WebAppendix A Modelling the impact and cost of road safety interventions

1. Epidemiology of road traffic injury

Age- and sex-specific road traffic fatality rates were taken from the Global Burden of Disease study (Table A1)[1-2]. Estimates of the incidence of long-term road traffic injuries were also based on data from this study, which provides total incident episodes of hospitalisable non-fatal injury due to road crashes for each age and sex group in different regions (Table A2).

Table A1 Fatal road traffic injuries per 100,000 population [1]

Region	Sex	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	All ages
AfrE	Male	25.7	26.5	34.2	71.3	75.9	82.6	115	118	42.2
	Female	6.6	8.3	0.4	6.3	2.4	9.4	1.5	6.9	7.3
SearD	Male	4.8	7.3	21.9	43.5	44.1	38.2	63.0	16.3	5.7
	Female	7.6	4.2	5.1	7.3	17.4	17.1	29.6	55.9	8.6

Table A2 Non-fatal hospitalisable road traffic injuries per 100,000 population[1]

Region	Sex	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	All ages
AfrE	Male	186	655	690	1,013	1,237	822	733	828	693
	Female	225	720	294	363	462	383	276	214	422
SearD	Male	259	442	483	479	522	524	650	688	459
	Female	257	552	195	251	343	351	497	553	325

In order to derive the proportion of total hospitalisable injuries having severe, long-term consequences, we selected a 'top 5' sequelae which between them account for 80% of non-fatal road traffic injury burden (fractured skull, intracranial injuries, fractured femur, injured spinal chord and injury to eyes). The proportion of these injury sequelae having a long-term duration ranges from 5% (fractured femur) to 100% (spinal chord injury). We derived an overall relative risk of mortality (RRM) associated with these five leading causes of non-fatal burden, based on the RRMs for the specific sequelae (ranging from 1.0 for injury to eyes, to 7.6 for spinal chord injury) and weighted according to their contribution to overall non-fatal burden. Using this 'top 5' method as the basis for all long-term road traffic injuries, we estimated a seven-fold elevated risk of mortality (Table A3).

Table A3 Long-term non-fatal road traffic injury: mortality risk and disability level

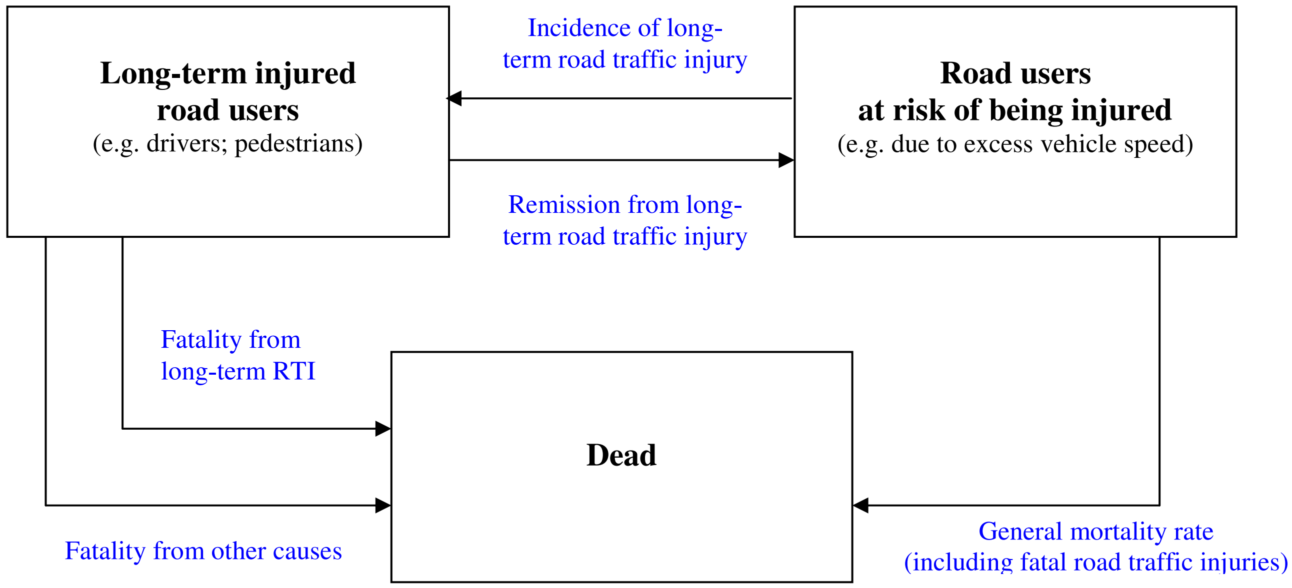
	% of incident episodes with long-term effects[1]	% non-fatal RTI burden [1, 2] *(% long-term burden)* AfrE	SearD	Relative risk of mortality [1]	Disability weight [1]
Fractured skull	15%	*5% (3%)*	*6% (3%)*	3.8	0.419
Intracranial injuries	5%	*15% (4%)*	*19% (4%)*	3.8	0.419
Fractured femur	5%	*22% (5%)*	*20% (5%)*	1.7	0.272
Injured spinal chord	100%	*21% (84%)*	*29% (85%)*	7.6	0.725
Injury to eyes	10%	*14% (4%)*	*9% (3%)*	1.0	0.347
Total		*78% (100%)*	*82% (100%)*		
Weighted average (AfrE)				**6.7**	**0.445**
Weighted average (SearD)				**6.8**	**0.483**

