Calculating disability adjusted life years (DALY) for traffic accidents and its economic consequences in Ecuador.

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Abstract. Road traffic fatalities in Ecuador are 20.4 deaths per 100,000 people. Men are the most affected by traffic accidents: 4.2 times higher than women (33 vs. 7.8 deaths per 100,000 people, respectively). Traffic accidents show a decrease: from 22 deaths per 100,000 people in 2010 to 18 deaths per 100,000 people in 2016. The estimation of DALY by the life expectancy method used age weighting β=0.04, r=0.03, *C*=0.1658. The average burden of disease is 141,430 DALY or 897 DALY per 100,000 people. The cost of DALY, using the approach of human capital, is US$806.8 million equivalent to 0.89% of GDP, 81% caused by males and 19% due to females. This percentage of GDP lost for road fatalities is equivalent as if each individual in Ecuador paid US$358. The provinces with the largest population contribute with the 52% to the total population, 67% to the number of vehicles and 49% of total deaths due to traffic accidents. However, when we analyze deaths per number of people and number of vehicles, these provinces are not the most dangerous for dying in a traffic accident. Considering number of deaths per 100,000 people, the most dangerous provinces are Sucumbíos (33.5), Cotopaxi (32.0), Orellana (31.2), together, they constitute just the 5.9% of the population and 3.8% of the total vehicles, however, the average rate of deaths of these three provinces is 1.58 times the national average (20.4 per 100,000 people). Considering the number of deaths per 100,000 vehicles, the most dangerous provinces are Napo (460), Imbabura (429) and Morona Santiago (400), together, they constitute just the 4.5% of the population and 1.9% of the total vehicles, however, the average rate of deaths of these three provinces is 2.7 times the national average (156 per 100,000 vehicles).

Keywords: Traffic accidents, Burden of disease, Human capital, DALY, Ecuador.

1. Introduction

Policy is an analytic category, the contents of which are identified by the analyst rather than by the policy-maker or pieces of legislation or administration (Heclo, 1972: 85), public policy[1] is an intellectual creation whose content should be identified (Majone, 1997: 35), therefore, quantifying deaths and health loss from injuries by traffic accidents provides a tool for policymaking to regulate traffic to eliminate what kills and disables people.

[1] Public policy is a set of elements and processes that with the concourse of some public authority or governmental institution, rationally articulate to maintain or modify some aspect of the social order. (Roth, 2014: 36).

More than 1.3 million people die each year in road traffic accidents, making road traffic injuries the tenth leading cause of death in the world (WHO, 2016). The World Health Organization (WHO) estimated road traffic accidents as the ninth cause of death in the world in 2004, and projected as the third leading cause of death for 2030. (WHO, 2008). These projections show the threat that traffic accidents will take as a cause of death.

In 2015, deaths for all causes were 769 deaths per 100,000 people; 8.7% of these deaths are caused by unintended injuries, 27% of unintended injuries correspond to traffic accident deaths. Overall, deaths by traffic accidents represent 2.4% of total deaths in the world.

Death rate per 100,000 people in the region (Americas) is lower than in the world (666 vs. 769), however, deaths caused by unintended injuries as percentage of total deaths is higher (9.7% vs. 8.7%) while the percentage of deaths caused by traffic accidents is lower than the world total (24 vs. 27%).

In Ecuador, death rate of road injuries, as percentage of total deaths (4.0%), is higher than the one observed in the world (2.4%) and in the region (2.4%). Also, traffic accident deaths as percentage of unintended injuries (32%) are higher than the percentage observed in the world (27%) and in the region (24%).

Deaths by traffic accidents are seventh among the leading causes of death. However, if we rank the leading cause of deaths by sex, road traffic injuries are the second among men after heart diseases and before diabetes, and fiftieth among women. (INEC, 2016).

Traffic as a source of road fatalities, then, is a threat for premature death and disabilities which leads to the question s of what are the consequences of it? what is the productivity costs of traffic accidents and how can they be measured? How big are the costs of deaths and injuries due to traffic accidents in Ecuador? These costs include the cost of years of life lost from premature death and years of life lived in state of less than optimal health. These estimates are necessary to have an idea of the magnitude of the problem, identify areas to allocate resources and design policies for prevention.

The aim of this work is to estimate the value of the productivity lost due to premature mortality and disability result of traffic accidents in Ecuador during the years 2010-2016. Section two of the document presents an analysis and description of the state of general deaths and traffic accidents deaths in Ecuador during the period of study. Section three describes the Disability Adjusted Life Years (DALY) theory behind the method and its assumptions. Section four presents the model to estimate the years of life lost, section five presents the results of the study and finally, section six summarize cconclusions.

