Calculating Disability-Adjusted Life Years (DALY) for traffic accidents and its economic consequences in Ecuador*

Cálculo de años de vida perdidos ajustados por discapacidad (DALY) por accidentes de tránsito y sus consecuencias económicas en 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 (95% CI 892-902). 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% by females. This percentage of GDP lost for road fatalities is equivalent as if each individual in Ecuador paid US$ 358 annually. The provinces with the largest population (Guayas, Pichincha, & Manabí) 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

Keywords

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death rate 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 death rate of these three provinces is 2.7 times the national average (156 per 100,000 vehicles).

Resumen

Muertes por accidente de tránsito en Ecuador son 20,4 muertes por cada 100.000 personas. Los hombres son los más afectados por los accidentes de tránsito: 4,2 veces más que las mujeres (33 vs. 7,8 muertes por 100.000 personas, respectivamente). Los accidentes de tráfico muestran una disminución: de 22 muertes por 100.000 personas en 2010 a 18 muertes por 100.000 personas en 2016. La estimación de DALY por el método de esperanza de vida utiliza ponderación de β = 0.04, r = 0.03, C = 0,1658. El promedio de años de vida perdidos es 141.430 DALY o 897 DALY por 100.000 personas (95% CI 892-902). El costo de DALY, utilizando el enfoque del capital humano, es de US$ 806.8 millones equivalente al 0,89% del producto interno bruto (PIB), el 81% causado por la pérdida de hombres y el 19% por la pérdida de mujeres. Este porcentaje del PIB perdido por muertes es equivalente a como si cada individuo en Ecuador pagara US$ 358 al año. Las provincias de mayor población (Guayas, Pichincha, y Manabí) contribuyen con el 52% de la población total, el 67% de la cantidad de vehículos y el 49% del total de muertes por accidentes de tráfico. Sin embargo, si analizamos las muertes por número de personas y número de vehículos, estas provincias no son las más peligrosas para morir en un accidente de tráfico. Considerando la cantidad de muertes por cada 100.000 personas, las provincias más peligrosas son Sucumbíos (33,5), Cotopaxi (32,0), Orellana (31,2), juntas, constituyen solo el 5,9% de la población y el 3,8% del total de vehículos. Sin embargo, la tasa promedio de muertes en estas tres provincias es 1,58 veces el promedio nacional (20,4 por 100.000 personas). Teniendo en cuenta el número de muertes por cada 100,000 vehículos, las provincias más peligrosas son Napo (460), Imbabura (429) y Morona Santiago (400), en conjunto, constituyen solo el 4,5% de la población y el 1,9% del total de vehículos, la tasa promedio de muertes en estas tres provincias es 2,7 veces el promedio nacional (156 por 100.000 vehículos).

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, p. 85), public policy[1] is an intellectual creation whose content should be identified (Majone, 1997, p. 35), therefore, quantifying deaths and health loss from injuries by

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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, p. 36).

traffic accidents provides a tool for policymaking to regulate traffic to eliminate what kills and disables people. 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, 2008a). 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%) (WHO, 2016, 2017a).

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 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, because of the concern about the high traffic accident rate (Tecniseguros, 2018) since the improvement of the roads in the country. Data is available until year 2016. The productivity loss is calculated for every death person regardless of age and sex, then the estimation is based on the potential contribution of every person given the national average productivity. Section two of the document presents the data and an analysis and description of the state of general deaths and traffic accidents deaths in Ecuador during the period of study. Section three presents the model to estimate the Disability-Adjusted Life Years (DALY). Section four presents the results of the study and finally, section five concludes.

Data

Ecuador is located in the northwest of South America and has a surface of 259,374 km² and a population of 14.4 million people (INEC, 2010). Politically, is divided in 24 proviand 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 and constitute 13.6% of the total country surface.

The evidences 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).

For traffic accident deaths, the INEC uses data collected by de Transportation National Agency, institution in charge of the national transportation (ANT). The register of deaths due to traffic accidents are classified according to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) in the category of External causes of morbidity and mortality: v01-v89 (WHO, 2018).

Deaths in Ecuador

General deaths were relatively constant during 2010-2016: average number of deaths was 63,948 with little variation through the years (coefficient of variation 3.3%), which represent 0.41% 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 (2.25% vs. 1.18%, respectively) (Table 1).