[1] *Source: Global Burden of Disease study (reference 1)*
[2] *Assessed by the metric of Years Lived with Disability (YLD)*

A final epidemiologically-driven input parameter for the population model concerns the health state valuation or disability weight associated with long-term road traffic injuries. Again, we derived a weighted average on the basis of the 'top 5' causes of years lived with disability (YLD) and their respective GBD disability weight on a 0-1 scale where zero denotes no disability; these ranged from 0.27 for fractured femur to 0.72 for spinal chord injury (Table A3). The composite disability weight in the two sub-regions reported here ranged between 0.45-0.48.

The population model for road traffic injury into which the aforementioned rates were fed is shown schematically below (Figure A1).

Figure A1 Population model for estimating health impacts of road safety measures



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WebAppendix B Road safety effect size estimates

Enforcement of speed limits (via mobile speed cameras): Fixed speed cameras were not considered a practical or affordable option in resource-poor settings, so we modeled the potential health impact of a sustained effort by traffic enforcement teams to raise the perceived risk of drivers being caught via the use of mobile/hand-held speed cameras at randomly chosen checkpoint sites. In their meta-analysis of the effect of stationary speed enforcement, Elvik and Vaa[1] report a 14% reduction in fatal crashes (95% confidence interval [CI], 8%-20%) and a 6% reduction in non-fatal crashes (95% CI, 4%-9%); all source studies are from high-income countries (it is quite possible that effect sizes could differ between different road user groups and also between sub-region of world, but we did not find evidence in support of this).

Drink-drive legislation & enforcement (via breath-testing campaigns): Many countries have passed laws that ban driving a vehicle over a certain blood alcohol concentration (BAC) limit, and this has an independent effect on some drivers' decision to drive after drinking alcohol. For greater effectiveness, however, a sustained programme of enforcement is required, together with mass media campaigns highlighting the dangers of driving under the influence and the penalties associated with breaking drink-driving laws. Here, we model the composite effect of *per se* drink-driving laws and its enforcement via random breath-testing of drivers at roadside checkpoints. Drink-driving laws are estimated to reduce traffic fatalities by 7% if widely implemented within a region[2], while enforcement via random breath testing (RBT) is estimated to reduce fatalities by a further 18% when fully implemented [2, 3]; the impact on non-fatal injuries was estimated to be a smaller reduction of 15%, based on earlier analysis of alcohol-attributable fractions for road traffic injury [4, 5]. Again, such effect sizes are based exclusively on studies from high-income countries.

Legislation & enforcement of seat belt use in cars (drivers and passengers): We modeled the impact of introducing compulsory belt use in both the driver and passenger seats of light vehicles. Based on a meta-analysis of high-income country studies[1], the average effect of legislation that makes use of seatbelts mandatory in light vehicles is a 11% reduction in fatal injuries (95% CI, 9%-11%) and an 18% reduction in serious injuries (95% CI; 18%-19%); depending on the increased rate of seatbelt usage (which in turn will depend on local levels of primary and secondary enforcement), lower and higher effects are also predicted, ranging from 7% for an increase of less than 25%, to 21% for an increase of more than 50%. A separate systematic review of safety belt laws by Dinh-Zarr et al[6] revealed a median reduction of 9% for fatal injuries (inter-quartile range [IQR], 2%-18%) and just 2% for (all, not just serious) non-fatal injuries (IQR, +11% to -15%). Finally, Rivara et al [7] undertook a review of the impact of primary and secondary enforcement seat belt laws in comparison with no such laws, and found an 8% reduction in fatal injuries (range 3%-14%) and a 14% reduction in (all) non-fatal injuries (range 12%-23%). Here, we employ the effect sizes from Elvik and Vaa [1] because these provide an average estimate for the different possible impacts of legislation (which depend on increased seatbelt usage and enforcement) and relate most closely to the non-fatal outcomes of interest in this model (long-term, serious injuries).

