Public Health Burden of Road Traffic Injuries

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ABSTRACT

Road transportation systems affect human health through complex pathways. Governments invest in road infrastructure because it encourages economic growth, which has direct and indirect benefits to health. However, an excessive reliance on motor vehicles harms population health and social wellbeing due to road traffic injuries, air pollution and reduced physical activity, among other effects. In this chapter, we start by reviewing the mechanisms through which road transport impacts population health. Next, we review the magnitude of the health loss due to injuries and vehicular pollution relative to other diseases in regions at different levels of economic development. We show that the health impacts of motorized road transport rank among the leading causes of health loss in all regions of the world. Finally, we describe how researchers construct estimates of the burden of road traffic injuries in information-poor settings.

Key Words: Injury Metrics; Burden of Disease; Public Health

3.1 HEALTH IMPACTS OF ROAD TRANSPORTATION SYSTEMS

The development of road transportation systems affects the health and well-being of society through multiple pathways. While some of these impacts are positive and are the intended
consequences of economic development processes, others harm human health through a variety of direct and indirect mechanisms (Figure 3.1).

3.1.1 Why do countries build roads?

National development agencies invest substantial resources in building and maintaining road infrastructure. Improving the mobility of people and goods is seen as a key strategy for driving economic growth and improving the health and well-being of people (World Bank 2008). The development of road networks stimulates economic development by connecting centers of industries and markets, spurring the growth of trade, and reducing costs by improving access to goods and services (Kessides et al 2010). For instance, the Golden Quadrilateral in India is a large-scale highway construction project that began in 2001. It is the fifth-longest highway in the world, that aims to improve the connection of four major cities (Delhi, Mumbai, Chennai, and Kolkata) in the country. Studies of the developmental impacts of this project suggest that it has improved the efficiency of the organized manufacturing sector, and has made medium-sized cities more attractive for manufacturing activities (Ghani and Goswami 2013).

By encouraging economic development, roads indirectly improve the health and well-being of populations. Economic development leads to higher employment and raises wages, giving individuals the opportunity to improve their nutrition and their ability to pay for health services. Rural roads have been shown to increase the enrollment of girls in school (World Bank 2008). The education of girls is an end in itself but it is also important to population health because it reduces fertility rates and improves maternal and child health, in addition to other population health benefits (Gakidou et al 2010). In addition to these indirect benefits, improving roads can also directly improve health by improving access to health facilities, and food markets (World Bank 2008).

It is partly for these reasons that motorized road transport has grown briskly in recent decades, especially in regions with the most rapidly growing economies. Since the mid-1990s,
China has built a highway system that is expected to surpass that of the United States in the near future (Yan 2011). The aforementioned Golden Quadrilateral project in India is part of a broader effort to improve highway infrastructure and encourage industrial growth (Ghani and Goswami 2013). Most people in sub-Saharan Africa do not have access to all-weather roads. However, international development agencies see the development of highway infrastructure as a key solution to reducing poverty in the region (World Bank 2008; Union 2005).

The belief that growth in road transportation is an essential driver for social development is firmly entrenched in developmental economics. However, several philosophers and social thinkers have questioned the basis of many of the assumptions that underlie the faith in motorization. Notably, Ivan Illich has argued that the modern transportation industry has severely restricted our freedoms by altering mobility to a system of industrially defined routes, driving wedges between neighbors, and pushing people away from their families and friends (Illich 1974). Appleyard studied what happens to social ties in communities when traffic volumes increase on residential streets (Appleyard et al 1982). He showed that when traffic is light, people have many social connections and an active street life. Heavy traffic frays these bonds; residents withdraw to their houses, and children have fewer friends. Knoflacher has assessed the trips and travel times of societies at vastly different levels of economic development and has shown that motorization does not bring additional mobility (i.e. trips per person per day) and no freedom in choice of transport modes (Knoflacher 2007). These arguments, if taken seriously, could have large implications on how we design transportation systems.

3.1.2 How does road transport harm health?

Although the aforementioned critique of motorization-centered economic growth has been largely ignored in current development practice, researchers and policy makers recognize the burden of many “externalities” produced by transportation systems. In economics, an “externality” is the unintended consequence of an action to a third party. In the case of road transport, these include road traffic crashes, air pollution, noise pollution, light pollution, community severance, and congestion (Figure 3.1). Many of these externalities have direct health impacts, causing diseases and injuries. Others have indirect health effects through their impact on quality of life and well-being.