Table 1: Number of deaths by sex and projected population and deaths as percentage of population (2010-2016)

	Number of deaths			Projected population[a]	Percentage of deaths as	
	Men	Women	Total		0/0	00/000
2009	33,868	25,846	59,714	14,762,258	0.40%	405
2010	34,895	26,786	61,681	15,012,228	0.41%	411
2011	35,268	27,036	62,304	15,266,431	0.41%	408
2012	35,314	28,197	63,511	15,520,973	0.41%	409
2013	34,670	27,829	62,499	15,774,749	0.40%	396
2014	35,476	28,302	63,778	16,027,466	0.40%	398
2015	36,329	29,496	65,825	16,278,844	0.40%	404
2016	37,435	30,605	68,040	16,528,730	0.41%	412
Average 2010-2016	35,627 / 56.0%	28,322 / 44.0%	63,948	15,772,794	0.41%	405
Growth rate 2009-2016	1.18%	2.25%	1.65%	1.62%		
Growth rate 2009-2016	0.17%	0.78%	0.44%	0.55%		

Notes: [a]*Garcés, Céspedes and Intriago (2012).*
Source: INEC (2010-2016).

Deaths by age show high mortality the first year of life, 1,117 deaths, decreasing persistently up to the age of 13 with 149 deaths, then it increases reaching 363 deaths per year at 20 years of age. From 20 to 40 years, number of deaths stabilizes around an average of 357 deaths per year. From 41 to 100 years, the death population shows a pattern of a J-shaped relationship of values across ages, reaching its peak at 84 years with 1,439 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: Total deaths by age: total population (a) and by sex (b) (2010-2016)

(a)

● Mean number of deaths by age (2010-2016)

(b)

■ Men: Mean 2010-2016   ▲ Women: Mean 2010-20016
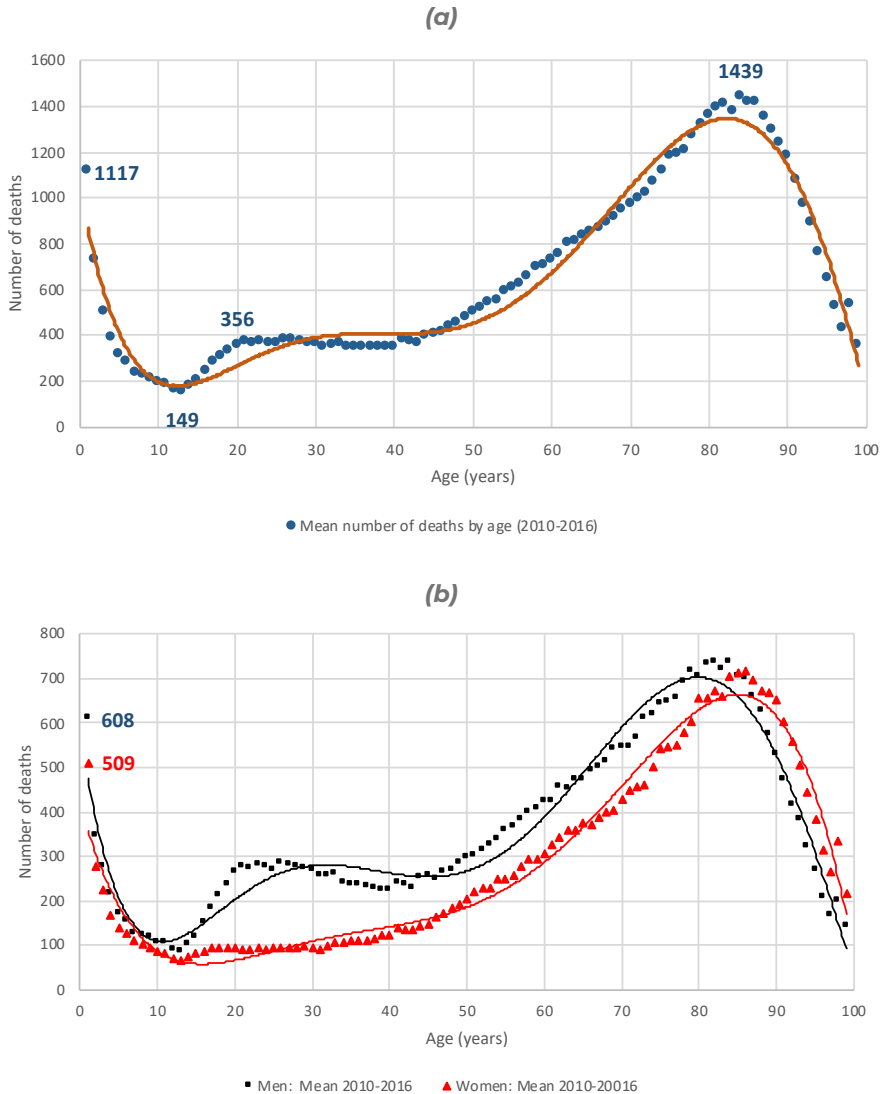
Source: INEC, 2010-2016.

Traffic accident deaths in Ecuador

Deaths in traffic accidents during the years 2010-2016 show a decrease through time: in 2010, deaths caused by traffic accidents represented 5.5% of total deaths or 22 deaths per 100,000 people, while in 2016 they were 4.5% of total deaths or 18 deaths per 100,000 people, this decline represents a 3.3% annual reduction of deaths per 100,000 people (Table 2).