Legislation & enforcement of helmet use by motor-cyclists (all riders): Riders of mopeds and motorcycles have a greatly elevated risk of road traffic injury, particularly head injuries. Head injuries are classified as admissions to hospital with head wounds, skull or facial fracture, concussion, or other intracranial injury. Motorcycle helmets provide a significant level of protection against such injuries. We model the impact of the mandatory use of motorcycle helmets among this road user group. The Cochrane review by Liu et al[8] estimates that wearing motorcycle helmets is associated with a 36% reduction in fatal injuries (unadjusted odds ratio [OR] from15 studies; 95% CI 0.52-0.80), which is close to the effect size reported from three controlled studies. Based on five controlled studies, the same review also established that wearing motorcycle helmets reduces non-fatal head injuries by 72% (OR = 0.28). This latter effect size was applied to the proportion of all motorcyclist non-fatal long-term injuries that are related to the head (up to 40% in sub-regions where rates of helmet use are low).

Legislation & enforcement of helmet use by bicyclists: Bicyclists face a considerable risk of injury if involved in a road crash. Again, head and face injuries represent a large proportion of the total injuries incurred. We model the impact of the mandatory use of bicycle helmets among children aged 15 years or less. The Cochrane review by Thompson et al [9] found no randomized controlled trials but, on the basis of four case control studies, concluded that helmets produce a 69% reduction in (non-fatal) head injuries (OR 0.31, 95% CI 0.26-0.37); one of these studies focused on severe brain injury (OR 0.26). A separate international review of studies spanning the period 1987-1998 found a slightly lower effect on head injuries - an OR of 0.40 rather than 0.31[10]. Such effects are applied to an estimated 25-40% of bicyclist non-fatal long-term injuries that are related to the head [11, 12]. Concerning the protective effect of bicycle helmets on fatal injury, Attewell [10] derived an odds ratio of 0.27 (95% CI, 0.10-0.71). Subsequent ecological time-series analyses have cast doubt on the magnitude of the implied reduction in head-related bicyclist injuries at the population level [11]. To reflect this disparity in the evidence base, we first employed the effect sizes reported by Attewell [10], and then subsequently assessed via sensitivity analysis the potential impact and cost-effectiveness implied by much lower effect sizes (50% and 25% of these baseline values).

WebAppendix B references:

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WebAppendix C Resource input and price estimates

Resource inputs

Legislation and programme management: All interventions require the passage of legislation in the 'start-up' period of implementation, and are also expected to need substantive public health expertise input. Day-to-day implementation of traffic enforcement is modeled to occur at the provincial level (see below), but all interventions are assumed to require basic programme management and evaluation inputs, not only at central and provincial levels of government, but also at district level. Table C1 below summarises these activities by intervention.

Media: All selected interventions involve a degree of media outreach (a relatively simple communication strategy was modeled for seatbelts and helmets, and a more intense strategy for speeding and alcohol-related measures on account of the more complex set of messages that need to be transmitted to the population). For interventions requiring moderate outreach, we estimate 5 TV emissions, 5 radio emissions and 2 newspaper advertisements/articles per week, both at national and provincial levels; for minimal outreach the numbers are halved. In addition, and for all media outreach levels, we include 1 wall-poster per 10,000 population.

Enforcement: All interventions require efforts to enforce road safety laws. The administrative level at which enforcement activities are modeled to occur is the province (reference population, 5 million). We employed the assumptions reported below to estimate the number of roadside checkpoints, together with associated officer time, vehicles and equipment. Speed checkpoints and roadside breath-testing are expected to require more enforcement officers and vehicles than other interventions. Checkpoints are modeled to last for 4 hours, with additional time for set-up and dismantlement. Officers are assumed to pull over an average of 4 vehicles per hour (e.g. for a team of 3, that would equate to 1 vehicle every 5 minutes). The total number of checkpoints required is dependent both on the target percentage of vehicles pulled over each year - taken to be 10% for all interventions except bicycle helmet enforcement (5%) - and on the underlying motorization rate for cars, motorcycles and bicycles; these were calculated for each WHO sub-region on the basis of country-level data taken from *World Road Statistics* [1].

Table C1 Traffic law enforcement resource inputs and assumptions

	Speed cameras	Breath-testing (alcohol)	Seat belts	Motorcycle helmets	Bicycle helmets
% vehicles pulled over per annum	10%	10%	10%	10%	5%
Vehicles processed per officer per hour	4	4	4	4	4
Officers per checkpoint	3	3	2	2	2
Duration of checkpoint (hours)	4	4	4	4	2
Set-up / dismantle / paperwork time (hours)	2	2	2	2	1
Vehicles used per checkpoint	2	2	1	1	0
Traffic cones used per checkpoint (sets of 10	2	2	2	2	0
Breathalyser kits used per checkpoint	0	1	0	0	0
Speed cameras used per checkpoint	1	0	0	0	0

