Economics of Global Burden of Road Traffic Injuries and Their Relationship with Health System Variables

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ABSTRACT

Background: To estimate the economic loss due to road traffic injuries (RTIs) of the World Health Organization (WHO) member countries and to explore the relationship between the economic loss and relevant health system factors.

Methods: Data from the World Bank and the WHO were applied to set up the databases. Disability-adjusted life year (DALY) and gross domestic product per capita were used to estimate the economic loss relating to RTIs. Regression analysis was used. Data were analyzed by IBM SPSS Statistics, Versions 20.0.

Results: In 2005, the total economic loss of RTIs was estimated to be 167,752.4 million United States Dollars. High income countries (HIC) showed the greatest economic losses. The majority (96%) of the top 25 countries with the greatest DALY losses are low and middle income countries while 48% of the top 25 countries with the highest economic losses are HIC. The linear regression model indicates an inverse relationship between nurse density in the health system and economic loss due to RTI.

Conclusions: RTIs cause enormous death and DALYs loss in low-middle income countries and enormous economic loss in HIC. More road traffic prevention programs should be promoted in these areas to reduce both incidence and economic burden of RTIs.

Keywords: Death, disability-adjusted life year, economic loss, health system factors, road traffic injuries

INTRODUCTION

Road traffic injury (RTI) as a major public health problem is the ninth leading cause of death globally. It is even more alarming that it is mostly the young population and poor and vulnerable road users who are the main victims. Over 1.2 million people die each year from road injuries and between 20 and 50 million suffer non-fatal injuries, which themselves are an important cause of disability.[1,2] The South-East Asia and Western Pacific Regions accounted two-thirds of deaths due to RTIs in the world.[3] In addition, cases of RTIs are increasing in most of the regions of

the world. Research into RTIs indicates that there are distinct differences in the pattern of economic growth between high-income countries (HIC) and low-middle-income countries (LMIC).[4,5] RTIs affect all age groups, but it is mostly young people who are affected.[1]

Injuries cause disability and death as well as being a great economic burden.[2] The global losses related to RTIs are estimated to be 518 billion United States Dollars (USD) and cost governments between 1% and 3% of their gross domestic product (GDP) - more than the total amount of these countries receive in development assistance per year.[3,6] The increase in RTIs world-wide also has a considerable impact on the economies of many countries, particularly in low income countries (LIC) and middle income countries (MIC) that are frequently struggling with other development needs. LIC and MIC, despite having only 48% of the world's registered vehicles have higher road traffic fatality rates of more than 90%.[1] RTIs can place a heavy burden on the family and friends of the injured person, many of whom also experience adverse social, physical and psychological short-term or long-term effects.[7] Risk factors for RTIs were widely explored literatures. General risk factors of RTIs include the increasing number of motor vehicles, social deprivation, demographic factors, insufficient transport planning, land use and road networks. Individual risk factors contributing to RTI could be young males, excess speed, alcohol consumption, medicinal or recreational drugs, fatigue, road-user's poor eyesight.[7,8]

Circumstance factors were classified as travelling in darkness, vehicle factors, defective road design and inadequate visibility due to environmental factors. The factors, which with special influence upon the severity of RTIs include the lack of vehicle crash protection, lack of roadside protection, non-use of protective devices in vehicles (for example, seat-belts and air bags), non-use of helmets, inappropriate speed and alcohol intake.[7]

RTIs put a huge strain on health-care services in terms of financial resources, hospital bed occupancy and the demand placed on health professionals. Persons from poor economic settings are disproportionately affected by RTIs, even in HIC. People of lower social-economic status were reported to have the highest risk for RTIs.[1]

Individual local level studies in several countries have tried to highlight the economic burden of RTI. However, the global economic burden of RTI at the country level is not well explored.[1] The important macro factors like death due to RTI and health system factors, like health expenditure, may have relationships with disability-adjusted life year (DALY).[1,2,8,9] No study has tried to explore the relationship between economic loss of RTI and health system factors.

The aim of the current study is to estimate the potential economic burden of RTIs at the global level. We have tried to estimate the economic loss of RTIs and related issues according to countries' income levels. The top 25 countries with greatest DALY and economic loss due to DALYs of RTI are presented. We have also tried to explore the relationship between economic loss of RTI and health system variables.

