as a main compo-

nent of direct costs accountable for traffic injury social costs. Owing to its life-related subject, the lost output is considered as an issue of concern in health sector related costs so that the WHO has presented useful methodologies to quantify the lost life due to mortality or disability. Although, the methodologies attempt to advice inclusive instruction, caution must be taken in selecting variables such as country specific discount rates and age ranges. For example, if the suggested 3 percent standard value of discount rate is applied in equations instead of the real dominant value of 12 percent in a developing country (as studied here for Iran), the results may be considerably misleading that can even change prospective national road safety policies.

However, this study is a module of general health-related cost of road traffic injuries, which has indicated a total amount of 4.45 Billion USD for three major components including medical costs, lost output, and indirect costs. The result shows that the lost output forms more than 31 percent (approximately one-third) of the total costs in health sector. As a social cumulative criterion, it stands for the second cost contributing factor after the cost of medical costs, but as a personal perspective, the study has shown that the lost output is identified as the main part of costs imposed on each individual killed by a road traffic injury (more than 65 percent of personal total costs). Therefore, the lost output due to road traffic injuries must be investigated as a major human-related factor of lost life quality.

As an informative illustration, Table 9 indicates the comparison of contents and results of two typical HC-based studies presented in recent years [Ayati, 2005; Ayati, 2008; Ahadi & Razi-Ardakani, 2015] with those specified in this study. The table shows significant advantages using the DALYs index in this study in estimating the lost output value that can somehow enhance more reliable results. The benefits rise by the advantageous usage of the following features:

• Allowing for only the lost useful years of life; eliminating the years, which do not lead to the pure production is an issue of importance especially in developing countries.

• Considering the GDP value as the main representative for lifelong production; the average value of annual wages in a nation is not criterion in estimating the national production values.

• High reliability using age-weighting correction constant; the age-weighting correction (C) and the parameter from the age-weighting function (β) are both the general constants, which are applied in estimating an average value for the lost years due to a premature death or permanent disability. The age range specific attributes are L and a.

• Considering the discount rate as a country specific economic index; using a national economic value can reflect the mass of production that the nation can make.

• Allowing for age range specific lost life both for fatalities and disabilities; the estimated values are split into separate consequences of crash victims (i.e. fatalities and disabilities) which can use their independent age classification.

• Allowing for the nature of injury (such as spinal cord, and brain injury) in the form of disability weight (used in eq. 3); the existence of disability weights classified by the nature of injury and presented by the WHO enhances the precision of the results in the sense that injury-targeted consequences can be quantified in each age range.

The results by different studies can be compared more expressly by the percentage of the lost output value to the total health sector RTI cost. Considering that the displayed resulted values by Ayati's studies exclude the pain, grief, and suffering costs, the lost output related amounts are much close to the results by the current study. The comparison shows that the resulted percentage in this study is higher than the results by Ayati in both 2005 and 2008 for rural and rural plus urban roads, respectively. Considering the absolute values (1.4 Billion USD in 2011 versus 0.75 Billion USD in 2007), the higher resulted amount reflects the inflated amounts from 2007 to 2011, which are much close to each other using an 18 percent average annual inflation rate. The results show the inherence of both studies, which can confirm the total amount calculated by DALYs index. Here, the added value by the DALYs index is its separable lost output values for different age ranges as well as the split values for fatalities and disabilities. The rough value earned by the average annual wages applied by Ahadi and Razi-Ardakani (2015) also shows the overestimation of the lost output by disregarding the exclusion of non-useful years.

Beyond the results and the advantages of this study,

Table 9. Comparison of lost output estimation results by Human Capital approach in Iran

