Reduced Road Traffic Injuries for Young People: A Preliminary Investment Analysis

REDUCED ROAD TRAFFIC INJURIES FOR ADOLESCENTS: A PRELIMINARY INVESTMENT ANALYSIS

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Abstract

Purpose: Deaths and serious injuries from road accidents remain a serious issue in developing countries, including for adolescents, for whom they are the largest cause of death. This paper provides an assessment of interventions to reduce these deaths and injuries for adolescents in 75 developing countries.

Methods

We draw on new data on deaths and injuries by age, gender and accident type for the 75 countries, and on the road safety experience of developed and, more recently, of developing countries. Critical tasks are to identify key interventions in road safety, and to estimate their impact and cost. We incorporate these impact and cost estimates in a modelling framework to calculate the reduction in deaths and serious injuries achieved out to 2030, relative to the base case. Finally, established methods are used to value the economic and social benefits arising from these reductions, and hence to calculate benefit-cost ratios.

Results

For the unchanged policy case, we estimate that there will be about 3 million deaths and 7.4 million serious injuries from road accidents for persons aged 10–24 years in the 75 countries to 2030. The preferred interventions avert one million of these deaths and 3 million serious injuries, at a cost of $6.5 billion per annum over 2016–30, or $1.2 per capita across the total population of these countries. After valuing the benefits of the deaths and serious injuries averted, we find a benefit/cost ratio of 7.6 for 2016–30, but of 9.9 if the interventions continue to 2050.

Implications and Contribution

Death and injury rates from road accidents have fallen sharply in developed countries in recent years. In the 75 developing countries studied, death rates are 5–6 times higher than in the developed countries and rose by 12% between 2000 and 2016. Road accidents are the leading cause of death for adolescents in developing countries. This study suggests that not only are the interventions available to address this problem, but they are available at a reasonable cost and would be high return investments, with benefits 7–10 times costs.

Introduction

For persons of all ages, road traffic accidents are responsible for about 1.35 million deaths and a heavy burden of serious injuries every year, with a global fatality rate of about 18 persons per 100,000 population each year [1]. While the global number of road traffic deaths has plateaued in recent years (Figure 1a), the global death rate has shown little decline, in spite of rapid falls in most developed countries. These trends suggest that the goals of WHO's Decade of Action for Road Safety (2011–20), 'to stabilize and then reduce the forecast level of road traffic fatalities around the world by 2020' [2], have been only partly fulfilled. This has led to the inclusion of road safety in the UN Sustainable Development Goals for 2030, both in terms of promoting well-being for all at all ages, and of making cities safer and more sustainable.

Internationally, road accidents, and the deaths and injuries they create, are increasingly concentrated in developing countries. As Figure 1a shows, deaths from road accidents in the 75 developing countries studied here (the former ‘Countdown’ countries; see Appendix 1 for country listings) accounted for nearly 80% of the global total in 2016, having increased by over 12% since 2000. The fatality rate from road accidents is three and a half times higher in low income countries than in high income countries, and over eight times higher than in ten best practice countries (Figure 1b). For example, the road accident fatality rate in Zimbabwe (45.4/100,000 persons) is more than fifteen times that in the countries with the lowest rates (UK 2.9, Sweden 2.9). Ongoing trends are reinforcing these patterns: over 2000–16 road deaths in the ten best practice countries fell by 45%, by comparison with the 12% rise in the 75 countries. Roads accidents thus constitute a major and continuing problem for developing countries as a whole, although there are divergent trends across countries.

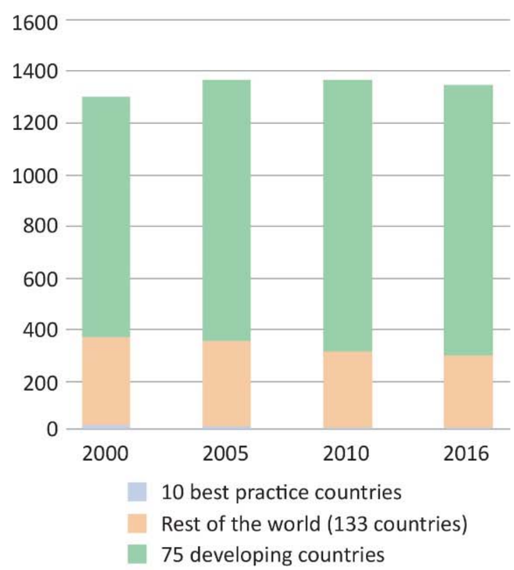
Within countries, young people are overrepresented in road traffic deaths, and these accidents are the largest cause of death among people aged between 10 and 24 years[1][1]. In 2016, about 243,000 young people were killed on the world’s roads, of which four-fifths were in the 75 developing countries and of which nearly 80% were males (Figure 2a). Figure 2a also shows that the source of the fatalities is quite different for developing and developed countries. For young males (females) in the 75 countries, 63% (58%) of adolescent deaths came from motor cycle, pedestrian or bicycle accidents and only 37% (26%) came from occupants of motor cars and trucks. In the OECD countries, cars and trucks predominated, with persons traveling in such vehicles accounting for 62% (73%) of deaths.

This fact provides one illustration of the many differences between developed and developing countries, and indeed within the developing country group, such as in road conditions, vehicle technologies, road safety practices, and in post-injury recovery and trauma care. As far as possible we base this analysis on actual data on the 75 countries, such as the pattern of accidents by vehicle type and the ratio of deaths to serious injuries by country. But there are important issues, discussed below, about assembling reliable estimates of the impact and cost of interventions in developing countries.