METHODS

Description of variables

Country level data of mortality, RTIs, socio-economic and health-care system variables are used from the World Bank[10] and the World Health Organization (WHO)[11] websites. There were fourteen variables of three different types consisting of (i) dependent and independent variables as (ii) macroeconomic and (iii) health system variables [Table 1]. The dependent variable is the economic loss associated with RTIs. The independent variables are divided into two groups: Macroeconomic factors and health system factors.

The unit for total expenditures on health is purchasing power parity (PPP), which can adjust differences in price levels among countries.[12] This meant that total expenditures on health measured by PPP were comparable within different countries.

Income groups are categorical variables. We delimited income groups based on the definition of the World Bank into four categories according to the 2009 gross national product (GNP) per capita: LIC $765 or less, LMIC $766-3035, upper middle income countries (UMIC) $3036-9385 and HIC $9386 or higher (World Bank, country income levels). Data is missing for three countries: Nauru, Niue and The Former Yugoslav Republic of Macedonia.

Table 1: Dependent variables and independent variables in three aspects

Variables	No. of countries
Dependent variables	
DALY (estimated total DALYs ('000), due to RTIs, 2004[a]	170
Economic loss of RTI (DALY×GDP per capita, USD), 2005	170
Independent variables	
Macroeconomic factors (6)	
Death (estimated number of road traffic deaths, 2005) of RTIs	161
GDP at USD, 2005[b,c]	170
GDP Per capita at USD 2005[b,c]	170
Country wise number of cars (motor vehicles per 100000 population), 2007	123
Vehicles/1000 population, 2007	136
Passenger car/1000 population, 2007	130
Health system factors (4)	
Total expenditure on health per capita (PPP international Dollar, 2008)[d]	170
Physicians density (per 10,000 population)	164
Nurse density (per 10,000 population)	164
Hospital beds (per 10 000 population)	165

[a]DALY=Disability-adjusted life year, [b]GDP=Gross domestic product per capita, [c]USD=United States Dollars, [d]PPP=Purchasing power parity, RTIs=Road traffic injuries

Estimation of the economic loss due to RTIs

The DALY is a measure of overall disease burden.[1] The DALY is a health gap measure for disease and injury. It is the sum of years of life lost (YLL) due to premature mortality in the population and the years lost due (YLD) to disability for incident cases of the disease or injury (DALY = YLL + YLD). DALY focuses more on the time lost due to premature death and the time spent as disabled by disease or injury and therefore it is an appropriate measurement method for RTIs.[13] One DALY represents the loss of 1 year of equivalent full health. DALY data were obtained from the WHO global burden of disease estimates for 2004 for each of the WHO member states.[11]

GDP per capita is the GDP divided by the mid-year population.[12] GDP is the monetary value of all goods and services produced within a country in a financial year, without deductions for depreciation of fabricated assets or for the depletion and degradation of natural resources. GDP is the sum of all consumer spending (C), governmental spending (G), businesses spending on capital (I) and national net exports (NX), i.e., GDP = C + G + I + NX.[12] GDP per capita is the country's GDP divided by the mid-year population.[12] GDP per capita and economic loss in this study are expressed in USD, 2005. Therefore, economic loss due to RTI has been calculated as the multiplication of DALY and GDP per capita.

Statistical analysis

In the present study, 170 countries with DALY value are applied to analyze. Arithmetic means with standard deviations were used to compare the differences within four income groups. Correlations between economic loss associated with RTI and all independent variables were used to test the bivariate relations. The significance level is set at 95%, $P < 0.05$. Based on the result of the correlations, RTI deaths, total expenditure on health and nurse density were used to build up the linear regression model. The aim of the linear regression analysis was to analyze the relationship between the economic losses associated with RTIs and the selected health system factors. The significance level was 95% ($P < 0.05$). All analyses were performed using IBM SPSS Statistics, Versions 20.0.

RESULTS

In the year 2004, 1,224,750 people died from RTIs, with a DALYs loss of 40,738,000 years. The total economic loss of DALYs for RTIs was 167.76 billion USD. The Republic of Moldova has the lowest percentage (0.015%) and Nepal has the highest percentage (6.30%) of GDP loss due to RTI According to the health system factors, the mean of physician density, nurse density and hospital beds are 16, 36 and 32/10,000 populations, respectively.