2. The data

The facts come from registers taken annually by de National Institute of Statistics and Censuses (INEC). The data are collected in death forms, which are designed and distributed by the INEC to the respective offices of Civil Registry, Identification and Certification, provincial Statistics Offices of the Ministry of Public Health and to public and private hospitals and clinics. The Civil Registry, Identification and Certification is the responsible for the registration and legalization of the vital fact. The statistics of this vital fact are data of the deceased: sex, date of birth and death, age at death, geographical place of death, place of occurrence of death, person certifying the death, marital status of the deceased; habitual residence of the deceased; area (urban, rural), literacy and instruction and ethnicity. Once the forms are filled out in the respective offices they are sent to the INEC, for processing and publishing. (INEC, 2010)

2.1 General deaths in Ecuador

General deaths were relatively constant during 2010-2016: average number of deaths was 63,559 with little variation through the years (coefficient of variation 4%), which represent 0.4% of the population. The number of deaths by sex shows men´s deaths are higher than women´s (56% vs. 44%, respectively). However, mortality among women shows a growth rate higher than among men (2.44% vs. 1.44%, respectively). (Table 1).

Table 1. Total deaths by sex and (2009-2016).

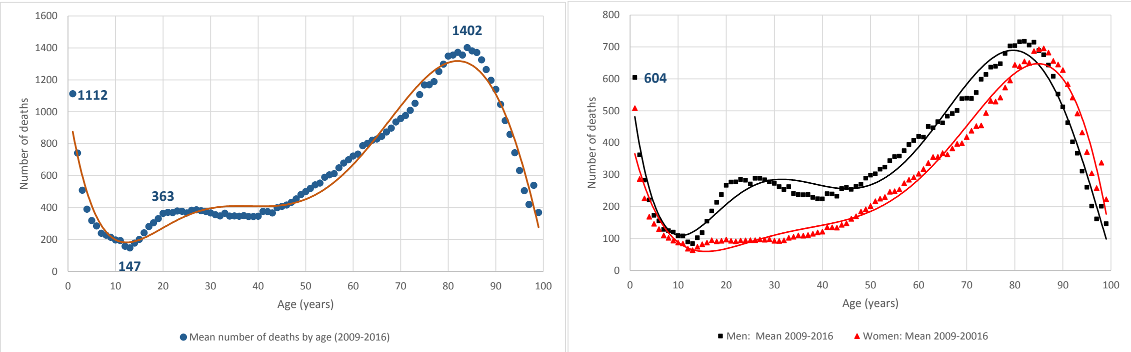
	Number of deaths[(a)]			Population[(b)]	Deaths as percentage of population
	Men	Women	Total		
2009	33,868	25,846	59,714	14,762,258	0.40%
2010	34,895	26,786	61,681	15,012,228	0.41%
2011	35,268	27,036	62,304	15,266,431	0.41%
2012	35,314	28,197	63,511	15,520,973	0.41%
2013	34,670	27,829	62,499	15,774,749	0.40%
2014	35,476	28,302	63,778	16,027,466	0.40%
2015	36,329	29,496	65,825	16,278,844	0.40%
2016	37,435	30,605	68,040	16,528,730	0.41%
Average 2009-2016	35,407 (56%)	28,012 (44%)	63,419	15,646,640	0.41%
Growth rate 2009-2016	1.44%	2.44%	1.88%	1.63%	

[(a)] INEC. 2010.
[(b)] Garcés, Céspedes and Intriago. 2012.

Deaths by age show high mortality the first year of life, 1,112 deaths, decreasing sustainably up to 13 years of age with 147 deaths, then it increases up to 23 years, reaching 363 deaths per year at 20. From 20 to 40 years, deaths stabilize around 362 deaths average per year. From 41 to 100 years, the death population shows a pattern of an inverted U-shaped relationship of values across ages, reaching its peak at 84 years with 1,402 deaths. (Graph 1a). Deaths by sex and age follow the same pattern, approximately, as the whole population deaths, except that man deaths are always higher than women´s up to 83 years old, from where women's deaths are higher than men´s. (Graph 1b).

Graph 1. Deaths (2009-2016) by age: total population (a) and by sex (b)

(a) (b)



Source: INEC, 2010.

2.2 People and traffic accident deaths in Ecuador.

Ecuador is located in the northwest of South America and has a surface of 259,374 km^2 and a population of 14.4 million people (INEC, 2010). Politically, is divided in 24 provinces, from which, three provinces, Guayas (25.1%), Pichincha (18.0%) and Manabí (9.3%), concentrate more than half of the population (Graph 1) and constitute 13.6% of the total country surface.