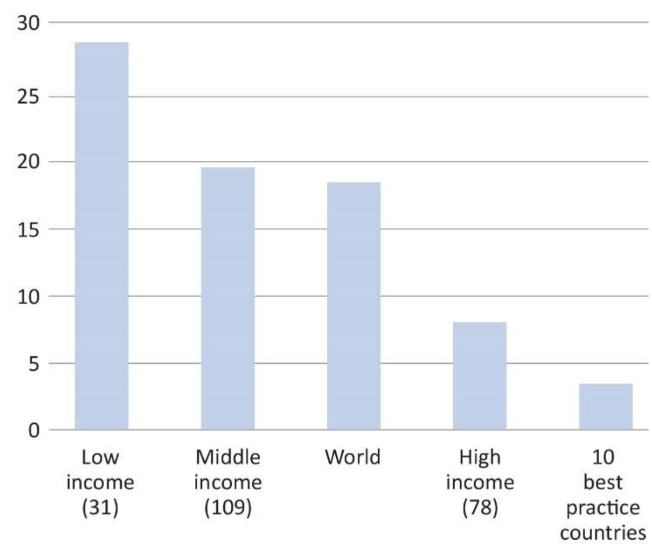
[1] In this paper we use ‘young people’ and ‘adolescents’ interchangeably, to refer to persons aged 10–24 years.

Figure 1 Number of deaths and death rate per 100,000 persons from road accidents, persons aged 10–24 years, by country type, 2015 and 2016

1a Number of deaths ('000 deaths), 2015



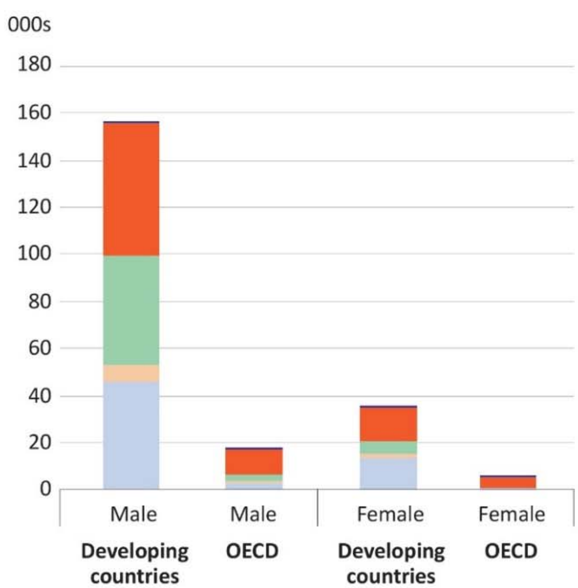
1b Death rates by country grouping, 2015



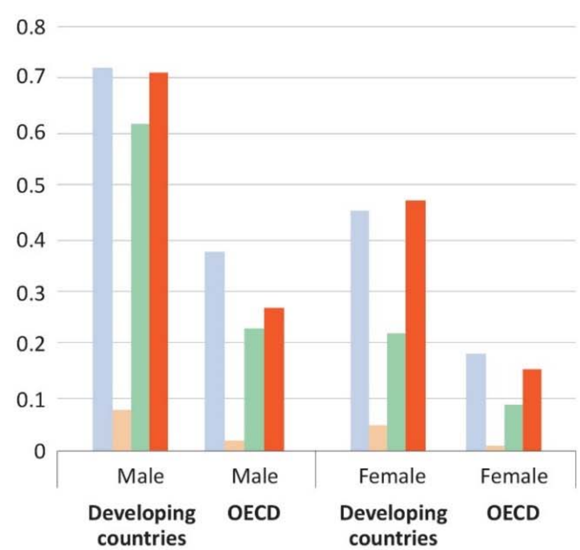
Note: See Appendix 1 for country listings.
Source: Figure 1a, IHME [1]. Figure 1b, World Bank [3].

Figure 2 Number of deaths from road accidents and death/serious injury ratios, persons aged 10–24 years, by country type, vehicle type and gender, 2016

2a Deaths ('000s)



2b Death/serious injury ratio

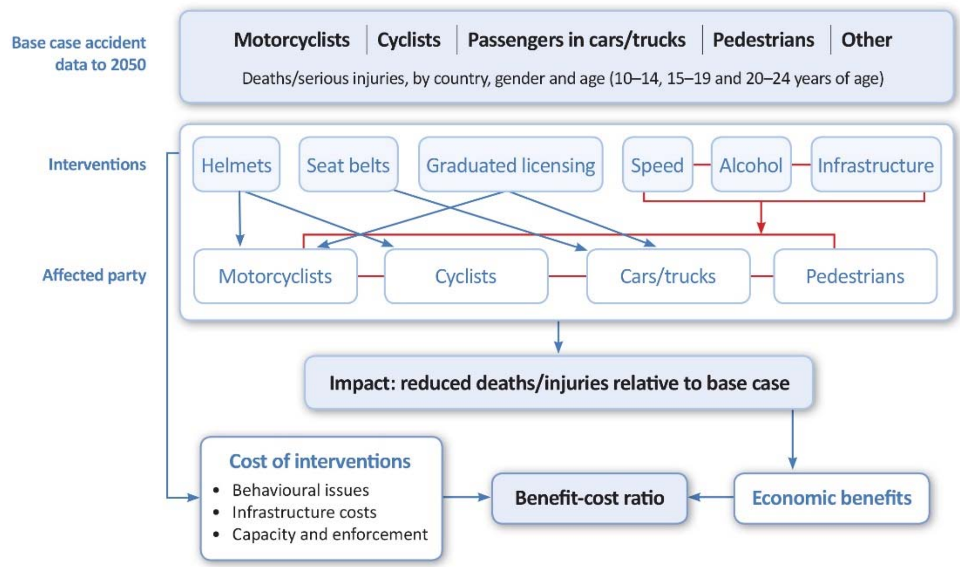


Note: See Appendix 1 for country listings.
Source: IHME [1].