Table 2: Number of deaths in traffic accidents by sex, percentage of total deaths and per 100.000 people (2010-2016)
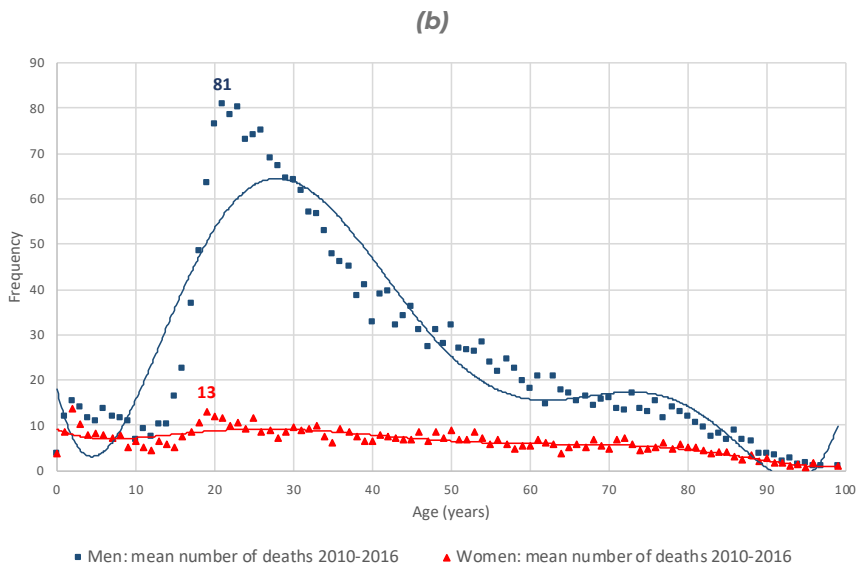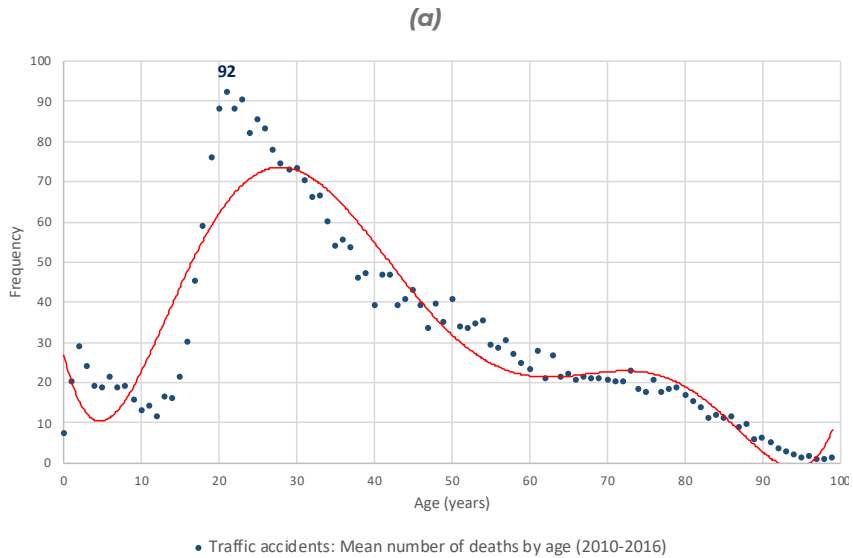
	Number of deaths in traffic accidents			Total deaths	Percentage of total deaths	per 100.000 people
	Men	Women	Total			
2010	2,644	660	3,304	59,714	5.5%	22
2011	2,750	617	3,367	61,681	5.5%	22
2012	2,529	657	3,186	62,304	5.1%	21
2013	2,497	612	3,109	63,511	4.9%	20
2014	2,660	663	3,323	62,499	5.3%	21
2015	2,569	589	3,158	63,778	5.0%	19
2016	2,411	569	2,980	65,825	4.5%	18
Average 2010-2016	2,580	624	3,204	62,759	5.1%	20.4
	81.0%	19.0%				
Growth rate 2010-2016	-1.5%	-2.4%	-1.7%	1.6%	-3.3%	-3.3%

Source: INEC (2010-2016).

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 continuously 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. This pattern of deaths supports the structure of deaths, in 2010, general deaths, the second demographic group of people dying is 15-49 years old (21.5%) after persons older than 65 (54.3%) (Villacís & Carrillo, 2012). This framework of mortality is common to Latin American countries, where it is hypothesized that high mortality among young people, mainly men younger than 40 die due to the "masculinities of under-development": studies show that in Latin America the health burden for men is 26% higher than it is for women (Baker, 1997; Cleaver, 2002, p. 3).