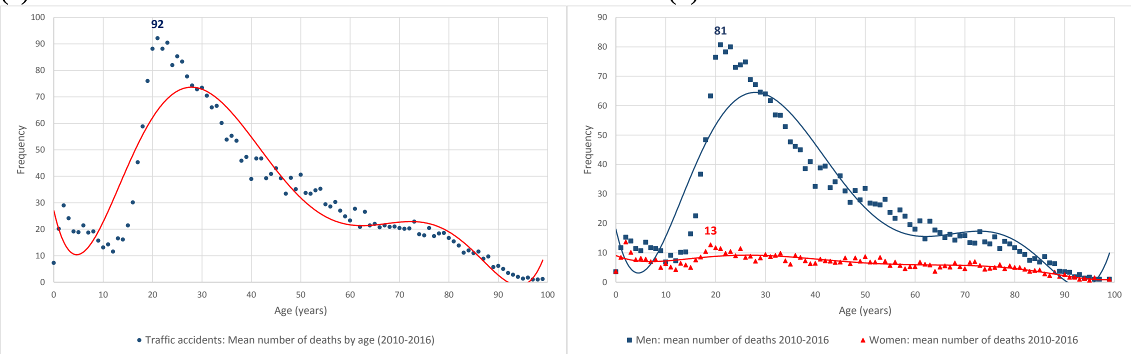
The development of deaths in traffic accidents during the years 2010-2016 shows a decrease through time: in 2010, deaths caused by traffic accidents represented 5% of total deaths or 22 deaths per 100,000 people, while in 2016 they were 4.4% of total deaths or 18 deaths per 100,000 people, this decline represents a 3.3% annual reduction of deaths.

Deaths caused by traffic accidents by age show a pattern of low frequency in young ages up to 21 years old, where the occurrence of deaths reaches its peak of 92 deaths (Graph 2a) from this age on, deaths decrease sustainably to reduce to one death for ages older than 90. The number of deaths by decades of age show its peak at the age interval of 21-30 years old (26%), the 44% of total deaths happen to be younger than 30 years old.

Men are the most affected by traffic accidents than women, 33 vs. 7.8 deaths per 100,000 people, respectively. This is 4.2 times higher for men than for women. Men´s deaths show a peak of occurrences, 81 deaths per 100,000 people at 20 years of age. From this age, deaths decrease sustainably up to one death per year for 100 year old people. The pattern of behavior shown by women is relatively flat (slope -0.0669 deaths per year of age) around an average of 7.8 deaths per 100,000 people. (Graph 2b).

Graph 2. Number of total deaths caused by traffic accidents by age (a) and by sex (b)

(a) (b)



Source: INEC, 2010.

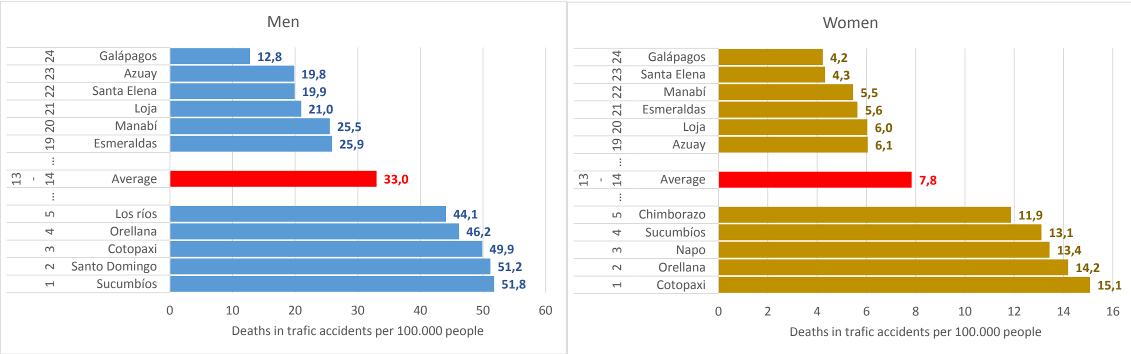
The average road traffic fatalities is 20.4 deaths per 100,000 people which are more than twice the occurrence in Japan (8.4) and above the European Union (11) and United States (15.2). (WHO, 2004:35).

The provinces with the highest number of men's deaths per 100.000 people due to traffic accidents are Sucumbíos (51.8), Santo Domingo (51.2), Cotopaxi (49.9), Orellana (46.2) and Los Ríos (44.2). The provinces with the highest number of women's deaths per 100.000 people are Cotopaxi (15.1). Orellana (14.2). Napo (13.4). Sucumbíos (13.1) and Chimborazo (11.9%). Graph 4 shows the five provinces with the highest and lowest death rates per 100,000 people for men and women. The complete list of the provinces ranked by death rate due to traffic accidents is in Table A1 in Annex 1.

Guayas, the province with the largest population, presents a death rate of 34.4 per 100,000 people for men which puts it in the position 10. Pichincha and Manabí present death rates lower than the average. (Graph 3a). The death rates for women in Guayas and Manabí show lower than the average, while in Pichincha the death rate is higher than the average: position 11 with a death rate of 8.6 deaths per 100,000 people. This rate is above the national average, 7.8 deaths per 100,000 people. (Graph 3b).

Graph 3. Provinces with highest and lowest number of deaths in traffic accidents per 100,000 people (a) men (b) women.

(a) (b)



Source: INEC, 2010.

2.2 Vehicles and traffic accident deaths in Ecuador.

In 2016, there were 2,056,213 vehicles, 67% of those are concentrated in three provinces (Pichincha 36%, Guayas 23% and Manabí 8%). The average number of persons per car is 7.7 while in Guayas is 8.2, Manabí 9.3 and Pichincha 3.9 persons per car.