Methods

This paper builds on the pioneering studies of Chisholm and Naci [4,5], who undertook modelling for developing countries at a regional level. We start from the path of deaths and serious injuries from road accidents—by age, gender and vehicle type—in an unchanged policy base case, and compare that path with one achieved through systematic implementation of a range of interventions (Figure 3). After identifying key interventions, we estimate the cost of these interventions and their effectiveness in reducing deaths and serious injuries for adolescents for the 75 countries. We then incorporate these estimates in a modelling framework to calculate the reduction in deaths and serious injuries achieved in each of the 75 countries, relative to the base case. Finally, we estimate the economic and social benefits arising from these reductions, and hence calculate benefit-cost ratios (BCRs). In the central case, the interventions, and hence the deaths and injuries avoided, run to 2030, although the economic and social benefits of fewer deaths and injuries continue beyond 2030. We outline the various elements of this methodology below.

Figure 3. Summary of overall modelling framework



Base Case Fatalities

Establishing a base case projection of deaths and serious injuries from road accidents for the 75 countries out to 2050 is a potentially complex task. Different transport modes have different accident rates (e.g. motor cars are safer than motor cycles), and the relative importance of transport modes varies over the development path. Many other factors influencing the extent of road accidents vary with the nature and pace of economic development. By analogy with the work of Simon Kuznets on inequality and economic development [6], some authors have argued that the incidence of road accidents follows a Kuznets curve (an inverted U curve), rising rapidly as GDP per capita rises from low levels, but then falling after per capita income passes a threshold level [7,8]. Here we abstract from these complexities, recognising that our central interest is in the difference between the policy case and the base case paths, rather than the characteristics of the base case itself.

Following McManus [7], the starting point for the base case is that the matrix of fatality rates (deaths per 100,000 population) in 2016—by age, gender and accident type—is held fixed for each country out to 2050. The population of each country varies over time, in line with the International Labour Organization (ILO) population projections, but this matrix of fatality rates remains fixed for each group within each country. The base case data of fatality rates by age, gender and vehicle or injury type are from the Global Burden of Disease (GBD) 2016 data [1]. Three age cohorts (10–14, 15–19 and 20–24 years of age) are used, for the following types of injured persons: pedestrian, cyclist, motor cyclist, motor vehicle occupant and other categories. This produces 30 baselines (age cohort × gender × transport mode) for each of the 75 countries. This study is the first to use the GBD 2016 data on road deaths and accidents for an international investment analysis.

Base Case Serious Injuries

For each death from road accidents there are a large number of people injured, with the figure of 16 persons sent to hospital for every death often quoted. Many of these injuries are minor, or of limited duration or with limited impact on employment, so we need an estimate of serious injuries. For the first time, the GBD 2016 data provide estimates of the incidence of injuries from road accidents, in addition to estimates of mortality. These estimates— again by age, gender and vehicle accident type for each country—provide our starting point.

In the benefits model, we take account only of injuries causing severe and profound limitations such as to preclude the person's ability to work at all in the future, assumed to be those with greater than 80% permanent impairment on standard impairment scales. There is very little data on the distribution of injuries by severity, but there are a number of country studies. We rely here on a detailed study [9], which found that in Australia in 2006, 4.1% or about 1 in 24 of those hospitalised had severe or profound limitation (i.e. impairment of 80 to 100%). In the absence of any other data, we assume that 4.1% of injury incidences as measured in the GBD data lead to a disability with severe or profound limitation. Such injuries we here call serious injuries.

These new estimates of injuries from GBD 2016 provide insight into the incidence of deaths and serious injuries for adolescents in accidents involving different types of vehicle and across countries. They imply an average ratio of 0.45 deaths per serious injury. The data for the 75 countries (Figure 2b) show that the death/serious injury ratio is highest for accidents involving cars and trucks (0.71 for males, 0.46 for females), for pedestrian accidents (0.72, 0.47) and for motor cycle accidents (0.62, 0.22). For cyclists the ratio is low (0.07, 0.05). These differences may relate significantly to speed, with many car/truck and motor cycle accidents involving vehicles travelling at high speed, often in non-urban areas, while pedestrians are in grave danger of being killed if struck by a rapidly moving vehicle.

It is also notable (Figure 2b) that across all vehicle types death/serious injury ratios are about twice as high in developing countries than in the OECD. This presumably reflects the many differences between developing countries and the OECD in road conditions, vehicle technology, safety programs and injury treatment. It also suggests that the assumption drawn from the Australian study (that 4.1% of GBD injuries are serious) may underestimate the extent of serious injury in the 75 countries.

For base case projections of serious injuries for each year, we hold the serious injury rate per 100,000 constant for each age cohort, gender and country over the time-period being modelled, and apply this rate to the projected number of deaths for each age cohort, gender and country, to obtain the level of serious injury for each category.

Interventions and Their Effectiveness

Over 1970-2015, the median OECD road accident fatality rate fell by 70%, as a result of the development and implementation of many road safety interventions. An important body of evidence has emerged from this experience, including that of some current OECD countries (such as Taiwan [47] and South Korea [48]) which implemented road accident programs in an early stage of their development. In recent decades, more attention has been given to road safety in many developing countries, and this experience is now being represented in the literature. As our focus here is on 75 developing countries, it is important to draw on the recent developing country literature, but also to apply carefully the findings of the broader literature.

To this end we did a search for journal articles in the Web of Science All Databases, which includes the Web of Science Core Collection, Current Contents Connect and MEDLINE, for the period 2009–18. Figure 4 shows the details of the search. Within the core set of 5943 articles, we established a separate stream for those related to developing, low income or middle income countries. The search focused on quantitative data on the cost and effectiveness of interventions, and identified 115 potentially relevant articles. Assessment of these papers resulted in a final set of 22 papers. The references of these and other papers yielded another 12 articles from before 2009, giving 34 articles in total. For the grey literature, we searched the publications of international organisations and institutions in individual countries to obtain internal reports and official crash statistics. From these two approaches, 73 documents were identified that were relevant to the study.