Comparisons of economic loss and related factors

Table 2 shows the mean of each variable according to four income groups. Both DALYs and Death reflect the decreasing trend from UMIC to HIC and increasing trend from LIC to LMIC. LMIC have highest burden of DALYs and RTI deaths. The economic loss due to DALYs of RTI was almost 33 times greater in HIC compared with LIC.

Table 2: Mean of variables based on different income groups

Mean±SD[a]	LIC[b]	LMIC[b]	UMIC[b]	HIC[b]
DALYs of RTI	156±182	522±1544	190±348	71±185
Death	5500±6469	15899±43638	5861±9670	2486±6460
GDP (billion) [c]	8±14	98±346	132±234	733±1952
GDP per capita[c]	414±286	1463±832	4502±1699	27331±16652
Economic loss (million)[c]	62±103	655±2200	933±1752	2104±7671
No. of cars	4±4	32±23	141±127	391±162
Vehicles/1000	18±22	67±44	178±99	495±167
Passenger car/1000	14±19	42±33	133±97	423±122
Expenditure on health[d]	70±36	226±147	703±271	2634±1481
Physicians density	3±7	10±11	20±15	28±10
Nurse density	9±13	23±23	38±29	71±37
Hospital beds	16±24	21±18	36±26	50±24

[a]SD=Standard deviation, [b]LIC=Low income countries, LMIC=Lower middle income countries, UMIC=Upper middle income countries, GDP=Gross domestic product, HIC=High income countries, [c]United States Dollars, [d]Purchasing power parity, International Dollars, DALY=Disability-adjusted life year, GDP=Gross domestic product

Top 25 countries with highest DALYs loss due to RTI

The top 25 countries with the greatest number of DALYs loss due to RTIs and their economic loss according to world-wide rank and percentage of economic loss of GDP are presented in Table 3. China has the highest amount of DALY loss, accounting for 8,192,000 (USD) while the United States of America shows the greatest financial loss at 53 billion dollars. Twenty four countries with the highest number of DALY losses are LIC and MIC.

Correlations

Table 4 illustrates the results of the correlations between estimated economic values of DALYs loss caused by RTIs and other variables. RTI death, GDP, number of cars, vehicles per thousand, passenger car per thousand, expenditure on health and nurse density were show significant positive correlations with economic loss, which means as the amounts of the variables increased, economic loss due to RTIs also increase ($P < 0.05$). Death and GDP express the significant relationship with economic loss in four income groups. In the cases of the other variables, the associations varied. Numbers of cars and vehicles per thousand have a significant relationship only HIC.

Regressions

The results of the regressions between estimated economic values of DALYs loss due to RTIs and health system factors are shown in Table 5. The model employed for all the countries representing 39.4% of the cases is significant ($F < 0.001$), which relates significantly with death, health expenditure and nurse density ($P < 0.01$). All the models based on different income groups are significant ($F < 0.01$). In LIC, death and expenditure on health have significant coefficient with economic loss of RTIs ($P < 0.01$). In lower and UMIC only death is significantly associated ($P < 0.001$). Furthermore, death and expenditure on health are correlated significantly in HIC ($P < 0.01$).

DISCUSSION

From an overall perspective, the results of the current study show that RTI is a serious public health issue with a great number of deaths and a large loss of DALYs, especially in LIC and MIC. Because of RTIs, countries are losing up to 6% of their GDP. Geographically, most of the RTIs occurred in South-east Asia, which has the highest number of deaths and DALY losses.