Comparison criteria	This study (2016)	Ayati (2005) (rural roads)	Ayati (2008) (rural and urban roads)	Ahadi and Razi-Ardakani (2015)
Incidence year	2011	2004	2007	2009
Method	DALYs Index	Court Verdicts (Dieh)		Average annual wages
Calculation process	• Annual output: GDP/capita • Lost years: Equations 2 and 4 for fatalities and equations 3 and 5 for disabilities • $YLL = NCe^{(ra)}/(\beta+r)^2\left[e^{-(\beta+r)(L+a)}\left[-(\beta+r)(L+a)-1\right]-e^{-(\beta+r)a}\left[-(\beta+r)a-1\right]\right]$ • $YLD = I\cdot DW\cdot C\cdot e^{(ra)}/(\beta+r)^2\left[e^{-(\beta+r)(L+a)}\left[-(\beta+r)(L+a)-1\right]-e^{-(\beta+r)a}\left[-(\beta+r)a-1\right]\right]$ • $C_{LOF}=\sum_{i=1}^{5}\left(N_{Fi}\times\sum_{j=0}^{YLL_{Fi}}\frac{GDPpc_{2011+j}}{(1+r)^j}\right)$ • $C_{LOD}=\sum_{i=1}^{11}\left(N_{Di}\times\sum_{j=0}^{YLD_{Di}}\frac{GDPpc_{2011+j}}{(1+r)^j}\right)$	• The total lost output per person equals the value of Dieh, the blood money or court award assigned by Islamic rules for a person killed or disabled in a road crash		• Annual output: average annual wage • Lost years: The fixed amount of 23.67 years for all ages • $Loss=\sum_{n=1}^{N}\frac{W}{(1+r)^n}$
Applied variables	• Annual GDP/capita • age-weighting correction constant; • discount rate; • Years of Life Lost due to premature death or disability; • the average lost life of victims for each age interval; and • Disability weight.	• The amounts of court awards (Dieh) for each fatality or disability		• average annual wage • N=23.67 years • discount rate
Lost output cost (Billion USD)	1.4	0.3 [2]	0.75 [2]	3.23
Generalized national crash cost (10^9 USD)	---	2.3	7.2	11.42
Total health sector-related RTI cost (10^9 USD)	4.8	1.5	4.4	6.52
Percentage of LOC to Generalized crash cost	---	13%	10.4%	28.2%
Percentage of LOC to total health sector RTI cost	29%	20%	17%	50%
Advantages	• Allowing for only lost useful years of life • Considering the GDP value as the main representative for lifelong production • high reliability by using age-weighting correction constant • Considering the discount rate as a country specific economic index • Allowing for age interval specific lost life both for fatalities and disabilities • Allowing for the nature of injury (spinal cord, brain injury, etc.) in the form of disability weight (used in eq. 3)	• Simplicity of calculation • Distinguish between fatalities and disabilities		• Simplicity of calculation • Considering the discount rate
Limitations	• Needing precise analysis data	• Not allowing for the discount rate • No distinguish between various age intervals in estimating lost years		• The average annual wage cannot represent the lost national product • No distinguish between fatalities and disabilities • No distinguish between various age intervals in estimating lost years (a fixed amount of 23.67 years is considered)

[1] One Million Rials = 40 US Dollars

[2] The amount is belonged to the Dieh values only which was stated as the net value of lost output. The total cost including the pain, grief, and suffering cost that is 3.78 times greater than the Dieh values was reported 1.5 and 3.6 Billion USD for years 2004 and 2007 respectively.

another major issue of concern is to incorporate the lost output as a matter of Willingness-to-Pay (WTP) approach. Ainy et al. [2014] used the willingness-to-pay approach to calculate the cost of traffic injuries in Iran. WTP data was collected for four scenarios for vehicle occupants, pedestrians, vehicle drivers, and motorcyclists. The costs of traffic injuries constituted 6•46% of gross national income. WTP was significantly associated with age, gender, monthly income, daily payment, more payment for time reduction, trip mileage, drivers and occupants from road users. The total estimated cost of injury and death cases exceeded 39 Billion USD. Moreover, in 2013, the cost of traffic injuries among the drivers of public vehicles constituted 1.25% of gross national income [Ainy et al, 2015]. WTP had a significant relation with gender, daily payment, more payment for time reduction, more pay to less traffic, and minibus drivers. On the other hand, Ahadi and Razi-Ardakani [2015] estimated the total value of health-related cost of road traffic injuries approximately 6.6 Billion USD for the year 2009, which included medical costs, lost outputs, and human costs, 48 percent of which was related to the lost output costs.

6. Conclusions and Recommendations

The lost output consists of the lost product concerning the lost life years due to disabilities and mortalities by road traffic injuries. To estimate the lost product, the monetary value of this product in lost life years should be considered. For this purpose, the estimation of killed victims and disabled individuals is carried out in two steps so that the personal value of YLL and YLD is considered for each age group and by considering the duration of these years, the annual value of GDP per capita is considered.

This study shows that the highest amount of the lost life years due to road fatalities belongs to the age range of 11 to 29 years old in Iran for whom an average value of lost useful life is estimated more than 12 years. The value is estimated on the basis of a 12 percent discount rate, which causes the decrease of the calculated YLL index in comparison to the standard 3 percent rate. It should be noted that the estimated value only belongs to the times in which the victim could have contributed to the social product. Furthermore, the highest lost output due to disabilities was estimated four years for the age range of 15 to 24 years old victims.

Consequently, the total output value or lost product due to death or disabilities by traffic injuries is estimated approximately 1.4 Billion USD in 2011. This value is displayed only as lost product and is not considered with the effects of pain, grief and suffering (indirect costs). As a social cumulative criterion, it stands for the second cost contributing factor after medical costs. As a personal perspective, the study has shown that the lost output is identified as the main part of costs imposed on each individual killed by a road traffic injury.

As described before, the term ‘lost output’ reflects an economic share of the generalized costs incurred by road traffic injuries that is related to the lost life years by a premature death or functional incapacitating. Therefore, it is viewed as an ex-post approach, which refers to the loss after the incidence of injuries. It is suggested that an ex-ante approach, notably using willingness-to-pay methods, should be exercised that shelters all socio-economic impacts of the road trauma losses. Several factors can be examined in such an alternative methodology to estimate the value of statistical life. Thus, a more comprehensive analysis can enhance the reliability by making hybrid methods, which comprise both approaches. It is also suggested to investigate the lost output effects of road traffic injuries on poor families, which may be accompanied with enormous social impacts of the poverty.

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