There is a broad consensus in this literature about the most effective interventions to reduce road accidents. As a result, we modelled (Figure 3) the following interventions for all categories of road accidents: speed compliance, alcohol enforcement and better infrastructure. Additional factors were included specifically for motor cycle riders (helmets), occupants of motor vehicles (seat belts) and young drivers (a Graduated Licensing Scheme).

Table 1 summarises the findings about the effectiveness of these various interventions from the 20 studies identified as having such information. Table 2 shows the effectiveness measures actually used in the modelling, with a single figure used for both fatalities and injuries, together with our assumptions about the extent to which these measures are in place in the base case. As noted, the estimates of the effectiveness of the interventions vary widely in the literature and these variations may reflect the intensity with which the interventions are applied.

Figure 4 Summary of literature search and number of articles found in Web of Science

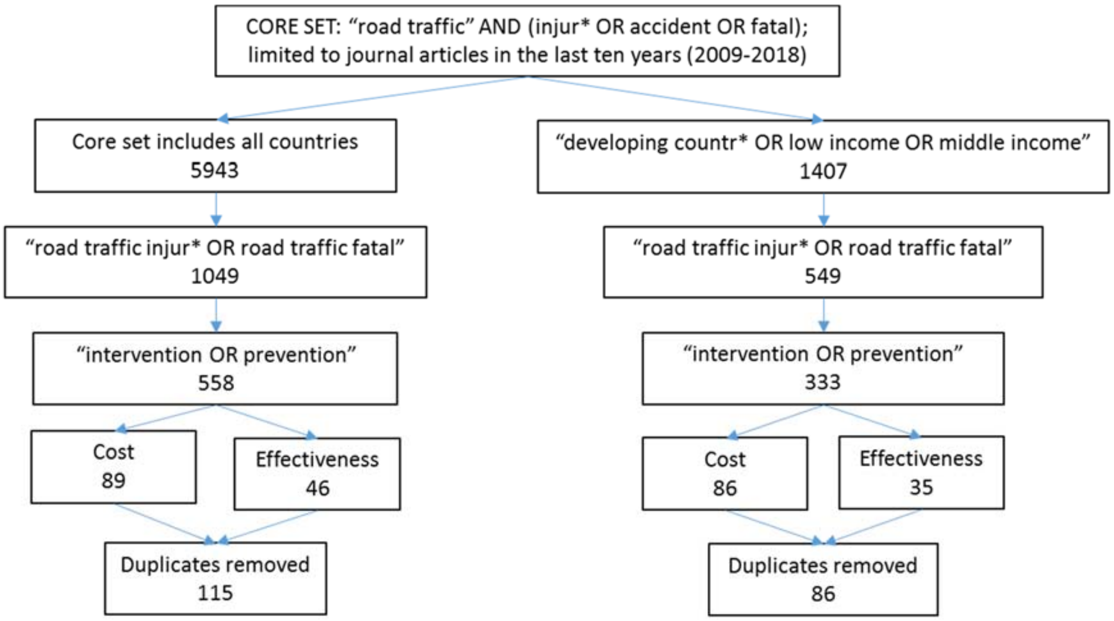


Table 1

Range of effectiveness of interventions

Intervention	Measure of effectiveness	Effectiveness summary range (%)	Effectiveness (% reduction)
Seat belts	Wearing seat	Fatalities 7–65 Injuries 18–83	65 [19], 7–9 [17], 11 [4], 11 [5], 11 [20], 40 [19], 18 [4], 77 [21], 18 [5], 18 [20]
Helmets	Wearing helmet	Fatalities 20–48 Injuries 18–72	36 [4], 20 [11], 42 [12], 29 [13], 36 [5], 18–29 [4], 41 [11], 69 [12] , 54 [13], 18–29 [5]
Alcohol	Modern constraints on alcohol use on roads	Fatalities 3–48 Injuries 3–48	10 [22], 25 [4], 22 (IQR 14–35) [23], 20 (18–22) [24], 25 [5] 3 [22], 15 [4], 35–48 [25], 15 [5]
Speed enforcement	• Systematic speed limit enforcement	Fatalities 17–25	17 [22], 25 [11]
	• Injury severity reduction due to % speed reduction	Injuries 14–56	56 [26], 14 [4], 30–40 [27], 14 [5], 14 [20], 15–24 [28]
	• Injury severity reduction due to speed reduction	Injuries 6–50	9 [22], 6 [4], 8–50 [27], 6 [20]
Graduated licensing scheme	Implementation of GLS scheme	Fatalities 31–57 Crash rates 4–43	57 [14], 20 [15] 28 (4–43) [16], 31 (26–41) [17], 20–40 [18]
Investment in safer roads		Injury accidents 7–20	7 (urban roads), 20 (rural roads) [20]

Note: IQR is interquartile range. In the right hand column the numbers in square brackets are the reference number for the source article.

Drawing on many studies shown in Table 1, the Global Research Safety Partnership (GRSP) Seat Belt Manual [29] sets out the benefits of wearing a seat belt compared to not wearing one (in a 4-wheel vehicle) as follows: 50% fatality reduction for drivers, 45% reduction for front seat passengers and 25% reduction for rear seat passengers. We represent these results by a 40% average reduction in fatalities from seat belt use.

Several studies have examined the benefit of helmet wearing, with a strong and repeated finding of significant reductions in the risk of death and serious injury, as summarised in Table 1.

In relation to alcohol, Bishai et al. [22] among others, examined the effect of alcohol enforcement to reduce deaths and found a 17% reduction, whereas Chisholm and Naci [5] use a figure of 25%. Table 1 provides the results of other studies. These effects are the estimated effects of putting in place an integrated system for the prevention of driving with excessive alcohol levels, as applies in many developed countries, relative to no alcohol controls.