Peden *et al.* found that 96% of deaths among children in RTIs occur in LMIC, which would explain the greater disability adjusted life years (DALYs) in these countries.[7] Another reason for LMIC having greatest death and DALY could be the large population in these countries, for example, in China and India. According to the prevention report of RTI from WHO, it was predicted that South Asia would have the largest

Table 3: Top 25 countries with greatest number of DALYs lost to road traffic injuries and estimated economic value of DALYs

Rank of DALY loss	Country	Income groups[a]	DALY s loss for RTI (*000)[b]	Economic loss for RTI (million)[c]	Rank of economic loss	Economic loss of RTI as % of GDP
1	China	LMIC	8192	14180	2	0.63
2	India	LMIC	6747	5161	7	0.62
3	Indonesia	LMIC	2364	3082	14	1.10
4	Russian Federation	UMIC	1360	7258	3	3.04
5	United States of America	HIC	1252	53252	1	0.42
6	Brazil	UMIC	1249	5921	4	0.67
7	Nigeria	LMIC	1231	981	27	0.87
8	Iran (Islamic Republic of)	UMIC	1067	2965	15	1.54
9	Iraq	LMIC	1025	1127	24	3.60
10	Bangladesh	LIC	742	292	59	0.49
11	Democratic Republic of the Congo	LIC	697	83	93	1.37
12	Mexico	UMIC	625	5146	8	0.61
13	Pakistan	LMIC	608	428	48	0.39
14	Sudan	LMIC	593	419	49	1.53
15	Ethiopia	LIC	592	97	87	0.79
16	South Africa	UMIC	550	2879	16	1.17
17	Thailand	LMIC	518	1385	20	0.79
18	United Republic of Tanzania	LIC	352	131	84	0.93
19	Yemen	LMIC	343	273	62	1.63
20	Cote d'lvoire	LMIC	338	287	60	1.76
21	Viet Nam	LMIC	335	211	71	0.40
22	Egypt	LMIC	318	369	54	0.41
23	Uganda	LIC	317	99	86	1.11
24	Angola	LMIC	316	582	39	1.90
25	Afghanistan	LIC	308	78	95	1.15

DALY=Disability-adjusted life year, RTI=Road traffic injury, GDP=Gross domestic product, [a]LIC=Low income countries, LMIC=Lower middle income countries, UMIC=Upper middle income countries, HIC=High income countries. [b]000=Number×1000; [c]United States Dollars

Table 4: Correlations between estimated economic values of DALYs loss to RTIs and other variables*

Variables	Total		LIC[a]		LMIC[a]		UMIC[a]		HIC[a]	
	r	Sig	*r*	Sig	*r*	Sig	*r*	Sig	*r*	Sig
Death	0.366	0.000	0.420	0.011	0.908	0.000	0.972	0.000	0.977	0.000
GDP	0.918	0.000	0.603	0.000	0.992	0.000	0.573	0.000	0.933	0.000
No. of cars	0.284	0.001	−0.181	0.409	−0.236	0.209	−0.113	0.552	0.415	0.004
Vehicles/1000	0.276	0.001	−0.145	0.460	−0.161	0.341	0.055	0.786	0.334	0.013
Passenger car/1000	0.181	0.040	0.145	0.454	−0.126	0.478	0.050	0.807	0.071	0.329
Expenditure on health	0.421	0.000	0.326	0.045	−0.041	0.782	0.215	0.208	0.515	0.000
Physicians density	0.122	0.119	−0.045	0.793	−0.008	0.956	0.135	0.445	−0.006	0.485
Nurse density	0.163	0.037	−0.006	0.973	−0.136	0.366	0.075	0.675	0.103	0.247
Hospital beds	0.048	0.539	−0.077	0.649	−0.002	0.989	0.071	0.683	−0.093	0.268

[a]LIC=Low income countries, LMIC=Lower middle income countries, UMIC=Upper middle income countries, HIC=High income countries, DALY=Disability-adjusted life year, RTI=Road traffic injury, GDP=Gross domestic product. *Correlation is significant at the 0.05 level (2-tailed)

Table 5: Regressions between estimated economic values of DALYs loss to RTIs and health system factors*

Variables	Total		LIC[a]		LMIC[a]		UMIC[a]		HIC[a]	
	β	Sig	β	Sig	β	Sig	β	Sig	β	Sig
R^2	0.394		0.406		0.828		0.949		0.963	
F	0.000		0.001		0.000		0.000		0.000	
Death	0.386	0.000	0.515	0.001	0.910	0.000	0.970	0.000	0.918	0.000
Expenditure on health	0.646	0.000	0.569	0.001	0.066	0.339	0.012	0.790	0.121	0.009
Nurse density	−0.236	0.008	−0.306	0.065	−0.030	0.665	0.033	0.441	−0.027	0.482