As motor vehicles have proliferated over the last century, road traffic crashes have grown to be amongst the leading causes of death in most countries globally (Lozano et al 2012). Managing road safety has proven difficult in the high-speed and high-energy road networks that characterize modern industrialized societies. In the 1970s, OECD countries began to recognize the need to improve safety, and invested substantially in improving safety in their transportation system. These efforts included establishing national safety agencies, strengthening legislation, enforcing traffic laws, redesigning highway infrastructure and vehicles to be safer, and educating drivers (WHO 2004). These efforts have led to a reduction in road traffic death rates in OECD countries since their peak a few decades ago. However, road traffic death rates remain a leading cause of death for children and young adults even in the countries that have made the most progress in road safety. In the Sweden, UK, and the Netherlands, which are widely acknowledged as the best performing countries (Koornstra et al 2002), road traffic injuries rank in the top five causes of death for people aged between 1 and 45 years (Lozano et al 2012).

Motor vehicles are a leading contributor to air pollution, carrying significant risks to human health (HEI 2013). Car and truck emissions include particulate matter, hydrocarbons, nitrogen oxides, carbon monoxide, sulfur dioxide, and other toxins. Fine particulate matter can penetrate deep into human lungs and poses the most serious health risk. Hydrocarbons combine with nitrogen oxides to form ground level ozone, irritating the human respiratory system and reducing lung capacity. Sulfur dioxide, which is a key product from the burning of sulfur containing diesel, forms fine particles harming the health of young children and those with asthma. In addition to emissions produced during operation, motor vehicles are significant sources of pollution during...
their manufacture, disposal, and in building and maintaining the supporting infrastructure (roads and refueling systems).

As societies have motorized, people have begun to walk less. This reduction in physical activity is an important contributor to increasing obesity and a wide range of non-communicable diseases that are associated with sedentary life styles. For instance, in the US, obesity has increased steadily since the 1980s in all states and among all age, sex, and socio-economic groups (Mokdad 1999). Researchers have shown that about one-third of all deaths in the US due to coronary heart disease, colon cancer, and diabetes are due to sedentary lifestyles (Powell and Blair 1994). People lead less active lives today because our choice of transport modes (walking, bicycling, or using motor vehicles) is determined by our built environment and the type of transport network (Ewing and Cervero 2010).

These issues — traffic injuries, vehicular emissions, and physical activity — are interlinked. Transportation policies and interventions designed to address one of these often affect the others. The science of understanding these inter-relationships is in its infancy at present. As an example of the findings of such work, early research suggests that the health benefits of cycling (increased physical activity, lower ambient air pollution) outweigh the injury risks (De Hartog et al 2010; Rojas-Rueda et al 2011; Woodcock et al 2009). As a result, it has been argued that it is important to promote cycling even if it results in an increase in injuries from bicycle crashes (Roberts 2013). Simultaneously, research shows that people tend not to walk and bike if they perceive these activities to be unsafe (Delinger and Stanton 2002). This suggests that safety is a pre-requisite for encouraging active transport in communities.

Urban planners, public health practitioners, transport planners and civil engineers are increasingly coming together to address these issues in a common framework of sustainable transport that aims to promote active transport (including walking and biking) while simultaneously reducing private motor vehicles. Supporting policies are being promoted by a large number of international developmental agencies, including the United Nations (UN 2011), the Intergovernmental Panel on Climate Change (Kahn Ribeiro et al 2007), and the multi-lateral development banks (RIO 2013). Reversing the growth of private motor vehicles and encouraging active travel is critical to ensuring that we leave the next generation with a livable planet.

### 3.2 MAGNITUDE OF THE PUBLIC HEALTH BURDEN OF ROAD TRAFFIC

The previous section described the multiple ways in which transportation policies impact human health. This raises several questions: How much do these negative health impacts matter? Do we need to worry about them? How do these harms compare with other threats to our health and well-being? Answering these questions is essential for deciding where to focus policy attention, providing balanced investments in solutions, monitoring progress of health and safety programs, and informing public debates about social priorities. However, addressing these questions requires a non-trivial analysis that requires addressing several theoretical and practical issues.