There is a long literature on the effect of reduction in speed levels on deaths and injuries from a given level of accidents, which centres around the percentage change in these outcomes for a given percentage reduction in average speed levels on different types of road. For example, Cameron and Elvik [28] find, on the basis of an extensive meta-analysis, that a mean speed reduction of 3 km per hour (e.g. from 65 km/hr to 62 km/hr on a 60 km/hr road) generates a 15% reduction in deaths on urban arterial roads, 20% on residential roads and 24% for rural highways, for all road users. As well as varying across road types, the reduction in deaths from a given reduction in speed also varies with the initial speed level.

The literature around graduated licensing systems (GLS) shows that these systems provide a safer learning environment, with robust license testing before solo driving and safer novice driving years. As shown in Table 1 several studies show that GLS delivers a reduction of more than 20% in novice driver and rider deaths and crashes when compared with a control group, although there is considerable variation in results across the different cases studies. These studies are all for the developed countries, although GLS are being considered in several low- and middle-income countries in view of high fatality rates for young drivers and riders.

Major crash risks arise in developing countries from poor infrastructure and from the construction of new, faster roads with inadequate safety provision. Modelling by the International Road Assessment Programme (iRAP) for the UN Sustainable Development Goals project estimated that bringing the 10% of roads where 50% of fatalities occur in all countries to a three star iRAP standard or better would reduce fatalities (and serious injuries) in those countries by more than 15% [30]. These estimates are supported by recent demonstration projects in India and other countries. In India, for example, a project in Karnataka state involved traffic calming, better delineation, pedestrian, bus and truck parking facilities, leading to nearly 60% reduction in road fatalities in the year following the completion of the project [36]. Another demonstration project on the 139 km Renigunta-Kapada Rd in Andhra Pradesh, India, led to a 43% reduction in injuries and 22% reduction in fatalities [36].

The intervention effectiveness values used are summarised in Table 2. These values are the estimated impact by 2030 arising from the progressive, well-resourced implementation of the six interventions over 2016–30. The modelling uses the same values for deaths and serious injuries, given our limited information on serious injuries. We recognise that the specific form of these interventions will vary across countries, reflecting local conditions and cultural traditions, but we assume that the levels of effectiveness shown in Table 2 are achieved in each country by 2030. The interventions are assumed to be independent, but with multiplicative effects. We vary the effectiveness value for particular interventions in some countries in which different circumstances apply, such as Islamic countries where the consumption of alcohol is restricted.

Table 2

Summary of assumptions about effectiveness of interventions used in modelling, by 2030

Intervention	Base case	Intervention effectiveness	Level of deaths/injuries after intervention
Seat belt usage	60% unless data available	40%	84% of base case (for 60% current usage)
Helmet usage	40% unless data available	36%	78% of base case (for 40% current usage)
Enforcement of alcohol limits	0	25%	75% of base case
Enforcement of speed limits	0	14%	86% of base case
Better preparation of novice drivers (eg GLS)	0	20%	80% of base case
Building better traffic infrastructure	0	15%	85% of base case

In terms of the existing level of these interventions, some data are available from the WHO regarding estimated levels of helmet wearing and seat belt usage (for 14 and 20 countries respectively). Where available, we use these data, but otherwise use a base case rate of 40% and 60% respectively for helmet wearing and seat belt usage. For other interventions, no data are available and the base case assumption is no implementation (see Table 2).

We construct the intervention path by applying these effectiveness values, by country, age and accident mode, to the base case. The difference between deaths and serious injuries in the intervention and base cases is the measure of the impact of the interventions.

We recognise that the estimates summarised in Tables 1 draw mainly on developed country experience, and that this is a limitation of this study. The following points are relevant to the use of these estimates for a study of 75 developing countries.

First, the basic physics of modern road accidents applies in all countries. To reduce such accidents requires safer vehicles moving at lower speeds on better roads, better drivers and riders in full control of their vehicles and with adequate protection, and more careful pedestrians protected from rapidly moving vehicles. While the methods for implementing such requirements will differ across countries, some commonality in response is to be expected. Secondly, there is a growing body of literature, mainly pilot interventions in low- and middle-income countries, which show substantial effects of these programs. These include studies for India [35, 43], Bangladesh [36], Uganda [37], Rwanda [38], Vietnam [39], China [40, 41], Iran [42], Chile [44] and Brazil [45]. Staton et al. [46] undertake a meta-analysis of 18 articles from 11 lower income countries, finding substantial reduction in accidents and/or injuries in most cases, but comment on the limitations of many studies and the critical role of enforcement.

Thirdly, in 2018, Vecino-Ortez et al. [49] studied the interventions that would best reduce unintentional injuries in the 84 countries where the world's poorest billion people live, finding that drink-driving enforcement and speed limitation were by far the most important. Their statistical method assumes that the effect sizes reported for high income countries can be transferred to low income countries. They argue that, if the interventions are properly implemented, this should be a lower bound to the effect sizes in low income countries, as the risk of injury is higher in these countries. As noted earlier, here we assume substantial investment in administrative and management capability to facilitate effective implementation, and allow for the cost of this investment.

The costs of interventions

For this study, the costs involved with implementing the proposed interventions consist of the cost of the following:

- implementing behavioural measures (helmets, seat belts, alcohol control, speed limits and GLS);
- developing road safety management capacity; and
- infrastructure improvements.

Each of these are critical to an effective package of road safety measures, and we consider them in turn.

In terms of costs, only five studies have been identified that provide specific estimates of the annual costs of full implementation of the four behavioural measures (helmets, seat belts, alcohol control and speed enforcement) {4,5,11,22,25]. The estimates are summarised in Table 3.