Men are the most affected by traffic accidents than women, 33.0 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 at 20 years of age, 81 deaths per 100,000 people. From this age, deaths decrease sustainably up to one death per year for 100 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: Deaths caused by traffic accidents by age:
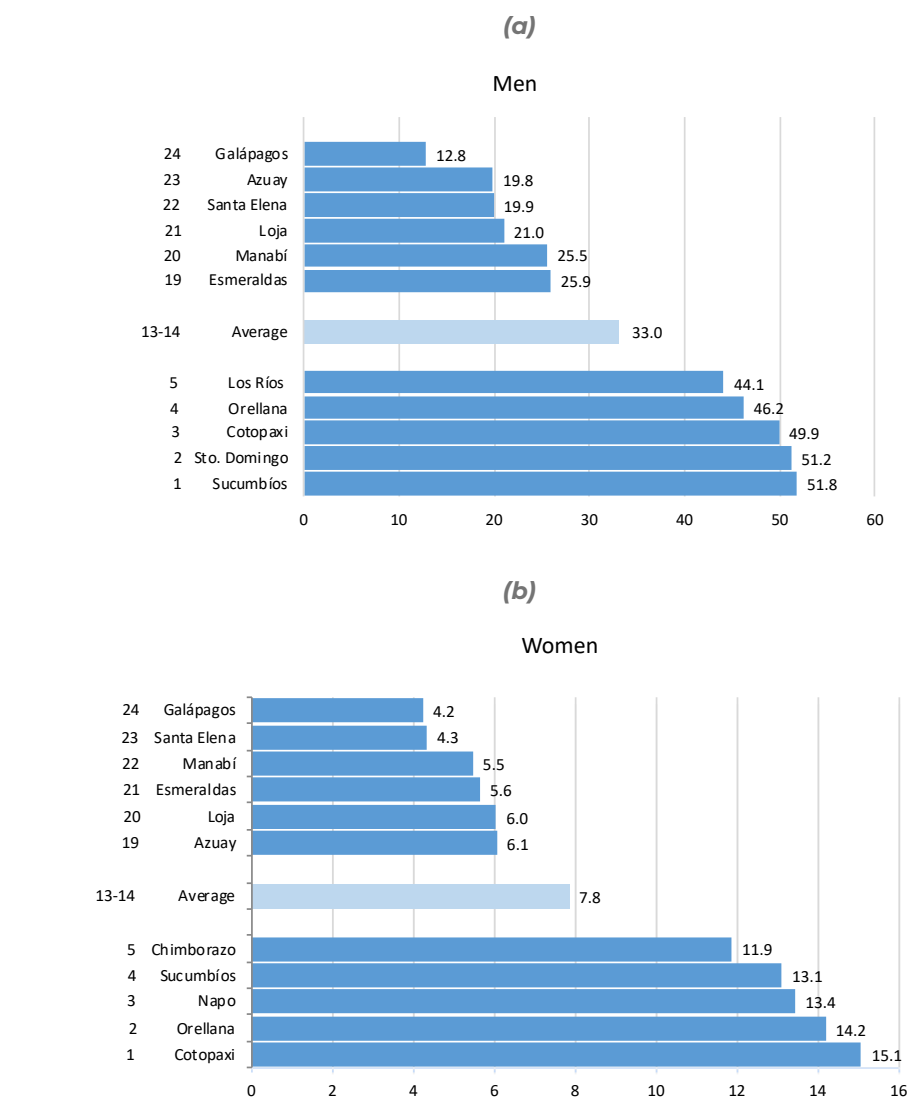total population (a) and by sex (b)

(a)

● Traffic accidents: Mean number of deaths by age (2010-2016)

(b)

■ Men: mean number of deaths 2010-2016   ▲ Women: mean number of deaths 2010-2016

Source: INEC (2010-2016).

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

Graph 3 presents the five provinces with the highest and lowest death rates per 100,000 people for men (Graph 3a) and women (Graph 3b). The complete list of the provinces ranked by death rate due to traffic accidents is in Table A1.

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

(a)

Men

24	Galápagos	12.8
23	Azuay	19.8
22	Santa Elena	19.9
21	Loja	21.0
20	Manabí	25.5
19	Esmeraldas	25.9
13-14	Average	33.0
5	Los Ríos	44.1
4	Orellana	46.2
3	Cotopaxi	49.9
2	Sto. Domingo	51.2
1	Sucumbíos	51.8

(b)

Women

24	Galápagos	4.2
23	Santa Elena	4.3
22	Manabí	5.5
21	Esmeraldas	5.6
20	Loja	6.0
19	Azuay	6.1
13-14	Average	7.8
5	Chimborazo	11.9
4	Sucumbíos	13.1
3	Napo	13.4
2	Orellana	14.2
1	Cotopaxi	15.1

Source: INEC (2010-2016)

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 10th. Pichincha and Manabí present death rates lower than the average. 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).