The most important theoretical issue in comparing the public health burden of multiple diseases is that it requires assessing the mortality and non-fatal health outcomes for population in varying age groups. It is common for researchers to describe the magnitude of a health problem by reporting the number of deaths. This has two problems. The first issue is that eventually everybody dies, making a simple comparison of death counts not meaningful. Consider that lung cancer and road traffic crashes annually kill about the same number of people globally (1.5 vs. 1.3 million people) (Lozano et al 2012). However, while most lung cancer deaths occur late in life, road traffic deaths impact young people, robbing them of many years of life. Thus, a more meaningful comparison is to aggregate the number of years of life lost (YLLs) due to premature mortality, compared to a full life. YLLs are calculated by subtracting the age at death from the
longest possible life expectancy for a person at that age. Road traffic crashes result in almost
twice as many life years lost as lung cancer (62 vs. 32 million YLLs) (Lozano et al 2012).

The more challenging issue is that many health conditions lead to varying levels and duration
of disability, making it impossible to compare their health burden based solely on mortality.
Consider, that a condition like low back pain is not usually considered a cause of death but is
the source of substantial disability. How do we compare the public health burden of low back
pain with conditions that kill? This requires the use of a summary measure of population health
that measures the health of a population by combining data on mortality and non-fatal health
outcomes into a single metric. Population health researchers have proposed several such metrics,
including the Disability-Adjusted Life Year (DALY), Quality-Adjusted Life Years, Disability-
Adjusted Life Expectancy (DALE), and the Health Life Year (Healy) (Gold et al 2002). Among
these, the DALY is the most widely used measure in burden of disease studies. DALYs measure
the health gap between the current health status of a population and an ideal where everybody
lives a full life in perfect health. DALYs aggregate two components: years of life lost (i.e. YLLs as
described above), and years lived with disability (YLD), which is the product of the number of
disability cases, the average duration of the disability, and a weight factor reflecting the severity
of the condition on a scale of 0 (perfect health) to 1 (death). These disability weights reflect social
preferences for different health states and are empirically determined through large population
surveys (Salomon et al 2012).

3.2.1 About the Global Burden of Disease (GBD) Project

The Global Burden of Disease Project (GBD) is a study that tracks the public health burden
of all diseases in all countries. GBD was originally commissioned in 1991 by the World Bank to
develop a comprehensive and comparable assessment of the burden of 107 diseases and injuries
and 10 selected risk factors for the world and eight major regions. The findings represented a
major improvement in global knowledge of population health metrics and proved to be influential
in shaping the global health priorities of international health and development agencies. The
study also stimulated numerous national burden of disease analyses that have informed debates
on health policy over the last two decades.

The 2010 revision of the project (GBD-2010) is the most recent iteration of the study, and
is a comprehensive update of the original study and presents estimates for 291 diseases and
injuries, 67 risk factors, and 1,160 sequelae (non-fatal health consequences) disaggregated by
sex and 20 age groups, for 21 regions covering the entire globe. The study is a collaboration of
hundreds of researchers around the world, led by the Institute for Health Metrics and Evalua-
tion at the University of Washington and a consortium of several other institutions including:
Harvard University, Imperial College London, Johns Hopkins University, University of Queens-
land, University of Tokyo, and the World Health Organization.

As part of GBD-2010, a concerted effort was undertaken to improve the estimates of the
public health burden of road injuries. A substantial project-wide effort was made to incorporate
data from vital registration and sample registration systems, as well as demographic surveillance
systems, among many others. This broad search was coupled with a targeted effort to improve
data on road injuries from the most information-poor settings. As a result, a wealth of data from
regions such as sub-Saharan Africa was used for the first time in epidemiological research. Key
data sources for injuries included:

- Vital registration statistics: These are tabulations from national vital registration systems,
  which usually record the causes of death listed on death certificates.
- Verbal autopsies: These are causes of death determined by a trained interviewer using a
  structured questionnaire that collects information about symptoms preceding death. Such
  surveillance is commonly done in regions that do not have reliable vital registration systems.
Mortuary/burial registers: Medico-legal records from mortuaries and burial permit offices were another important source of data for information-poor regions.

Household surveys: These were a critical source for estimating the incidence of non-fatal injuries.

Hospital databases: Large hospital registries were used as a valuable source of information about the sequelae resulting from injuries.

Prospective studies of disability outcomes: The results from follow-up studies of patients after an injury were used to estimate the duration of disability and the probability of its performance.