Table 3
Range of costs of interventions, four behavioural interventions (Int$ unless stated to be US$*)

Cost range, $ per capita	Cost range, share of Gross Domestic Product (GDP)	Source
Seat belts		
$0.09 – $1.45 (per capita 2016 $)	0.003% – 0.011% of GDP (2005)	Chisholm & Naci 2008 [4]
$0.09 – $0.30 (per capita 2016 $)		Chisholm & Naci 2012 [5]
Helmets		
$0.14 – $0.49 (per capita 2016 $)	0.001% – 0.007% of GDP (2005)	Chisholm & Naci 2008 [4]
$0.13 – $0.17 (per capita 2016 $)		Chisholm & Naci 2012 [5]
US$0.011 – $0.304 (per capita 2016 US$)		Bishai & Hyder 2006 [11]
Alcohol		
$0.15 – $0.33 (per capita 2016 $)		Chisholm & Naci 2012 [5]
$0.15 – $2.24 (per capita 2016 $)	0.004% – 0.012% of GDP (2005)	Chisholm & Naci 2008 [4]
US$0.251 (per capita 2016 US$)	0.0079% of GDP	Ditsuwan et al. 2013 [25]
Speed enforcement		
$0.17 – $0.36 (per capita 2016 $)		Chisholm & Naci 2012 [5]
$0.011 – $0.304 (per capita 2016 US$)		Bishai & Hyder 2006 [11]
$0.17 – $2.37 (per capita 2016 $)	0.005% – 0.013% of GDP (2005)	Chisholm & Naci 2008 [4]
US$0.0032 (per capita 2016 US$)		Chisholm & Naci 2008 [4]
	0.00091% of GDP	Bishai et al. 2008 [22]
Total – all four		
Sum of above	0.013% – 0.043% of GDP (2005)	Chisholm & Naci 2008 [4] Chisholm & Naci 2012 [5]
Integrated implementation	0.007% – 0.024% of GDP (2005)	Chisholm & Naci 2008 [4] Chisholm & Naci 2012 [5]

Note: * 'Int$' reference to $s expressed in purchasing power parity terms. These provide a better way of comparing costs across countries and have been used in the sources cited. 2005 Int$ were converted to 2016 Int$ using a global average of available inflation figures between 2005 and 2016 of 1.283.

There is also the question of the costs of a coordinated implementation of the four measures, as opposed to the sum of the costs of implementing the four measures individually. Chisholm and Naci [4,5] estimate a cost for coordinated implementation varying between 0.007% and 0.024% of GDP, depending upon the region of implementation. This percentage figure is lower than the sum of the individual intervention costs, which vary between 0.013% and 0.043% of GDP, due to cost savings from coordinated implementation. Having regard to the fact that our effectiveness measures assume a high level of enforcement, we use the figure for coordinated implementation in the highest cost region (0.024% of GDP) from Chisholm and Naci [4] across all countries. The only data regarding costs associated with implementing a graduated licensing scheme are those provided by Healy et al. [15] and are estimated to be 0.006% of GDP when fully implemented. Consequently, this figure is added to the 0.024%, producing a total for behavioural measures of 0.03% of GDP. This cost turns out to be relatively low compared to the costs of building safety management capacity and improved infrastructure.

The studies summarised in Table 3 do not cover those involved in building and maintaining the management capacity and systems required for the listed interventions to be effectively implemented, nor the costs of improving the quality of the infrastructure resulting in safer roads. A report from the World Bank estimates the costs of developing management capacity. They recommend that two US$20 million demonstration projects are implemented in each 'GDP equivalent entity of $50 billion' over a five-year period (say 2016 to 2021) to build capacity and systems [33]. In percentage terms, this equates to expenditure of 0.08% of GDP per annum to build the required capacity.

In addition to this period of capacity building, authorities will require an allocation of funding for ongoing adequate maintenance and governance of legislative processes, enforcement systems, data assembly and management (crash, offence, licensing and vehicle registration), infringement management and court systems. The operation and maintenance of these capacities would require further, though reduced funds, for each of years from 2022 to 2030. We assume these to be about two-thirds of that in the capacity building stage, or 0.055% of GDP.

Modelling undertaken by iRAP for the Sustainable Development Goals project [30] has developed estimates of the investment required to target improved infrastructure safety on 10% of all country road networks where 50% of fatalities are occurring. It is estimated that this pattern of investment would achieve a 30% reduction of those 50% of fatalities, i.e. a 15% overall reduction in fatalities. For all the 75 countries, the estimated total investment required over 15 years to achieve this 15% reduction in fatalities would be US$170 billion, with an average expenditure of US$11.4 billion annually. For the purposes of allocating costs to the various 75 countries, the figure was converted to a percentage of total GDP and represents a figure of 0.055% of GDP per annum.

The total cost estimated in this study to implementing the various interventions, to develop and maintain management capacity and to build better infrastructure, corresponds to 0.165% of GDP (0.03+0.08+0.055) in the first five years, and 0.14% of GDP for subsequent years.

These costs refer, of course, to the implementation of these measures to the whole population. As this study is concerned with persons in the 10–24 age bracket, costs are apportioned according to the share of persons aged 10–24 years in the overall population. The percentage of 10–24 year olds was calculated for all 75 countries according to ILO estimates and an average of 22.9% was calculated for all 75 countries for 2016. This share of costs is applied to adolescents.

Economic and Social Benefits

The costs discussed above are the costs of implementing the various measures outlined. The benefits arising from the interventions are the economic and social costs of road accidents avoided because of the reduction in accidents. The analysis here focuses only on the avoided deaths and serious injuries, involving severe and profound impairment such as to preclude employment. Two types of benefits arise from fewer deaths and serious injuries: increased employment and productivity leading to higher GDP and the social benefits of each healthy life, over and above the benefits of higher GDP. This methodology is explained in Stenberg et al. [34] and in Sheehan et al. [10].

Results

Summary Base Case and Interventions: Deaths and Serious Injuries

The results for deaths and serious injuries are summarised in Table 5. In the base case, there are projected to be just under 3 million young people in the 10–24 years cohort killed in road accidents over the period 2016–2030, with nearly 7.4 million serious injuries. The interventions reduce this tragic toll significantly: one million deaths—one third of the total—are averted across 75 countries, as are over two million severe injuries, 27.2% of the total in the base case.