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, and 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 deaths per number of vehicles, the most populated provinces are not the most dangerous for dying in a traffic accident.

Table 3 presents the provinces with the highest number of deaths per number of people and number of deaths per number vehicles. 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.

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. Also, these provinces show a high number of people per vehicle, more than twice the average of vehicle occupancy, which in case of a traffic accident the consequences are in the same proportion, more than twice the victims. If we consider one traffic accident in Pichincha, in average yields 3.9 persons involved in that accident, while the same event in Imbabura would cause 5 times as much persons with a potential of death and injury.

Table 3: Provinces with the highest population, deaths per 100.000 people and deaths per 100,000 vehicles

	Population %	Vehicles %	Deaths %	Persons per vehicle	Deaths per Rank[a]	100.000 people	Deaths per Rank[a]	100.000 vehicles
Guayas	25.0	23.0	25.0	8.2	13	20.5	19	169
Manabí	9.0	8.0	7.0	9.3	16	15.5	24	144
Pichincha	18.0	36.0	17.0	3.9	20	19.5	22	75
TOTAL	52.0	67.0	49.0					
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	4.9	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

Note: [a]Province rank in a continuous of danger, from 1 most dangerous province to 24 less dangerous province due to number of deaths.
Source: INEC (2010).

The most dangerous provinces to die by traffic accidents coincide with provinces located in the Amazonia region: Morona Santiago, Napo, Orellana, Sucumbíos and two provinces in the Mountain region: Imbabura and Cotopaxi. These conditions of danger

with respect to the frequency of deaths by traffic accidents can be related to certain structural characteristics of the country and of the provinces:

- Health institutions, in need of one, to be taken to a nearest place, the national average is 32,5 minutes, while in most of the Amazonian provinces, it takes between 38,6 and 59,8 minutes, this is some precious time when in case of a traffic accident to assist an injured person (SICES, 2018).

- Education, the average illiteracy rate is 5.6%, Cotopaxi has 9.7% illiteracy while Imbabura 8.8%. The Amazon provinces have lower rates than the average illiteracy rate (SICES, 2018).

- Roads, the country roads are classified as 'good roads' or 'precaution roads'. Ecuador has a total of 10,133 km of roads and 32%, almost one third of them, are considered 'precaution roads'. However, in the Amazonian the precaution roads are between 49% (Morona Santiago) to 78% (Sucumbíos) of 'precaution roads' (MOPT, 2018).

- Poverty, the national extreme poverty[2] (indigence) rate is 8.7%. The Amazonian provinces have rates that go from 19.6% (Sucumbíos) to 36.8% (Napo) of indigency. Imbabura has a 52% of indigency, six times the national average. All the provinces with high road accidents and deaths are way up the national average of indigence (SICES, 2018).

These features explain why in these provinces, the number of deaths due to traffic accidents are the highest, in spite of the low population and low number of cars; which means, the poorer the province the less value the life.

The model

We use the DALY to estimate the economic consequences of premature death and injuries caused by traffic accidents, it quantifies the burden of traffic accidents from mortality and disability. It is a measure of the health gap that combines life-time lost due to premature mortality and non-fatal conditions of traffic accidents.

Once we have the amount of lost years of healthy life (DALY), it is possible to estimate the economic cost for society setting that amount as an opportunity cost to society: the ideal health situation where the society lives an advanced age free of threat of dying and living without disabilities due to traffic accidents. In this way, the decision takers can estimate the gains of modifying the causes of this resource waste.

The DALY measures burden from traffic accidents as the sum of years of life lost (YLL) and the equivalent years of life lost from the disability (YLD) for people living with its consequences:

$$DALY = YLL + YLD$$

where:

$$YLL = N * L$$

N = number of deaths
L = standard life expectancy at age of death in years

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2   Extreme poverty was originally defined by the United Nations in 1995 as «a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to services" (UN, 1995). In 2018, extreme poverty refers to an income below the international poverty line of US$ 1.90 per day (in 2011 prices, equivalent to US $2.12 in 2018), set by the World Bank. This is the equivalent of US$ 1.00 a day in 1996 US prices, hence the widely used expression "living on less than a dollar a day" (Ravallion, Chen & Sangraula, 2008).

$$YLD = I * DW * L$$

I = number of disability cases
DW = disability weight
L = average duration of the disability until remission or death (years)

The model also applies several social value weights in the calculation: these includes time discounting and age weights. Detail on these features, following Murray (1996) and Devleesschauwer, Havelaar, Maertens, Haagsman, Praet (2014), is presented in Annex.

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

$$YLL = M * \int_A^{A+L}\{KCxe^{-\beta x} * e^{-r(x-a)}\} dx \tag{1}$$

integrating,

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

where,

K = age - weighting modulation factor[3]
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 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, 2008a, 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) 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. That is to say that for every death person, at least one survivor to the accident live with a severe disability or for every 10 deaths 9 persons survive with severe disability.