The provinces with the largest population (Guayas, Pichincha, Manabí) together contribute with the 52% to the total population, 67% to the number of vehicles and 49% of total deaths due to traffic accidents. However, when we analyze deaths per population and number of vehicles, the most populated provinces are not the most dangerous for dying in a traffic accident.

Table 2 presents the provinces with the highest number of deaths per number of people and number of vehicles where it is shown that the most dangerous provinces considering number of deaths per 100,000 people, are Sucumbíos (33.5), Cotopaxi (32.0), Orellana (31.2), in that order. Together, they constitute just the 5.9% of the population and 3.8% of the total vehicles, however, the average rate of deaths of these three provinces is 1.58 times the national average: 32.2 vs. 20.4 deaths per 100,000 people. (Table 2, deaths per 100,000 people).

In the same way, considering the number of deaths per 100,000 vehicles, Napo (460), Imbabura (429) and Morona Santiago (400) are the provinces where their traffic is the most dangerous in the country, their average of 429 deaths per 100,000 vehicles is 2.7 times the national average. (Table 2, deaths per 100,000 vehicles).

Table 2. Provinces with the highest population, highest number of deaths per 100.000 population and highest number of deaths per 100,000 vehicles.

	Population	Vehicles	Deaths	Persons per vehicle	Deaths per 100.000 people		Deaths per 100.000 vehicles	
Guayas	25%	23%	25%	8.2	13	20.5	19	169
Pichincha	18%	36%	17%	3.9	16	19.5	24	75
Manabí	9%	8%	7%	9.3	20	15.5	22	144
Total	52%	67%	49%					
Sucumbíos	1.2%	1.3%	2.0%	7.6	1	33.5	11	254
Cotopaxi	2.8%	1.8%	4.4%	12.2	2	32.0	4	390
Orellana	0.9%	0.7%	1.4%	10.0	3	31.2	8	312
Total	5.9%	3.8%	7.8%					
Napo	0.7%	0.3%	1.2%	17.3	5	26.6	1	460
Imbabura	2.7%	1.1%	3.0%	19.5	11	22.0	2	429
Morona Santiago	1.1%	0.5%	1.2%	17.7	8	22.7	3	400
Total	4.5%	1.9%	5.4%					
National average				7.7		20.4		156

3. Disability Adjusted Life Years (DALY)

Disability Adjusted Life Years is a summary measure of people health that combines years of life lost from premature death and years of life lived in states of less than optimal health, loosely referred to as "disability"[2], of specified severity and duration. (Lopez et al, 2006: 45; WHO, 2017: 5). DALY is used to measure total burden of disease, both from years of life lost and years lived with a disability. One DALY equals one lost year of healthy life.

Premature death is one that occurs before the age to which the dying person could have expected to survive if they were a member of standardized model population with a life expectancy at birth equal to that of the world´s longest surviving population, Japan.

Time lived with disability means living with any restriction or lack of ability (resulting from an impairment) to perform an activity in the manner considered normal for a human being. (WHO, 1980: 28).

The DALY is a health gap measure that combines both time lost due to premature mortality and non-fatal conditions. The loss of healthy life due to non-fatal condition requires estimation of the incidence of the injury in the specified time period. For each new case, the number of years of healthy life lost is obtained by multiplying the average duration of the condition by a severity weight that measures the loss of healthy life using an average health state weight. (Murray and Lopez, 1996).

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[2] Impairment: any loss or abnormality of psychological, physiological, or anatomical structure or function. Disturbances at the organ level. Disability: any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner considered normal for a human being. Disturbances at the person level. Handicap: a disadvantage for a given individual, resulting from an impairment or a disability that limits or prevents the fulfilment of a role that is normal for that individual. Disturbances at the surrounding level. (WHO, 1980: 27-29).

This measure was used in The Global Burden of Disease and Injury (GBD), a joint study between the World Bank, the World Health Organization (WHO) and Harvard School of Public Health, with the objective to quantify the burden of disease and injury of human populations and define the world's main health challenges. This measure was used in The World Development Report: Investing in Health (World Bank, 1993) to define priorities for investments in health. (Mathers *et al*, 2001).

The DALY measures burden from a specific cause as the sum of years of life lost from that cause and the equivalent years of life lost from the disability caused by the condition.

Disability adjusted life years = years of life lost + years living with a disability

DALY(*c*,*a*,*s*) *YLL(c,a,s)* *YLD(c,a,s)*

for given cause *c*, age *a* and sex *s*,

$YLL(c,a,s) = N(c,a,s) \times L(a,s)$,

where,

N(c,a,s) is the number of deaths due to cause *c* for given age *a* and sex *s*.

L(a,s) is the standard loss function in years for age *a* and sex *s*. The loss function specified in terms of the life expectancies at various ages in standard life tables.