This major reduction of three million deaths and serious injuries is distributed across the different country groupings shown in Table 4 broadly in line with opening population shares, with 56.1% of the lives saved and 61.4% of the injuries averted being in the lower middle-income group, which contained 57.2% of the adolescent population in 2016. While the three age bands within the 10–24 year age group each have about one-third of the total adolescent population, the incidence of both lives saved and injuries rises rapidly with age, to over 50% in the 20–24 years ago group. This undoubtedly reflects the increasing involvement of older adolescents with motorised transport and particularly with motor cycles and cars, which have higher death/injury ratios than other vehicle types. Young males are more heavily involved in road accidents than young females, and as a result this is true also of deaths and serious injuries averted.

Table 4

Number of base case and interventions road fatalities for deaths and serious injuries, 10–24 year olds, thousand persons, 75 developing countries, 2016–2030

Deaths			
Income level	**Base case**	**Interventions case**	**Lives saved**
Low	512.7	344.4	168.3
Lower middle	1614.2	1053.6	560.6
Upper middle	858.3	587.7	270.5
Total	2985.2	1985.7	999.5
Serious injuries			
Income level	**Base case**	**Interventions case**	**Serious injuries averted**
Low	870.7	643.0	227.7
Lower middle	4460.3	3227.3	1233.0
Upper middle	2046.6	1498.1	548.5
Total	7377.6	5368.4	2009.2

Note: Countries in the income levels are listed in Appendix 1.
Source: Author estimates.

Summary: Benefits, Costs and Benefit-Cost Ratios of Interventions

As is to be expected, this large scale saving of young lives and the avoidance of the personal and community costs associated with serious disability has major economic and social benefits. Our estimates of these benefits, expressed in net present value (NPV) terms to 2030 and 2050 using a 3% discount rate, are summarised in Table 5. In terms of benefits, this table is divided into four columns. The first two columns (NPV GDP) are the benefits associated with higher employment or productivity, arising from the avoidance of death or serious injury, while the next two columns (NPV social benefits) cover the other social benefits from the avoidance of death and serious injury.

Table 5

Road deaths interventions benefits and costs, 75 developing countries, US$ billions, net present value (NPV) to 2030 and 2050, 3% discount rate

	NPV GDP		**NPV social benefits**		**NPV cost**
Income level	**Deaths**	**Serious injuries**	**Deaths**	**Serious injuries**	
NPV to 2030					
Low	7.3	9.6	10.5	7.4	4.8
Lower middle	70.6	135.7	35.9	40.1	35.1
Upper middle	91.6	176.2	18.3	18.9	56.8
Total	169.5	321.5	64.7	66.3	96.8
NPV to 2050					
Low	20.8	27.7	29.7	21.0	10.8
Lower middle	172.5	326.9	89.8	98.6	66.7
Upper middle	200.3	381.6	41.7	42.4	91.5
Total	393.6	736.2	161.1	161.9	169.1

Note: Countries in the income levels are listed in Appendix 1.
Source: Author estimates.

The cost estimates, again expressed in net present value terms to 2030 and 2050 using a 3% discount rate, are summarised in the right hand column of Table 5. Over the fifteen years 2016–30, the total cost is put at $96.8 billion, amounting to $6.5 billion per year across all 75 countries. This amounts to $4.6 per capita per annum (across the adolescent population) or $1.2 per capita per annum across the total population of the 75 countries. Because much of the cost is in building systems, processes and infrastructure up front, the marginal cost of continuing the interventions out from 2030–50 is much lower, at $3.6 billion per year and $2.6 per capita per year across the adolescent population.

The resulting BCRs are summarised in Table 6. Out to 2030, the overall BCR at a 3% discount rate is 7.6, and reasonably uniform across country groupings. This rises to 9.9% out to 2050, for the reasons noted above. Even allowing for the uncertainty surrounding the estimates, these are strong BCRs by any standards.

Table 6

Road deaths interventions benefit-cost ratios (BCRs) to 2030 and 2050, 75 developing countries

	Economic		**Economic plus social**	
Income level	**Deaths**	**Deaths plus serious injuries**	**Deaths**	**Deaths plus serious injuries**
BCR to 2030				
Low	1.4	3.3	3.5	6.9
Lower middle	2.3	5.8	3.6	8.1
Upper middle	2.5	7.0	2.9	7.8
Total	2.0	5.0	3.5	7.6
BCR to 2050				
Low	1.8	4.2	4.5	8.8
Lower middle	3.0	7.5	4.7	10.5
Upper middle	3.4	9.7	4.0	10.9
Total	2.6	6.5	4.5	9.9

Note: Countries in the income levels are listed in Appendix 1.
Source: Author estimates.

Discussion

Deaths and injuries from road traffic accidents are a major issue for developing countries, inflicting widespread economic and social harm. They can and should be addressed, by local adaptation of policies that have been relatively well developed in advanced countries. This study shows that implementing such policies would be a very good economic and social investment, with BCRs at a 3% discount rate ranging from about 7 to 11. Nor are the costs of the investments necessary to avoid three million deaths and serious injuries over 2016-30 prohibitive. They are estimated at $1.2 per capita per annum across the whole population of the 75 countries, or $4.6 per capita per annum across the adolescent population. The benefits that have been realised by effective road safety policies in most developed countries are massive. It is urgent that these be replicated in developing countries.

There are several variations here on the methods used and the results presented in Sheehan et al. [10], notably the increase in the population covered from 10–19 years to 10–24 years, and the use of a new approach to serious injuries based on the GBD 2016. Both of these work to increase the BCRs obtained from the analysis, which are about 30% higher in this study than those obtained in the previous one. The incidence of road accidents among young people rises with age, so that the inclusion of persons aged 20–24 years generates a higher return to a given set of policies, and the new measure of injuries shows a much higher serious injuries/deaths ratio than that used in Sheehan et al. [10]. The present study uses a more extensive analysis of the literature, especially for developing countries, than provided in that earlier study.