These data sources are discussed in more detail in the next section. Prior to their analysis in GBD-2010, these data were subjected to a systematic harmonization and data cleaning. This includes adjusting for completeness of mortality data sources, mapping across different coding schemes, and reattribution of poorly specified causes. Mortality from road crashes was estimated in 40 age-sex groups for all countries from 1980 to 2010 using Cause of Death Ensemble Modeling (CODEm), which involves developing a large range of plausible statistical models between the cause and known covariates, testing all possible permutations of covariates, and generating ensembles of the component models (Foreman et al 2012). The performance of all component models and ensembles is evaluated based on their out-of-sample predictive validity and the best-performing model or ensemble is chosen. The burden of non-fatal outcomes of injuries was estimated by first constructing estimates of the incidence of the external causes of injuries using household survey data, hospital data, and the injury mortality estimates. Hospital databases were used to estimate the incidence of health outcomes (e.g., fractures, dislocations, etc.) that result from road injuries. Long-term disabilities were estimated from these health outcomes using data collected from studies that have followed patients after they sustained a road injury. Finally, YLDs were computed by applying disability weights. These methods rely on many assumptions and will likely undergo substantial refinements in the years to come. However, they are the only known attempt at large-scale coupling of empirical data to construct global estimates of the burden of non-fatal road injuries.

3.2.2 Estimates of the Global Burden of Disease

Results from GBD-2010 show a world undergoing a rapid transition in population health, away from mostly infectious disease in children to non-communicable disease (NCDs) and injuries that affect adults. Over the last two decades, life expectancies have increased across most of the world, the burden of HIV and malaria has fallen, and fewer children younger than 5 years are dying. However, the results also reveal huge health gaps in different regions of the world.

Figures 3.2 and 3.3 illustrate the cause-of-death profiles of different regions of the world highlighting the dramatically different health needs of regions. In sub-Saharan Africa, which is the least developed of the regions shown, the mortality profile is dominated by infectious and neonatal diseases comprising about two-thirds (66.5%) of all deaths; and accounting for nine of the top-10 causes of death. NCDs comprise about one-fourth (24.9%), and injuries account for the remainder (8.6%). By comparison, in India infectious and childhood disease comprise a smaller proportion (35.0%) of all deaths, NCDs comprise a larger proportion (53.5%), and injuries comprise the remainder (11.5%).

China has a mortality profile that is remarkably similar to that of high-income countries despite having a much lower income. This is primarily because of China’s success in managing infectious and childhood diseases. These account for only 5.9% of deaths in both China and high-income countries (Figure 3.1). In sharp contrast with Africa, NCDs and injuries account for nine of the top-10 causes of death in China.
Road injuries are a leading cause of death in all four regions (Figure 3.3) but the importance of road traffic deaths varies relative to other causes in regions at different stages of development. Although the per-capita ownership of motor vehicles steadily increases in regions with economic development, the proportion of deaths that are due to road crashes has a more complex relationship. Road injuries comprise the same proportion of all deaths (2.8%) in Sub-Saharan Africa and India, and have a similar cause-of-death rank (10 and 9, respectively). The proportion of road deaths is substantially higher in China (3.4%), and they are the fourth leading cause of death. However, the proportion of road deaths is substantially lower (1.2%) in high-income countries (8th leading cause of death). This is a result of the trend in road traffic crashes and the trend in other diseases in these countries. These results suggest that as the economies of low- and middle-income countries have grown, they have made substantial progress in reducing infectious
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<table>
<thead>
<tr>
<th>Rank &amp; Cause</th>
<th>Global burden of disease</th>
<th>Burden attributable to motorized road transport</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deaths</td>
<td>DALYs</td>
</tr>
<tr>
<td>1</td>
<td>Ischemic heart disease</td>
<td>7,029,270</td>
</tr>
<tr>
<td>2</td>
<td>Stroke</td>
<td>5,874,181</td>
</tr>
<tr>
<td>3</td>
<td>COPD</td>
<td>2,899,941</td>
</tr>
<tr>
<td>4</td>
<td>Lower respiratory infections</td>
<td>2,814,379</td>
</tr>
<tr>
<td>5</td>
<td>Lung cancer</td>
<td>1,527,102</td>
</tr>
<tr>
<td>6</td>
<td>HIV/AIDS</td>
<td>1,465,369</td>
</tr>
<tr>
<td>7</td>
<td>Diarrheal diseases</td>
<td>1,445,798</td>
</tr>
<tr>
<td>8</td>
<td>Road injury</td>
<td>1,328,536</td>
</tr>
<tr>
<td>9</td>
<td>Diabetes mellitus</td>
<td>1,281,345</td>
</tr>
<tr>
<td>10</td>
<td>Tuberculosis</td>
<td>1,195,990</td>
</tr>
<tr>
<td>All other causes</td>
<td>24,207,527</td>
<td>1,682,995,639</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52,769,676</strong></td>
<td><strong>2,482,258,070</strong></td>
</tr>
</tbody>
</table>

Note: In the “burden attributable to motorized road transport” column, emissions from road transport contribute to deaths and DALYs from ischemic heart disease, stroke, COPD, lower respiratory infections, and lung cancer. Road transport crashes contribute to deaths and DALYs from road injury. Source: Transport for Health Report (Bhalla et al 2014).