The sex difference in the loss function was based on evidence of an intrinsic biological difference in life expectancy for males and females. (Murray, 1996).

$YLD(c,a,s) = I(c,a,s) \times DW(c,a,s) \times L(c,a,s)$,

where,

I(c,a,s) number of incident cases for cause *c*, age *a*, and sex *s*;

DW(c,a,s) disability weight for cause *c*, age *a*, and sex *s*, factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death).

L(*c*,*a*,*s*) average duration of disability in years until remission or death.

One DALY can be thought of as one lost year of healthy life. The sum of these DALY across the people, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. The four pillars of DALY involve different methods of weighting for:

3.1 Life expectancy.

Measures the burden of a disease in terms of life lost relative to how long a person should live, that is, the 'ideal' length of expected life. The idealized standard is the highest national life expectancy observed among Japanese, where females have a life expectancy at birth of 82.5 years and males 80 years.

The DALY uses a global loss function that is the same for all people of a given age and sex, irrespectively of other characteristics such as race, socioeconomic status, or occupation.

This study assumes a life expectancy at birth according to the life expectancy for Ecuador[3]. It imposes an ideal length of life expected on each population and measures the burden of a disease in terms of life lost from that point.

3.2 Age

Age weighting reflects the value of life at different ages, that is, years of life vary in value depending on an individual's age. (Graph 4a). The social preference to age weighting weights the value of young adults more heavily than one lived by a young child or older adults.

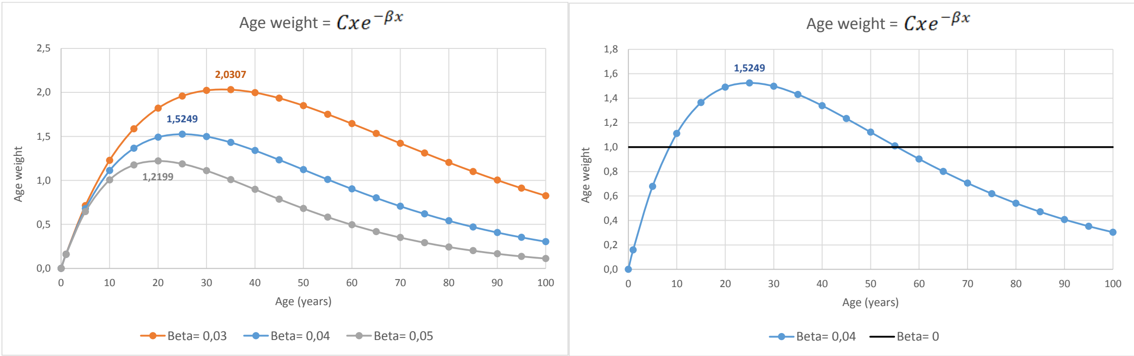
$$Age\ weight^{4} = Cxe^{-\beta x}$$

where:
C= 0.1658,
x = age in years.
ß controls the shape of the age weighting function

A higher weight is given to the healthy life years lived in the socially more important life span between 9 and 56 years. (Devleesschauwer *et al*, 2014). The relative value rises until around the age of 25, up to 1.524 compared to 1 without weight, when ß=0.04 and then falls. (Graph 4b). This suggests that adding 10 years of life to a 10 year old is worth more than adding 10 years of life to a 50 year old.

Graph 4. Age weighting functions used in DALY (β=0.03, 0.04, 0.05) (a) and β=0.04 (b)
(a) (b)

[3] Dempsey (1947) proposed that the limit to life be selected as life expectancy at birth for a given population.
[4] WHO has adopted the approach of using C=0.1658 in all country and regional estimates of the burden of disease and for cost-effectiveness analysis. It is recommended that the values of C=0.1658 and β = 0.04 be used for standard age weighting and for comparability with other studies. (WHO, 2011).



Source: Murray, 1996.

3.3 Future time

Discounting future benefits is standard practice in economic analysis. Positive rate of time preference captures the uncertainty that increases with time; i.e. an individual would prefer a benefit today rather than in the future.

The timing of when benefits accrue matters, future benefits should be weighted to take account of how far in the future they accrue. (Fox-Rushby and Cairns, 2005: 141-142): each additional year is worth a little less than the preceding year. This pattern of values reflect individuals' preferences for benefits sooner rather than later, as well as the small risks of death in any particular year and the diminishing marginal utility of additional life years. (Fox-Rushby, 2002: 10).

A positive discount rate of 3% is likely to represent 'the lower limit of acceptability for those economists who are persuaded by opportunity cost arguments… and the upper limit for public health practitioners who are willing to accept a positive rate of discount' (Murray, 1996, p54).