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3   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*.

Results

We estimated *DALY* for the years 2010-2016 using the life expectancy for Ecuador[4] (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 must 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 4 presents the DALY with age weighting and discount rate 0.03 estimates.

Table 4: Years of Life Lost (YLL), Years Lived with Disability (YLD) and Disability-Adjusted Life Years (DALY) caused by traffic accidents in Ecuador during 2010-2016

	Population[a]	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

Notes: [a]*Garcés, Céspedes and Intriago (2012).*

Traffic fatalities caused 141,430 *DALY* or 897 *DALY* per 100,000 people with a 95% confidence interval goes from 892 to 902 *DALY* per 100,000 people (Kleinman, 1977).

Since there is no consensus of whether or not to apply age weighting and time discounting, we estimate DALY without age weighting and without time discount [DALY (0, 0)], we get 740 DALY per 100.000 people: which means that giving importance to the productivity variation of the individual and accounting for time discounting the consequences of traffic fatalities are costlier and should be taking into account.

These figures are comparable with the occurrence in Thailand 893 *DALY* per 100,000 persons, (Bundhamchareon *et al.*, 2002). Table 5 shows DALY outcomes for some other countries.

Table 5: DALY outcome for road traffic injury per 100,000 people.

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

Source: Polinder et al. (2012)

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

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. 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[5] 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, & Astrop, 2000, p. 11). Sven-Ake Blomberg (1999) reported for Brazil 0.5% of GDP, Korea 8.1%, New Zealand 4.2%, among others.

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 US$ 354 in 2015 (MT, 2015).

Conclusions

Considering the period of study, 2010-2016, traffic accidents cause, 3,201 deaths per year equivalent to 5% of total deaths (deaths by traffic accidents represent 2.4% of total deaths in the world) and an estimated of 2,996 persons with non-fatal injured who have to live with a disability from the date of the accident to death, they are the sixth cause of death (worldwide, it is third cause). Men are the most affected by traffic accidents than women, 33.0 vs. 7.8 deaths per 100,000 people, respectively. This is 4.2 times higher for men than for women.

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 younger than 30 years old. 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.

The *DALY* cost to society is 0.89% of GDP per year, 81% caused by males and 19% by females. The loss of productivity is equivalent to as if each inhabitant in Ecuador had to pay annually the equivalent of a minimum salary. This loss of productivity may be considered to support decision makers in allocating resources among competing priorities.

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.

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5   This cost does not include the cost of medical treatment, administration cost, and property damages.

Some features that are common to the most dangerous provinces to die by a traffic accident are located in the Amazonia area (Sucumbíos, Orellana, Napo and Morona Santiago) and two in the central region (Imbabura and Cotopaxi). These provinces, besides the loss of productivity due to the high number of fatalities caused by traffic accidents, show other characteristics that could explain the high rates of traffic fatalities:

- the Amazonia shows the highest extreme poverty rates: the national rate of extreme poverty is 8.7% compared to the Amazonia is more than three times, 28.3%. Napo and Morona Santiago rates are around four times the national average, 36.8% and 34.9%, respectively (SICES, 2018).

- the Amazonia shows the worst health services measured as the average time to reach a health institution: national average time is 32.5 minutes, however in the Amazonia takes more time, in Orellana, for example, takes one hour (SICES, 2018). This long time to reach a health institution in case of an emergency is related to the kilometers of roads (km) per provincial surface (km^2): in the most populated provinces the kilometers of roads per 1,000 km^2 goes from 53 to 67 km/1,000 km^2 (MOPT, 2018).

- in the Amazonia roads are scarce, they go from 14 km/1,000 km^2 (Orellana) to 31 km/1,000 km^2 (Napo). Imbabura has the longest net of roads (72 km of roads per 1,000 km^2) but more than one half (52%) of them are precaution roads. Cotopaxi has 39 km of roads per 1,000 km^2 and the lowest precaution roads (4%) however 35% of the vehicles is older than 2003 (MOPT, 2018).

These hypotheses need to be addressed in future studies to identify how to organize society with respect to traffic behavior and review public policy aiming to improve society quality of life. Additionally, in 2015, there were 3,065 traffic accidents caused by driver´s inexperience (47%), no observance of road signs, speeding, alcohol (44%), pedestrians (5%), bad roads, weather conditions, car failure (5%) (INEC, 2015). These tragedies are consequences of perverse incentives of the law: price regulation which causes competition to get more passengers per trip and not by service quality, this situation makes transportation vehicles speeding to win passengers and make happen the traffic accidents with all their consequences. The main cause of traffic accidents (47% of total traffic accidents) is the driver´s inexperience, drivers are issued driver´s licenses without enough training and some of them have failed exams (Vivanco, 2018).