Infectious, childhood, and maternal diseases. However, progress in managing road safety has been much more difficult except in high-income countries which have expended substantial efforts to address safety issues (Koornstra et al 2002).

Table 3.1 illustrates the leading causes of death worldwide, associated DALYs, and the amount of these deaths and DALYs that can be attributed to vehicular air pollution and motor vehicle crashes. Injuries and air pollution generated by motorized road transport were associated
with six of the top 10 causes of death and five of the top 10 causes of DALYs in 2010. In fact, the top three causes of death, premature mortality (YLLs), and overall health loss (DALYs) are diseases that are linked to air pollution, which is closely associated with motorized road transport. Overall, injuries and air pollution from road transport caused 1.5 million deaths globally, representing 2.9% of deaths from all causes. Together, they were the sixth-leading cause of death in 2010, with a death toll exceeding that from HIV/AIDS, tuberculosis, malaria, and diabetes. They were responsible for 79.6 million healthy life years lost, or DALYs, which is 3.2% of the total global burden of disease and injuries.

Injuries resulting from road crashes account for 95% of the combined burden of ill health (pollution and injuries) from motorized road transport. Road injuries killed 1.33 million people globally in 2010 and were the eighth-leading cause of death, accounting for 2.5% of all global deaths. The road injury death toll exceeded that from diseases such as tuberculosis and malaria which receive substantial attention in the global health research and development community. They were the 10th-leading cause of healthy life years lost (DALYs), contributing 3.0% of the total global health burden. They were also the eighth-leading cause of premature mortality. Exposure to pollution from vehicles, in terms of particulate matter pollution derived from vehicular emissions, resulted in 184,000 deaths globally. This includes 91,000 deaths from ischemic heart disease, 59,000 deaths from stroke, and an additional 34,000 deaths due to lower respiratory infections, chronic obstructive pulmonary disease (COPD), and lung cancer combined.

### 3.3 MEASURING THE LOCAL BURDEN OF INJURIES

The final section of this chapter discusses how researchers can estimate the burden of road traffic injuries in a specific population of interest, such as a country, province, or city. We will focus on the most important measurement issues in injury metrics and provide pointers to other resources that have more detailed information.

#### 3.3.1 General approach

The main goal of a burden of road traffic injury analysis is to generate a set of numbers that convey the magnitude of the harm to health caused by crashes. Estimates from such an analysis are almost always viewed in a comparative context. For instance, researchers may be interested in knowing the burden of road traffic injuries relative to other health issues in the country in order to assess whether the issue is being appropriately addressed in local health priorities. Alternatively, they may be interested in comparing the road safety performance of one region with that of other regions in order to learn from other experiences. Thus comparability (across diseases or across regions) is critically important to burden of disease analysis. This has important implications on the data sources and methods used in estimation.

Consider the issue of underreporting in police statistics. Around the world, the data from traffic police are the most commonly available statistics on the incidence of road traffic crashes. However, most injury researchers are aware that these official government statistics underreport road traffic injuries (Aeron-Thomas 2000; Elvik and Mysen 1999; Bhalla et al 2014). The amount of underreporting varies by injury severity, with comparatively less underreporting of deaths compared with non-fatal injuries. Similarly, we expect underreporting to vary by region based on the surveillance capacity of the local police agency and legal requirements that affect reporting. In most countries, there are relatively few studies that have characterized the quality of police data by cross checking with other data sources. In the absence of such evidence, police data do not provide incidence data that can be compared across countries or across diseases.