[a]LIC=Low income countries, LMIC=Lower middle income countries, UMIC=Upper middle income countries, HIC=High income countries, DALY=Disability-adjusted life year, RTI=Road traffic injury. *Coefficient is significant at the 0.05 level

growth in road traffic mortality during 2000 and 2020, perhaps because of the high numbers of two-wheeled and three-wheeled vehicles.[3]

There are some reasons why we develop a standard measurement to estimate the economic loss of RTIs through DALYs loss. First of all, within countries, there are variations of rates of RTIs. The top five countries with the greatest DALYs of RTIs accounted for 5% of the total DALY loss. These countries were China, India, Indonesia, the Russian Federation and the USA. These countries represent a huge geographic area and population level. On the other hand, if we compare the cost of RTIs at the country level - there are great variations between countries. The top five countries, in relation to economic loss of RTI, constitute more than half (51.56%) of the total economic loss of RTI in the world.

Secondly, there are both underestimations and overestimations of the cost of RTIs within countries. The reporters from the WHO suggested that the costs in LIC and MIC may be significantly underestimated.[3] Although the WHO data represent the best available at present, they have various limitations. If we compare individual country-based studies the results may be significantly different. For example, Blincoe *et al.* estimated the human capital cost of RTIs in USA to be USD 230 billion[14] while the current study estimated the cost as being USD 53.252 Billion. The amount is over four times higher than the estimated cost calculated in the current study. Both direct and indirect costs per year of the RTIs in Europe were likely exceed 207 billion USD through the comprehensive data and measurement techniques.[15]

Thirdly, available studies have estimated the economic loss of RTIs in different ways using different methods of costing. In industrialized countries, the overall cost of RTIs were estimated with reference to: Cost of injuries and fatalities sustained in the accidents, the cost of damage to property and administrative costs (for instance, legal expenditure and insurance) as well as the value of transportation problems caused by crashes. It is hard to measure the cost of injuries and fatalities. One probable explanation may be the indefinite time of the rehabilitation of serious disability.[7] Considering the vast infrastructural, economic and demographic differences, the countries have significant differences in their manner of systems for reporting deaths and economic factors. That is a major reason for the plethora of materials of RTIs and related issues in HIC instead of LIC and MIC; though, the burdens of RTI deaths are opposite. Blincoe's study also found that almost 75% of the RTIs costs were paid for by society (through, for example, insurance premiums, taxes and travel delays). This mean, some economic losses related to RTIs are covered by governments for the relevant public policies.[14,16]

Fourthly, this study has attempted to induce further discussion about the need for in-depth economic analyses of the global burden of RTIs. The global economic losses of RTIs presented here are based on estimated DALYs. An American study advocated that DALY is the available common metrics to qualify the public health burden.[17] We can compare the health burden among injuries and other disease through DALYs.[17] Therefore by using a standard method throughout the world, the current study has estimated the economic loss due to RTIs, which may give a standard platform for comparison purposes and which could help inform future policy issues.

Most importantly, the current study has focused on the issue of RTIs world-wide in the

financial context. China and India have the highest DALYs and also (almost) highest economic loss due to RTIs. As we have observed that the top 25 countries of RTI DALYs and RTI economic loss are mostly different. The reason is clear. HIC have comparatively lower DALYs, but very high levels of GDP per capita. Therefore, economic losses due to RTIs were the biggest economic burden in the HIC. In the study by Jacobs *et al.*, the percentages of GNP in relation to economic loss for RTIs increases from low to HIC,[6] similar to current findings, which calculated the cost via GDP.

Furthermore, in the present study, we analyzed the correlation between economic loss of RTIs and related factors. Globally, as the number of cars, vehicles and passenger car per 1000 population, total health expenditure and nurse density increase, the economic losses increase. The relationship between economic loss due to RTIs and health system factors has demonstrated statistically significant associations at the global level. From the linear regression result, when we control the other factors, increasing nurse density would contribute to the reduction of economic losses due to RTIs. Thus, policy makers could build up RTI prevention and intervention programs, focusing on increasing the number and skills of nurses.