The public transportation market consists of 428 cooperatives with 11 thousand buses carrying 130 million passengers with total sales of $720 million annually, it represents around 1% of the gross domestic product (GDP) (Rivera, 2018). It would be an attractive market for companies that offer better service with technology and innovation. The government part would be freeing prices to promote market competition based on differentiated service. The opportunity cost of traffic accidents (DALY = 0.89% GDP) could be allocated to finance public policies of prevention, better roads, programs of driver´s training and society awareness.

During 2010-2016, average assignment to community services was 0.48% of GDP, culture and recreation 0.26% GDP, environment protection 0,16% GDP (CEPAL, 2017). Together these three sectors of social investment add up to 0.9% GDP comparable to the loss due to traffic accidents, then reducing loses in this part of the economy could reinforce activities in these sectors of social investment to minimize deaths and its economic consequences confronted in the country roads.

In 2015, Ecuador is ranked 79 among 230 countries with 19,6 deaths per 100.000 people due to traffic accidents (WB, 2018), it has less traffic accident deaths than Venezuela (41.7), Brazil (22.6), Paraguay (23.4) and Bolivia (23.3) and is fifth in South America. The average for Latin America and the Caribe is 19,54 deaths per 100.000 people. These figures could indicate that to traffic accident records are relatively according to the region records and it is possible to have a real picture of the problem since, in Ecuador, traffic accidents are recorded by the Transit National Agency (ANT) in charge of enforcing the national policy of transportation, INEC is the statistics and censuses institution that systematize the information and its source of traffic accidents and deaths is the ANT. Any difference in cost estimation of deaths would be because of differences in structural condition of the economic circumstances of a specific country.

DALY calculation is restricted to the estimation of years of life lost from the disability (YLD) to the survivors of a traffic accident. Further research is needed to measure DALY of disabilities to make a better estimation of the cost of this threat on the roads. As a final thought, it is advisable to consider integrating road safety in areas of health promotion and prevention of damage, consider epidemiological surveillance system for damages caused by traffic accidents to society: roads, vehicles, people. Access to hospital and emergency care must be improved. Public policies need to integrate health and safety in transport, promote greater attention to road safety considering its effects on health and its costs and convert scientific information into policies.

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Annex

Table A1: Province ranking from lowest to highest for traffic accident deaths per 100,000 people for men, women and total

	Deaths in trafic accidents per 100.000 people						
	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

Disability-Adjusted Life Years

Disability-Adjusted Life Years (DALY) 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"[6], of specified severity and duration (Lopez *et al.*, 2006; WHO, 2017b). 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).

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 & Lopez, 1996).

This measure was used in The Global Burden of Disease and Injury (GBD), a joint study between the World Bank, the 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 (WB, 1993) to define priorities for investments in health (Mathers, Vos, López, Salomón, & Ezzati, 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:

$$DALY(c,a,s) = YLL(c,a,s) + YLD(c,a,s)$$

where,

DALY = Disability - Adjusted Life Years for given *c* cause, *a* age and *s* sex,
YLL = years of life lost
YLD = years living with a disability

$$YLL(c,a,s) = N(c,a,s) \text{ x } L(a,s),$$

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6   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. Impairment: any loss or abnormality of psychological, physiological, or anatomical structure or function. Disturbances at the organ level (WHO, 1980).

where,

N = number of deaths due to cause c for given age a and sex s.
L = 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).

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

where,

I = number of incident cases for cause c, age a, and sex s;
DW = 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 = 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:

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 (WHO, 2017a). 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. 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.

Mary Dempsey (1947) proposed that the limit to life be selected as life expectancy at birth for a given population. Thus, this study assumes a life expectancy at birth according to the life expectancy for Ecuador (Table A2).

Table A2: Life expectancy at birth in Ecuador by sex

	Life expectancy at birth (years)		
	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).

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 A1 a). The social preference to age weighting weights the value of young adults more heavily than one lived by a young child or older adults.

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

where:

C = 0.1658,
x = age in years.
β = 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 A1 b). 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 A1: Age weighting functions used in DALY (β=0.03, 0.04, 0.05) (a) and β=0.04 (b)

(a)

(b)