Rather than relying solely on police data, an alternate approach is recommended for estimating the burden of road traffic injuries (Bhalla et al 2009). This approach involves analyzing
sources other than police reports, including death registers, hospital records, funeral records, injury surveillance studies, and health surveys, to triangulate to a local snapshot of the incidence of fatal and non-fatal road traffic injuries. The analytical process includes filling information gaps, adjusting for completeness and coverage, and the redistribution and reclassification of cases coded to ill-defined causes. These triangulated estimates should then be compared with police-based figures to test the validity of official government statistics. Once reliable estimates of the incidence of road traffic injuries have been developed, standard burden of disease methods can be applied to convert incident cases into summary measures of population health (YLLs, YLDs, and DALYs). A detailed step-by-step guide to estimating DALYs from incidence data is available in the WHO publication *National Burden of Disease Studies: A Practical Guide* (WHO 2001).

Let us start by defining the key concepts of interest, followed by a discussion about data sources and analytical methods. The information presented below draws substantially from a previous publication (Bhalla et al 2009).

### 3.3.2 Definitions of key concepts

Table 3.2 summarizes a set of definitions related to road traffic injury measurements. These are derived from the Tenth Revision of the International Statistical Classification of Disease and Related Health Problems (ICD-10) (WHO 2004) because it provides a more inclusive definition for what constitutes a “road” particularly as it relates to low- and middle-income countries.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Concept Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What is a “Road Traffic Crash?”</strong></td>
<td>A road traffic crash is an event that produces injury and/or property damage, involves a vehicle in transport, and occurs on a road or while the vehicle is still in motion after running off the road. Note the use of the term “crash” instead of “accident.”</td>
</tr>
<tr>
<td><strong>What is a “Road?”</strong></td>
<td>A road is the entire width between property lines (or other boundary lines) of land open to the public as a matter of right or custom for purposes of moving persons or property from one place to another.</td>
</tr>
<tr>
<td><strong>Types of road user transport mode</strong></td>
<td>Pedestrian, bicycle, motorized two wheeler, motorized three wheeler, car, van (including pickup trucks), truck, bus, others.</td>
</tr>
<tr>
<td><strong>What is a road traffic “fatality?”</strong></td>
<td>Any death for which a road traffic crash is the underlying cause. The “underlying cause” of a death is the disease or injury which initiated the train of events leading directly to death regardless of how long ago the event occurred. Note that there is no time limit between the crash and the death. There is also no restriction on where the death happens (at crash scene, hospital, home, etc.).</td>
</tr>
<tr>
<td><strong>What is a road traffic “injury?”</strong></td>
<td>A road traffic injury is an injury caused in a road traffic crash. “Injury” is the reduction in functional health status due to energy exchanges that have relatively sudden discernable effects.</td>
</tr>
<tr>
<td><strong>Levels of injury severity</strong></td>
<td>Injury severity is defined in terms of the levels of impairment – i.e. reduction in functional health status – e.g. minor/moderate/severe impairments.</td>
</tr>
<tr>
<td><strong>Types of institutional medical care</strong></td>
<td>A hospital admission is a hospital stay exceeding 24 hours. Visits less than 24 hours are referred to as outpatient visits.</td>
</tr>
</tbody>
</table>

Source: Based on Bhalla et al. 2009.
The definition does not restrict a “road” to a path prepared for vehicle use but includes any public path (including, e.g., a path in a rural field) that is customarily used for transport in the community. Similarly, the term “road traffic crashes” encompasses all crashes that occur on the road, regardless of whether they involved motorized or non-motorized vehicles.

The definition of what constitutes a road traffic death based on how soon after the crash the death occurs has been discussed extensively in the literature (WHO 2009). Such time restrictions (death within 1 day, 1 week, 1 month and 1 year) are operational definitions that take into account the practicality of reporting for the agency collecting the data. Conceptually, however, there should not be any time restriction on an underlying cause of death. Furthermore, burden of disease methods rely extensively on estimating mortality based on death registration data, which are usually coded using ICD rules that do not include a time-based restriction on the underlying cause of death. Thus, not adopting a time-based restriction is also operationally easier in such work. Finally, it should be noted that translating between estimates that rely on the various time-restricted definitions is relatively straightforward. The adjustment ratios (WHO 2009) show that only a very small fraction (∼3%) of road injury deaths occur after 30 days from a crash.