This study shows that LIC and MIC have limited resources in health-care since they have less health expenditure, physician density, nurse density and fewer hospital beds. A review focusing on LIC and MIC pointed out that in surgical wards 48% of beds were occupied by RTI patients, who accounted for the most use of operating theatres and intensive care units in some countries.[18] In addition, when expenditure on health increases, DALY rates decrease. Many studies propose that medical care and technology improvement can contribute to the reduction of road traffic fatalities in industrialized countries.[19,20] According to Spanish research, primary health-care would be an optimal arena in which to promote RTI prevention and intervention.[21] All the studies show the need for comprehensive construction of and investment in healthcare systems in LIC and MIC.

This is the first study that calculates the economic loss due to RTIs at a global level using a standard method and also compares them by income groups. The monetary aspect of RTIs could be used by governments when deciding public health policies. Moreover, the study tries to determine the relationship between economic losses due to RTIs and health system factors, which could also be useful in the development of injury prevention strategies. This provides further strength for the argument that prevention works – also from the economic point of view.

However, there are some limitations in this study. The first problem is the value of the data. Missing data of the countries have under-estimated the situation. Also, extreme data inside each income group have made the standard deviation bigger than the mean. The high level of dispersion of the country level data may prevent the significant association as reflected in the standard deviations. However if we drop the extreme data, which means we do not consider that country, so we include the extreme data in this study. Because of the underreported death or injury of road traffic, there may be some underestimated governmental data relying on police reports, especially in the LIC.[22,23] Bhalla suggested that instead of police reports, the country-specific patchwork of alternate data sources including death registers, hospital records, funeral records, injury surveillance studies and health surveys would be more completed estimated and representative.[17] Afterward, we did not compare the data for each country over time. The current study reveals the challenges arise in estimating the economic loss of RTIs at the country level due to variation of death rate, population size, per capita income and national income.

Country level studies using national statistics generally use information from near about years as it is difficult to receive information for the same year.[2,3,7,9,14,24] To get statistics for the maximum number of countries the current study has used DALY from 2004, GDP from 2005 and other macroeconomic and health system variable from 2008. However, considering the macroeconomic nature and health system variables we can assume that there were no overall significant changes in the country statistics.[3,14,17,24,25] Therefore, the current study has tried to provide an overall relationship and results for the world, instead of individual country.

As the aforementioned equation in method, DALY has two parts YLL and YLD. It is worthwhile to note here that the economic loss of RTIs due to disability, YLD may differ from

that for YLL due to premature mortality. Unlike those lost their lives due to RTIs, persons who are disabled as a result of RTIs may affect the national economies significantly. Therefore, the estimation of economic loss of RTIs in the current study might over-or under-estimate the actual economic loss of RTIs. However in the absence of other common measures of burden of disease and injuries at the global level, DALY is the most appropriate measure, which provides the best available measure of economic loss of RTIs.

Suggestions for further studies

Recently, the international responses to RTI prevention of World Health Organization comprise seat belt and helmet promotion, speed management, drinking refraining and so on.[1] There are many measures could change the road traffic death rate over time, such as, highway safety policies and intervention, road user type distribution and demographics.[16] WHO structured a report about strategies for RTIs prevention to guide the RTI intervention programs.[8] Most HIC have stronger road traffic policies and higher use of strategies expressed to be effective at reducing RTIs, including seat belt use, traffic law enforcement (e.g., motorcycle helmet laws, blood alcohol content laws) and traffic calming intervention.[1,6,26] Unfortunately, to the LIC and MIC, the reduction for traffic injury were not reported an improvement,[3] which increase the necessary to explore the economic cost and relevant factors of RTIs to structure appropriate interventions in these countries. Because of the high burden of RTIs in South East Asia, the specific risk factors research and prevention is exigent required in this area.

CONCLUSIONS

RTIs cause enormous death and DALY loss in LMIC and tremendous economic loss in HIC. South East Asia with the greatest number of death and DALY loss is needed to pay more attention. The regression model suggests that increasing nurse density could decrease the economic loss of RTIs. So the RTIs prevention in the health-care system can put more effort on increasing the number and skills of nurse. The study illustrates the necessary to have further and depth research of the economic burden due to RTIs world-wide and more investigations about the relationship of the health system factors and RTIs burdens. And, more RTIs prevention and intervention programs should be constructed in LIC and MIC.

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