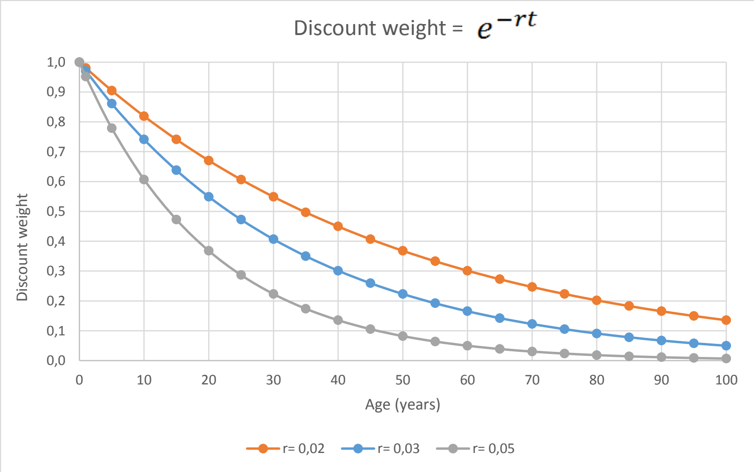
The discount rate is a continuous discounting function of the form (Graph 5):

$$e^{-rt}$$

where:
r = discount rate expressed as a decimal (e.g. 0.03)
t = time

With this notation, DALY(3, 0) denotes the DALY with a 3 percent discount rate and uniform age weights (0 equals no weights), DALY(3, 1) denotes the 3 percent discount rate and varying age weights. The most widely reported variant is the DALY (3, 1), that is, one that uses a 3 percent discount rate and no uniform age weighting. (Jamison et al, 2006: 29; Murray, 1996).

Graph 5. Discount weight (time preference for future benefits) function



3.4 Disability (Fox-Rushby, 2002)

Disability adjusted life years arise from the work of the International Classification of Impairments, Disabilities and Handicaps (ICIDH). A disability weight is a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death). (Table 3). Years Lost due to Disability (YLD) are calculated by multiplying the incident cases by duration and disability weight for the condition.

Table 3. Disability weights for seven groups of indicator conditions.

	Weights	Indicator conditions
1	0.00-0.02	Vitiligo on face, weight-for-height less than two standard deviations
2	0.02-0.12	Watery diarrhea, severe sore throat, severe anaemia
3	0.12-0.24	Radius fracture in a stiff cast, infertility, erectile dysfunction, rheumatoid arthritis, angina
4	0.24-0.36	Below-the-knee amputation, deafness
5	0.36-0.50	Recto-vaginal fistula, mild mental retardation, Down's syndrome
6	0.50-0.70	Unipolar major depression, blindness, paraplegia
7	0.70-1.00	Active psychosis, dementia, severe migraine, quadriplegia

Source: Murray, 1996: 40-41.

Over 1.2 million people die each year on the world's roads, with millions more sustaining serious injuries and living with long-term adverse health consequences. (WHO, 2015: *x*). In developing countries due to rapid and unplanned urbanization, absence of adequate city infrastructure and lack of a legal regulatory framework, make the number of road accidents rise exponentially. (Peden *et al*, 2004: *ix-xii*). Data on the magnitude of non-fatal injuries in road traffic accidents are very limited. Between 1.2 million and 1.4 million people die every year as a result of road traffic crashes. A further 20 to 50 million more are injured (WHO, 2004, 2008, 2009). That means, that for every death in road traffic, there are between 16.7 to 35.7 injured people. The reason for the wide range of the estimate is due to the known underreporting of casualties and the methodological difficulties in measuring the non-fatal outcomes. (WHO, 2011: 34; Peden *et al*, 2004: 5). It is estimated that for every fatality, 30 people will be hospitalized and 300 will require outpatient treatment. (Puur *et al*, 2013).

Non-fatal injury victims are at risk of persistent health and social problems, evidence reveals a variety of influences including physical and cognitive functioning, social participation, productivity, psychological well-being, life satisfaction and quality of life. (Halcomb *et al*, 2005), patients with major trauma have shown that significant effects often persist decades after injury. (Anderson *et al*, 2001, Andelic *et al*, 2009), even mild injuries (e.g., concussions) have been found to exert lasting influence on the victims. (Ryan and Warden, 2003). Also, injuries cause secondary morbidity, for instance psychiatric conditions after road accidents or ocular disease after traumatic brain injury. (Haagsma *et al*, 2011, Rutner *et al*, 2006). These injuries can have considerable impact on quality of life, and often carry with them significant economic costs. (WHO, 2015: 12).

4. The model

Combining the social weighting functions: value of life and time discounting, we have years of life lost (YLL):

$$YLL = M * \int_{A}^{A+L} \left\{KCxe^{-\beta x} * e^{-r(x-a)}\right\} dx$$

integrating,

$$YLL[r,K,\beta] = \frac{KCe^{ra}}{(r+\beta)^2}\left\{e^{-(r+\beta)(L+a)}[-(r+\beta)(L+a)-1] - e^{-(r+\beta)a}[-(r+\beta)a-1]\right\} + \frac{(1-K)}{r}(1-e^{-rL}) \qquad (1)$$

where,

K is the age-weighting modulation factor[5]

[5] The age-weighting function specifies the relative value of a year of life lived at different ages either for YLL or YLD estimates. To estimate the total years of life lost due to death at age x, the age-weighting function is integrated over all ages above x.