Age weight = $Cxe^{-\beta x}$
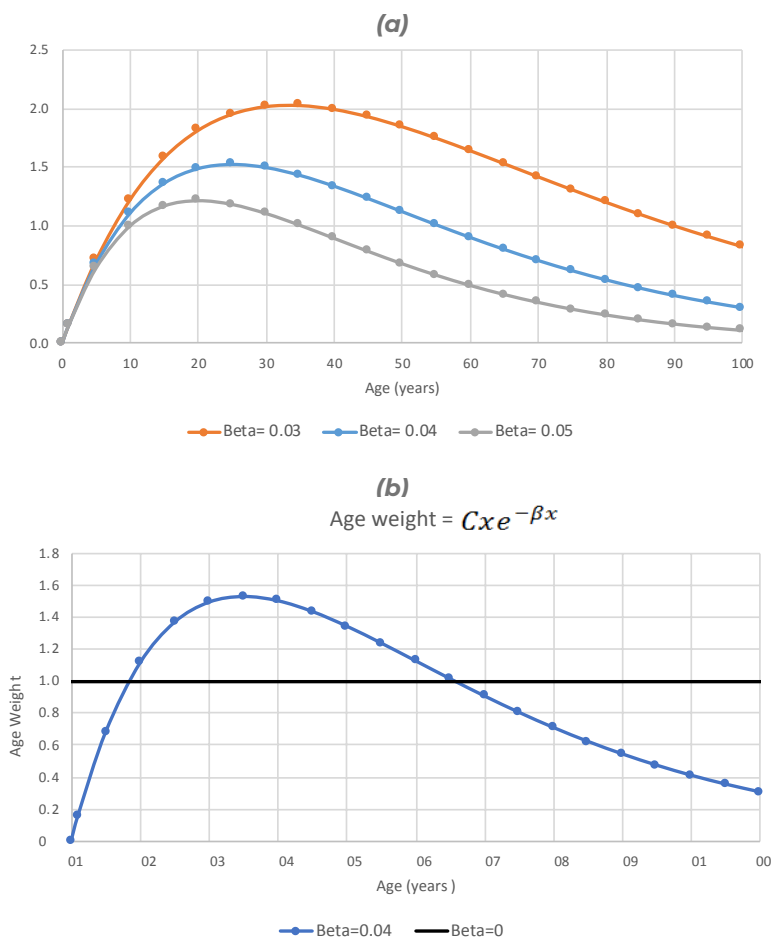
Source: Murray (1996).

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: each additional year is worth a little less than the preceding year (Fox-Rushby & Cairns, 2005).

This pattern of values reflects 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).

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).

The discount rate is a continuous discounting function of the form: (Graph A2)
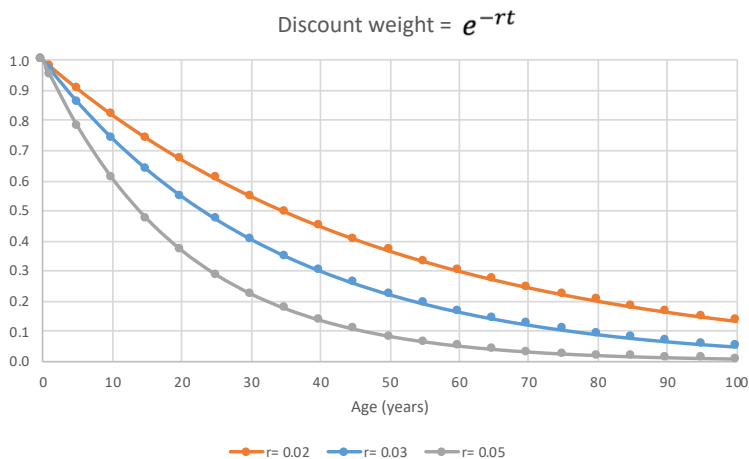
$$e^{-rt}$$

where,

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

Graph A2: Discount weight (time preference for future benefits) function

Discount weight = e^{-rt}

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, D., Breman, J., Measham, A., Alleyne, G., Claeson, M. *et al.*, 2006; Murray, 1996).

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 A3). Years Lost due to Disability (*YLD*) are calculated by multiplying the incident cases by duration and disability weight for the condition.

Table A3: 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).

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). 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).

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, 2008a, 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; Peden *et al.*, 2004). It is estimated that for every fatality, 30 people will be hospitalized and 300 will require outpatient treatment (Puur A., Altmets, K., Saava, A., Uusküla, A. & Sakkeus, L., 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, E., Daly, J., Davidson, P., Elliot, D. & Griffiths, R., 2005), patients with major trauma have shown that significant effects often persist decades after injury (Anderson *et al.*, 2001, Andelic N., Hammergren, N., Bautz-Holter, E., Sveen, U., Brunborg, C. & Røe, C., 2009), even mild injuries (e.g., concussions) have been found to exert lasting influence on the victims (Ryan & Warden, 2003). Also, injuries cause secondary morbidity, for instance psychiatric conditions after road accidents or ocular disease after traumatic brain injury (Haagsma, J., Polinder, S., Toet, H., Panneman, M., Havelaar, A. H., *et al.*, 2011, Rutner, D., Kapoor, N., Ciuffreda, K. J., Craig, S., Han, M. E. *et al.*, 2006). These injuries can have considerable impact on quality of life, and often carry with them significant economic costs (WHO, 2015).