The most sensitive resource input parameter concerning enforcement relates to the proportion of vehicles that need to be pulled over each year in order to derive the effective coverage of these interventions at the population-level. Since the impact of these traffic laws and their enforcement depends on changes in the *perceived* risk of being caught, the analytical challenge is to establish what (relatively small) proportion of vehicles actually needs to be pulled over in order to obtain the (relatively large) effective coverage/saturation of these road safety measures in the target population. We base our pull-over rate of 10% on the recommendation of the European Transport Safety Council [2], noting the findings of their research which shows a rapidly increasing proportion of drivers who think they will get stopped on a typical journey as the pull-over rate rises above 1 in 16 drivers. The impact on baseline results of double and half this pull-over rate (5%, 20%) were also explored.

Resource costs and prices

Unit costs or prices for almost all of resource inputs described above have been estimated for the 14 WHO sub-regions as part of the WHO-CHOICE project, based on a series of regression analyses that makes use of a large international database of observed values for these various resource items to predict prices in different countries and sub-regions[3]. All prices reported here are for the year 2005. Specific values by WHO sub-region are available from the WHO-CHOICE website at www.who.int/choice/costs. Prices for road safety devices that are not available from the above source include the following: traffic cones, breathalyser kits, mobile/hand-held speed cameras, seat-belts and motor/bicycle helmets (Table C1).

Table C1 Cost of road safety devices

Device	Description / Source	Useful life *(years)*	Price *(US$, 2005)*
Traffic cone	*Wenzhou Jinniu Alarm Device Co.Ltd*	5	$3-5
Breathalyser	*Intoxilyzer S-D2; CMI Inc.*	3	$ 400
Speed camera	*Handheld Radar Gun; Optics Planet*	3	$ 575
Seat belt	*3-point non-retractable; Wesco Performance*	10	$ 20-30
Motorcycle helmet	*Hard shell helmet; Bishai & Hyder*[4]	5	$ 20-40
Bicycle helmet	*Hard shell helmet; Bishai & Hyder*[4]	5	$ 20

WebAppendix C references

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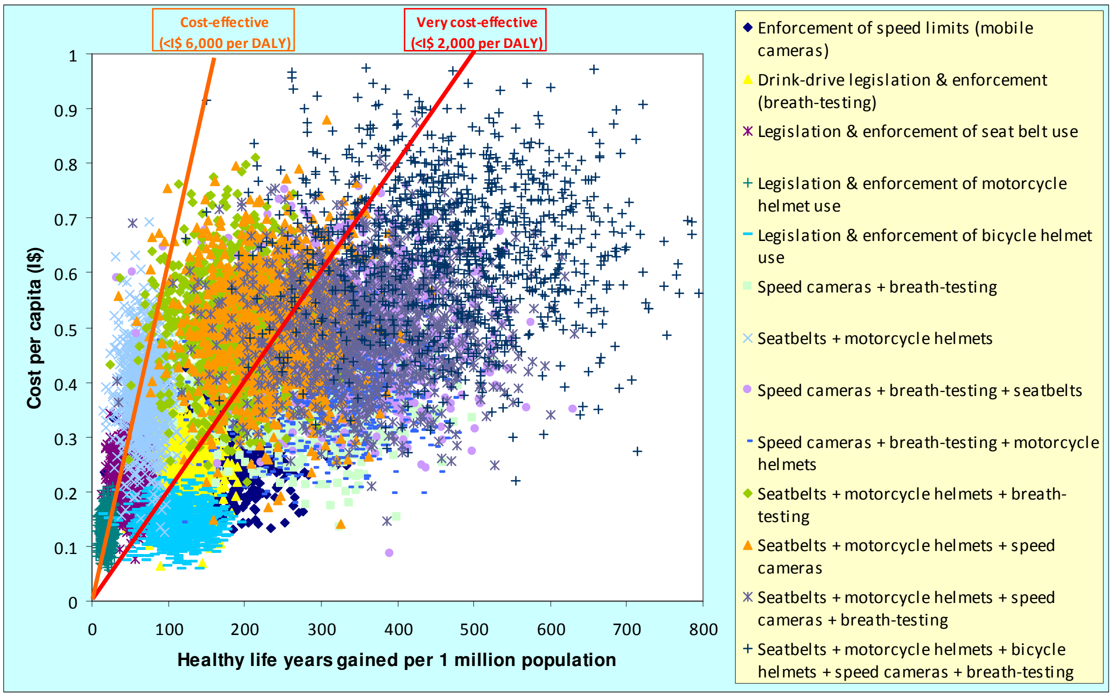
WebAppendix D Results of probabilistic uncertainty analysis

Probabilistic uncertainty graph - AfrE



Probabilistic uncertainty graph - SearD