C constant: 0.1658
r discount rate: 0.03
β parameter from the age weighting function: 0.04
a age of death
L expectation of life at age *a*,

To estimate years lived with disability (YLD), we use the relationship of number of injured per number of deaths in a traffic accident. The number of injured for every death reported (non-fatal injuries/deaths) is estimated using reported injuries by traffic accidents. The number of injured for every death reported (non-fatal injuries/deaths) goes from as low as 8.5 injured for every death in Thailand (Peden *et al*, 2004) to 130.4 in Sri Lanka (Bhalla *et al*, 2010). (Table 4).

Table 4. Relationship of non-fatal injuries/deaths due to traffic accidents in different countries.

Deaths	Non-fatal injuries	Number injuries/ deaths	Author
12,864	20,704	1.62	Peden *et al*, 2004 Viet Nam
13,000	>1 million	8.5	Peden *et al*, 2004 Thailand
30,721	1.1 million	35.8	Bhalla *et al*, 2009 Iran
2,300	300,000	130.4	Bhalla *et al*, 2010 Sri Lanka
19,389	1 million	51.6	Bartels *et al*, 2010 Mexico
1	13	13	Hijar *et al*, 2003 Mexico
110,000	2.5 million	22.7	Gururaj, 2008 India
200,000	4 million	20	Labinjo *et al*, 2009 Nigeria
1.3 million	20-50 million	26.9	Puvanachandra *et al*, 2012 Egypt

Then, the weighted average of number of injuries/deaths, by the country's population density, gives $\bar{x}$= 36 (*s*=43) injured for every death in a traffic accident. This average corresponds with the highest estimate reported by the WHO of 35.7 injured persons for every death. (WHO, 2004, 2008, 2009). Then, for every death in a traffic accident one can expect at least 36 victims due to non-fatal injuries.

Serious post-crash disabilities due to traffic accidents occur in about from 1% (Bull, 1985) to 87%. (Ameratunga *et al*, 2004) of total casualties. Furthermore, the WHO (2011) reports that 2.6% of traffic accident victims suffer the consequences of a sever disability (WHO, 2011: 30) and have to live the rest of their life with that disadvantage.

Then, for our purposes, for every death in a traffic accident there are 36 injured and from them, 2.6% suffer severe disabilities, thus, for every death, 0.936 persons survive with severe disabilities until death.

5. Results

We estimate DALY for the years 2010-2016 using the life expectancy for Ecuador[6] (WHO, 2017b); for YLL (Equation 1) C =0.1658, discount rate r = 0.03 and age weighting β=0.04 and for YLD we assume that for every death, there are 0.936 non-fatal injured who has to live with a disability from the date of the accident to death. Using these assumptions and based on individual characteristics at the time of death including age and sex, Table 5 presents the DALY estimates.

Table 5. Years of Life Lost (LLY), Years Lived with Disability (YLD) and Disability Adjusted Life Years (DALY) caused by traffic accidents in Ecuador during 2010-2016

	Population	YLL (3,4)	YLD= 0,936*LLY	DALY	DALY per 100,000 people
2010	15,012,228	74,511	69,742	144,253	961
2011	15,266,431	77,293	72,347	149,640	980
2012	15,520,973	73,585	68,875	142,460	918
2013	15,774,749	71,727	67,136	138,863	880
2014	16,027,466	75,794	70,943	146,737	916
2015	16,278,844	72,349	67,719	140,068	860
2016	16,528,730	66,111	61,880	127,991	774
Average 2010-2016	15,772,774	73,053	68,377	141,430	897

Traffic fatalities caused 141,430 DALY or 897 DALY per 100,000 people. This figure is comparable with the occurrence in Thailand 893 DALY per 100,000 persons, (Bundhamchareon *et al*, 2002). Table 6 shows DALY outcomes for some other countries.

Table 6. DALY outcome for road traffic injury per 100,000 people

Serbia	1,800
Thailand	893
Mexico	700
United States	520
Zimbabwe	461
Netherland	460

Source: Polinder *et al*, 2012.

Since one DALY equals one lost year of healthy life, each DALY is used to measure total burden of traffic accidents, both from years of life lost and years lived with a disability.

[6] The life expectancy at birth for males and females for Ecuador for the years 2010-2016 are presented in Table A2 in the Annex.

Assuming that every DALY costs to society the average production of the country and since the average GDP per capita of the period is US$5,705, we have that the national economic costs of road traffic is US$806.84 million[7] or 0.89% of GDP per year, 81% caused by males and 19% due to females.

Road crash costs, expressed as a percentage of GNP, range from 0.3% in Vietnam to 4.6% in USA. Overall, in most countries, costs exceed 1% of GNP. (Jacobs, Thomas and Astrop, 2000: 11). Blomberg (1999) reported for Brazil 0.5% of GDP, Korea 8.1%, New Zealand 4.2%, among others. (Blomberg, 1999).