Finally, it is important to emphasise that this is a preliminary investment analysis. While we use the best data available, there remain major limitations in many aspects of that data, especially in terms of the measurement of effectiveness and in the estimation of costs. A continuing, country-specific, research program is needed to build a sounder basis for policy in developing countries, and to assist policy makers to develop effective road safety programs that fit with the social and cultural contexts of individual countries. This paper shows that the returns to developing and implementing such programs would be high.

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APPENDIX 1: Country lists

75 COUNTRIES DEVELOPING (FORMERLY COUNTDOWN COUNTRIES)		
Afghanistan	Ghana	Pakistan
Angola	Guatemala	Papua New Guinea
Azerbaijan	Guinea	Peru
Bangladesh	Guinea-Bissau	Philippines
Benin	Haiti	Rwanda
Bolivia	India	Sao Tome and Principe
Botswana	Indonesia	Senegal
Brazil	Iraq	Sierra Leone
Burkina Faso	Kenya	Solomon Islands
Burundi	Kyrgyzstan	Somalia
Cambodia	Laos	South Africa
Cameroon	Lesotho	South Sudan
Central African Republic	Liberia	Sudan
Chad	Madagascar	Swaziland
China	Malawi	Tajikistan
Comoros	Mali	Tanzania
Congo	Mauritania	The Gambia
Cote d'Ivoire	Mexico	Togo
Democratic Republic of the Congo	Morocco	Turkmenistan
Djibouti	Mozambique	Uganda
Egypt	Myanmar	Uzbekistan
Equatorial Guinea	Nepal	Vietnam
Eritrea	Niger	Yemen
Ethiopia	Nigeria	Zambia
Gabon	North Korea	Zimbabwe

10 BEST PRACTICE COUNTRIES	
United Kingdom	Denmark
Sweden	Switzerland
Israel	Spain
Maldives	Iceland
Norway	Netherlands

HIGH INCOME (78 COUNTRIES)		
Andorra	Gibraltar	Oman
Antigua and Barbuda	Greece	Palau
Aruba	Greenland	Poland
Australia	Guam	Portugal
Austria	Hong Kong SAR, China	Puerto Rico
Bahamas, The	Hungary	Qatar
Bahrain	Iceland	San Marino
Barbados	Ireland	Saudi Arabia
Belgium	Isle of Man	Seychelles
Bermuda	Israel	Singapore
British Virgin Islands	Italy	Saint Maarten (Dutch part)
Brunei Darussalam	Japan	Slovak Republic
Canada	Korea, Rep.	Slovenia
Cayman Islands	Kuwait	Spain
Channel Islands	Latvia	St. Kitts and Nevis
Chile	Liechtenstein	St. Martin (French part)
Curaçao	Lithuania	Sweden
Cyprus	Luxembourg	Switzerland
Czech Republic	Macao SAR, China	Taiwan, China
Denmark	Malta	Trinidad and Tobago
Estonia	Monaco	Turks and Caicos Islands
Faroe Islands	Netherlands	United Arab Emirates
Finland	New Caledonia	United Kingdom
France	New Zealand	United States
French Polynesia	Northern Mariana Islands	Uruguay
Germany	Norway	Virgin Islands (U.S.)

MIDDLE INCOME (109 COUNTRIES)		
Albania	Ghana	Pakistan
Algeria	Grenada	Panama
American Samoa	Guatemala	Papua New Guinea
Angola	Guyana	Paraguay
Argentina	Honduras	Peru
Armenia	India	Philippines
Azerbaijan	Indonesia	Romania
Bangladesh	Iran, Islamic Rep.	Russian Federation
Belarus	Iraq	Samoa
Belize	Jamaica	São Tomé and Principe
Bhutan	Jordan	Serbia
Bolivia	Kazakhstan	Solomon Islands
Bosnia and Herzegovina	Kenya	South Africa
Botswana	Kiribati	Sri Lanka
Brazil	Kosovo	St. Lucia
Bulgaria	Kyrgyz Republic	St. Vincent and the Grenadines
Cabo Verde	Lao PDR	Sudan
Cambodia	Lebanon	Suriname
Cameroon	Lesotho	Swaziland
China	Libya	Syrian Arab Republic
Colombia	Macedonia, FYR	Tajikistan
Congo, Rep.	Malaysia	Thailand
Costa Rica	Maldives	Timor-Leste
Côte d'Ivoire	Marshall Islands	Tonga
Croatia	Mauritania	Tunisia
Cuba	Mauritius	Turkey
Djibouti	Mexico	Turkmenistan
Dominica	Micronesia, Fed. Sts.	Tuvalu
Dominican Republic	Moldova	Ukraine
Ecuador	Mongolia	Uzbekistan
Egypt, Arab Rep.	Montenegro	Vanuatu
El Salvador	Morocco	Venezuela, RB
Equatorial Guinea	Myanmar	Vietnam
Fiji	Namibia	West Bank and Gaza
Gabon	Nauru	Yemen, Rep.
Georgia	Nicaragua	Zambia

LOW INCOME (31 COUNTRIES)	
Afghanistan	Madagascar
Benin	Malawi
Burkina Faso	Mali
Burundi	Mozambique
Central African Republic	Nepal
Chad	Niger
Comoros	Rwanda
Congo, Dem. Rep.	Senegal
Eritrea	Sierra Leone
Ethiopia	Somalia
Gambia, The	South Sudan
Guinea	Tanzania
Guinea-Bissau	Togo
Haiti	Uganda
Korea, Dem. People's Rep.	Zimbabwe
Liberia	