In comparison to deaths, non-fatal injury outcomes are more difficult to define and classify. Langley et al propose an energy-based definition for injury – “the damage produced by energy exchanges that have relatively sudden and discernable effects (Langley and Brenner 2004). Defining thresholds for levels of injury severity is conceptually difficult and, as a result, has received substantial attention by injury researchers. The crudest injury classifications are dictated by the operational simplicity of classifying injury severity by hospital admissions and outpatient care. However, especially in comparative work across countries, such a definition is problematic because access to medical care can vary substantially. Instead, a conceptual definition should be based on medical pathology. The Abbreviated Injury Scale (AIS) and its derivative scales are the most commonly used injury severity classifications. However, these existing measures have threat to life as their central focus and do not effectively describe the loss of functional health status that can result from non-fatal injuries. Thus, for instance, an injury requiring an amputation that results in life-long disability, and hence a substantial health burden, can have the same AIS level as an injury with no discernable disability a few days after the event. This is a severe shortcoming of AIS-based injury scales for characterizing the public health burden of non-fatal injuries. There is a growing body of work that focuses on measuring the long-term health impairments due to non-fatal injuries. A recent review paper by Plunder et al. provides an overview of existing knowledge about measurement issues related to measuring the population health burden of non-fatal injuries (Polinder et al 2010).

3.3.3 Triangulating from local data sources

Although injury researchers typically turn to traffic police data for information on the incidence of fatal and non-fatal injuries, as discussed above, police data often underreport injuries. Therefore, injury researchers should start by doing an environmental scan of data sources that can inform epidemiological estimates of injuries in the population of interest. The types of data sources identified vary substantially by region. Table 3.3 illustrates the types of data sources (other than police data) available in four low- and middle-income countries, Iran, India, Mexico, and Ghana. These countries are at varying levels of economic development and have substantially different health surveillance infrastructure and capacity.

Let us first consider methods for estimating the incidence of road traffic deaths. High quality vital registration data are considered the gold standard for population-level cause-of-death analysis. Such data are usually collected by national vital registration systems, which are intended to be comprehensive in terms of population coverage. Such data systems exist in many developing countries although the coverage and completeness of reporting and the quality of cause of death...
TABLE 3.3  Selected data sources for estimating the incidence of deaths and injuries from road traffic crashes in four countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Deaths</th>
<th>Non-fatal injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>National death registration system: covers 29 provinces (i.e. all except Tehran); ICD-10 derivative causes of death.</td>
<td>Hospital data sample: Data collected from all hospitals in 12 provinces (outpatient for 4 days, and hospital admissions for 4 weeks), followed back to household post-discharge.</td>
</tr>
<tr>
<td></td>
<td>National forensic medicine system: estimates available for all provinces.</td>
<td>Demographic and Health Survey (DHS): Approx. 110,000 households, included questions about road traffic injury involvement and care</td>
</tr>
<tr>
<td>India</td>
<td>National Sample Registration System (Hsiao 2013): Nationally representative sample of deaths in India, causes evaluated by verbal autopsy.</td>
<td>World Health Survey (WHS): representative sample with questions about road traffic injuries and care; conducted in six states</td>
</tr>
<tr>
<td></td>
<td>National Medical Certification of Cause of Death (MCCD) System: Cause of death for reporting hospital in urban areas; covers approx. 500,000 deaths from all causes annually.</td>
<td>Survey-New Delhi: 5,412 households, all injury causes (Verma and Tiwari 2004)</td>
</tr>
<tr>
<td>Mexico</td>
<td>National death registration system: ICD-10 coded cause of death, estimated to be near complete.</td>
<td>Survey-Bangalore: 20,000 households, stratified by urban/rural and socio-economic status (Aeron-Thomas et al 2004)</td>
</tr>
<tr>
<td></td>
<td>Demographic Surveillance System (DSS) Sites at Navrongo: verbal autopsy based cause of deaths.</td>
<td>SAEH-Ministry of Health national hospital discharge database: covers all Ministry of Health hospitals, approx. 115,000 unintentional injury hospital admissions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>World Health Survey: representative sample with questions about road traffic injuries and care.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Encuesta nacional de Salud y Nutricion (ENSANUT) national health survey: Sample size 54,068 individuals, included questions on RTI involvement and care.</td>
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<tr>
<td></td>
<td></td>
<td>World Health Survey: representative sample with questions about road traffic injuries and care.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Survey – Kumasi (urban) + Brong Ahafo region (rural): sample of approx. 21,000 individuals (Mock et al 1999).</td>
</tr>
</tbody>
</table>