In terms of cost per capita to society, considering the average GDP (US$90,217 million) and average population (15.8 million inhabitants) during the 2010-2016 period, the cost of DALY due to traffic accidents would be US$358 per capita. This amount is equivalent as if each inhabitant in Ecuador would be paying one minimum salary per year. The minimum salary fixed annually by the government was $354 in 2015 (MT, 2015).

6. Conclusions

Road traffic fatalities are more than twice the occurrence in Japan and above the European Union and United States, 44% of total deaths occurs among people younger than 30 years old, men are more affected by traffic accidents than women.

The most populated provinces are not the most dangerous for dying in a traffic accident. Sucumbíos, Cotopaxi and Orellana provinces are the most dangerous provinces: the average rate of deaths of these three provinces is 1.58 times the national average. They represent just the 5.9% of the population and 3.8% of the total vehicles,

Considering the number of deaths, Napo, Imbabura and Morona Santiago are the most dangerous provinces: the average rate of deaths of these three provinces is almost three times the national average. They constitute just the 4.5% of the population and 1.9% of the total vehicles.

These traffic fatalities in Ecuador caused 141,430 DALY or 897 DALY per 100,000 people, figures comparable with the occurrence in Thailand and lower than those in Serbia and above the Netherlands.

[7] This cost does not include the cost of medical treatment, administration cost, and property damages.

The DALY cost to society is 0.89% of GDP per year, 81% caused by males and 19% by females. This loss of productivity is equivalent to as if each inhabitant in Ecuador payed the equivalent of one minimum salary per month.

This loss of productivity may be considered to support decision makers in allocating resources among competing priorities.

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Annex 1

Table A1. Province ranking for traffic accident deaths per 100,000 people for men, women and total

		Men			Women			Total
1	Galápagos	12,8	1	Galápagos	4,2	1	Galápagos	8,7
2	Azuay	19,8	2	Santa Elena	4,3	2	Santa Elena	12,3
3	Santa Elena	19,9	3	Manabí	5,5	3	Azuay	12,6
4	Loja	21,0	4	Esmeraldas	5,6	4	Loja	13,4
5	Manabí	25,5	5	Loja	6,0	5	Manabí	15,5
6	Esmeraldas	25,9	6	Azuay	6,1	6	Esmeraldas	15,9
7	Zamora Chinchipe	28,3	7	Guayas	6,7	7	Pastaza	18,1
8	Pastaza	29,2	8	Pastaza	6,8	8	Zamora Chinchipe	18,4
9	Bolívar	30,0	9	Los ríos	7,2	9	Pichincha	19,5
10	Pichincha	31,0	10	Zamora Chinchipe	7,5	10	Bolívar	19,6
11	Tungurahua	31,7	11	El oro	7,6	11	Tungurahua	20,3
12	Carchi	34,0	12	Cañar	8,0	12	Guayas	20,5
13	Morona Santiago	34,3	13	Carchi	8,5	13	Carchi	21,1
14	Imbabura	34,4	14	Pichincha	8,6	14	Imbabura	22,0
15	Guayas	34,4	15	Bolívar	9,6	15	Cañar	22,0
16	El oro	36,6	16	Tungurahua	9,6	16	El oro	22,3
17	Cañar	37,8	17	Imbabura	10,2	17	Morona Santiago	22,7
18	Napo	39,3	18	Santo domingo	10,7	18	Chimborazo	25,9
19	Chimborazo	41,1	19	Morona Santiago	10,7	19	Los ríos	26,0
20	Los ríos	44,1	20	Chimborazo	11,9	20	Napo	26,6
21	Orellana	46,2	21	Sucumbíos	13,1	21	Santo domingo	30,8
22	Cotopaxi	49,9	22	Napo	13,4	22	Orellana	31,2
23	Santo Domingo	51,2	23	Orellana	14,2	23	Cotopaxi	32,0
24	Sucumbíos	51,8	24	Cotopaxi	15,1	24	Sucumbíos	33,5
	Total men	**33,0**		**Total women**	**7,8**		**Total**	**20,3**

Table A2. Life expectancy at birth in Ecuador by sex

	Life expectancy at birth		
	Both	Male	Female
2010	75,0	72,1	78,1
2011	75,3	72,3	78,4
2012	75,5	72,7	78,4
2013	76,0	73,3	78,8
2014	76,0	73,2	78,8
2015	76,2	73,5	79,0
2016	76,4	73,5	79,3

Source: WHO, 2017b

Table 1. Pattern of total deaths, deaths caused by injuries and road injuries for the world, the region (Americas) and Ecuador

2015	World	Region	Ecuador
Population (000 000)	7,344	986.5	16.1
Death rate per 100,000	769	666	513
Death by unintended injuries as % of total deaths	8.7%	9.7%	12.7%
Traffic accident deaths as percentage of unintended injuries of total deaths	27% 2.4%	24% 2.4%	32% 4.0%

Source: WHO, 2016, 201