Source: Based on Bhalla et al 2009.
attribution can vary substantially (Mahapatra et al 2007; Lopez et al 2007). Iran and Mexico have national vital registration systems that have high population coverage and are relatively complete. In the absence of national death registration systems, some countries rely on sample registrations systems, which rely on a representative sample of deaths. In India, for instance, the Sample Registration System (SRS) uses verbal autopsy performed by trained paramedics to track causes of deaths in representative set of urban and rural communities and reports the causes of death (including one category for road traffic injuries) (Hsiao et al 2013). In addition, in urban areas in India, cause of death information is also available from hospitals that report to the national Medical Certification of Cause of Death (MCCD) system. Although the sample of deaths included is not representative, it reports approximately 500,000 deaths annually (an estimated 30% of all urban deaths). Finally, some regions of the world, notably Africa (represented by Ghana in Table 3.3) do not have functional national death registration systems that can provide cause of death statistics. In such cases, community health surveillance projects (such as the INDEPTH network of disease surveillance system sites) may be able to provide useful insight into the patterns of causes of death from which road traffic injury death rates can be estimated (Bhalla et al 2013).

Converting these data sources to incidence estimates requires several analytical adjustments. In analyzing vital registration data, estimates of the true completeness and coverage should be derived by comparing the total number of deaths reported by the registration system with total national deaths, estimates for which are often available from other more reliable sources. Death registration systems often include a large number of deaths coded to poorly specified causes (e.g. unspecified accident, undetermined intent, and unknown cause of death). As a general rule, deaths coded to partially specified causes of death should be reapportioned to fully specified causes using all available information. For detailed examples of how to assess road traffic mortality using death registration data, see our analysis for Iran (Bhalla et al 2008), Mexico (Bartels et al 2010), and Sri Lanka (Bhalla et al 2010).

In many countries (e.g. Ghana in Table 3.3), available mortality data can only provide reliable statistics for sub-national regions, and a process of aggregation and triangulation is necessary to develop a national road traffic injury mortality estimate. For instance, there are no nationally representative sources of information about causes of death in most African countries (Bhalla et al 2013). However, in many countries, urban mortuaries can allow generating estimates of urban injury deaths, and rural Demographic Surveillance Sites can allow estimating road traffic mortality in selected rural settings. Thus, aggregating estimates of urban and rural deaths using data from mortuaries and DSS sites can be used to generate plausible estimates of national road traffic deaths.

Next, let’s consider the sources of information for estimating non-fatal injuries. The two primary sources of data for estimating non-fatal injuries are hospital datasets and health surveys, both of which can be either national or sub-national. As illustrated in Table 3.2, often countries have some combination of both types of datasets. Hospital data and household surveys have complimentary strengths. Household surveys are usually the only population representative source of estimate of incidence of injuries in a region. Surveys can be specific to injuries or be broader national health surveys; Table 3.2 illustrates examples of both. Injury specific surveys typically measure more details about road traffic crashes, but often tend to be at a community level. For our purposes, national surveys, even if they only include fewer questions about injuries, have the advantage of providing direct estimates of the national incidence of non-fatal injuries.

Unlike surveys, hospital datasets are usually poor sources of information for measuring population incidence of injuries for several reasons. It is often difficult to define the catchment-population for individual hospitals. Even when a hospital registry aggregates data from all hospitals in a region, such data only provide information about hospitalizations in the population. However, in low-income settings many severely injured victims may not have access to a hospital. The strength of hospital data is that they provide medical descriptions of injuries making it possible to characterize the disability outcomes and, thus, the public health burden of injuries.

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Therefore and efficient way to couple health surveys and hospital data is to use the surveys to estimates the population incidence of road injuries, and hospital data to estimate the disability consequences of severe injuries.

In summary, the guiding principle of the burden of disease approach is that estimates of population health metrics (such as incidence and prevalence) should be generated after careful analysis and correction for bias of all available data sources. It is important to ensure comparability of estimates with other diseases and/or across regions. Researchers interested in developing estimates should start with the many resources available that provide guidelines and examples of analysis.

**ADDITIONAL RESOURCES**

- **GBD Project website** ([http://www.healthdata.org/gbd](http://www.healthdata.org/gbd)): The website provides description of data sources, methods, and tools for visualizing results of the GBD study.
- **Global Burden of Injuries Project website** ([http://www.globalburdenofinjuries.org](http://www.globalburdenofinjuries.org)): Includes data, methods, and estimates for the incidence of road traffic injuries in 18 countries (Bhalla et al 2011), burden of injuries in sub-Saharan Africa (Bhalla et al 2013), and detailed case studies for several low- and middle-income countries.

**REFERENCES**


