

TRAFFIC SAFETY AND HUMAN BEHAVIOR

SECOND EDITION

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TRAFFIC SAFETY AND HUMAN BEHAVIOR

Second Edition

BY

David Shinar

*Ben Gurion University of the Negev,
Beersheba, Israel*



United Kingdom – North America – Japan
India – Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2007

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British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN: 978-1-78635-222-4 (Print)

ISBN: 978-1-78635-221-7 (Online)

ISBN: 978-1-78714-633-4 (Epub)



Certificate Number 1985
ISO 14001

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INVESTOR IN PEOPLE

To

Naomi and Yuval, who contributed by just being and by giving me a new perspective on life. May all the safety issues raised here be resolved by the time they can read this.

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PREFACE TO THE SECOND EDITION

“Understanding the human side of driving is critical for making large-scale improvements in traffic safety.” (Njord and Steudle, 2015, p. 3).

This second edition came into being as a result of a confluence of three factors: the publisher’s suggestion that it is time for an update, my entry into a new phase of my professional life (emeritus), and my realization that in the past 10 years there has been a most significant expansion in our knowledge about driving and safety. Much of the new research was spurred by changing cultural norms that emphasize sustainability (including sustainable safety), and from gradually evolving perceptions concerning the critical issues of safety and mobility. Let me elaborate here about the last – more substantive – factors: added knowledge, cultural change in our norms, and change in the critical issues of road users’ behavior in the context of traffic safety.

In terms of cumulative knowledge, we have experienced (and are still experiencing) an explosion of interest and empirical research related to the safety of mobility: driving, riding, and walking. Prior to the first edition of this book, I was able to find only 17 books that were directly related to road safety. But in the 10 years since the publication of the first edition in 2007, 28 more books have been added to the list. The books, of course, only reflect the tip of the publications iceberg. There is a much greater increase in dedicated scientific conferences and refereed articles of original research. For example, Google Scholar lists approximately 62,000 articles containing all the words “road,” “safety,” “behavior,” and “driving or riding” published prior to 2007, and over 70,000 in the 9 years since then. Narrowing the search scope to the combination of “traffic safety” and “human behavior” yields approximately 2,300 articles published prior to 2007, and over 3,000 since then. As cynical as one might be about the plethora of new and not-so-significant articles, with such a wealth of information there are bound to be some novel and unexpected findings. And there are. Consequently, each of the book chapters has been supplemented with new findings that either confirm previously drawn conclusions or refute them and merit new thinking.

The cultural shift was a gradual one that started in the last century and gained normative acceptance in this last decade. In the past, traffic crashes – invariably labeled as accidents – and injuries were accepted as part of the cost of mobility. But Sweden’s 1997 policy shift to “Vision Zero” meaning striving toward zero traffic fatalities, was the harbinger of the new norm of zero tolerance for road fatalities. This has been translated to a practical yet aggressive goal for continued reduction traffic fatalities. This goal, common to both national and international institutions is to cut fatalities by 50 percent every 10 years. Commitment to such a demanding goal requires close cooperation among different agencies and careful considerations of the impact of changes in

the traffic system on the behavior of its road users. These implications are discussed in nearly every chapter.

Finally, within the realm of traffic safety and human behavior the specific “hot” issues of concern, and approaches to crash prevention and injury reductions have also changed over the past decade. For example, interest and research in aggressive driving and its contribution to crashes peaked around 2004-2005 while I was writing the first edition of this book. But the interest in distracted driving was nearly nil before 2009 and has been rising fast since then with no signs of abatement as of this writing (based on Google Trends). Distracted driving research – or at least the focus on it – is fueled by the constantly expanding technological communications and advanced driver assistance systems. These are brought into the cars by their manufacturers or by their drivers, and can both aid and impede safety.

Instead of the behavioral crash countermeasures – such as education, public information, and enforcement – that starred in the early part of this century, we are now increasingly looking to technology to solve our problems of speeding, driving while impaired, and distraction. Technological innovations are a rapidly growing part of the arsenal of crash countermeasures and driver assistance systems designed to keep drivers safe in their lanes with safe headways to vehicles and obstacles ahead. But the acceptance, use, and utilization of the new technologies are human behavioral issues that are discussed throughout the book. And as always with people, when their environment changes, it is naïve to assume that “all other things” will stay the same. Behavior will not, and this is illustrated in current research on driver adaptation to new support systems.

Two issues that were hardly addressed in the first edition were bicycling and the emergence of autonomous vehicles; going back to basics (locomotion through pedaling) on the one hand and jumping into the future (commanding the car) on the other hand. Increasing congestion, the desire for environmental sustainability, and renewed interest in health have catapulted bicycling to the fastest growing mode of travel. Bicycling and the interactions of bicyclists with the rest of the traffic – drivers and pedestrians – have spawned many studies that are now discussed in a dedicated chapter on bicycling behavior and safety. A special emphasis in this chapter is how to integrate cyclists into the traffic system while ensuring their safety.

The second new issue is that of the autonomous vehicle. Though autonomous vehicles had been considered nearly a century ago, at the dawn of this century it was still, for most people, a speculative issue worthy of discussion by futurologists. But the vigorous entrance of high-tech companies and automotive manufactures into this arena have made the autonomous vehicle a reality that could change our mobility and life patterns as much as the introduction of the combustion engine changed it a century ago. Contrary to “common sense” the autonomous vehicle does not make driving a non-sequitur. Instead, the expected need of human control and rapid intervention in unforeseen critical situations make this a complex issue as far as human-vehicle interactions

(and distraction) are concerned. This has significant implications for injury reduction and crash prevention, which are discussed in the last chapter.

Two significant research methods have contributed greatly to new knowledge and new conclusions concerning driving behavior and traffic safety: the use of naturalistic driving studies (NDS) and the technique of meta-analysis (MA). NDS is the ultimate ecologically valid study of road user behavior because it tracks road users as they move through traffic in their own vehicles going about their own business. Meta-analysis is a technique that synthesizes the results of multiple studies which have addressed the same issue using similar methods and outcome measures, to provide a robust measure of an effect or a countermeasure. As often happens in empirical research, the application of these methods – in different domains – either confirmed previous tentative less robust conclusions or actually debunked earlier misconceptions. The two techniques are described in Chapter 2, and results from their applications are evident in nearly every chapter of the book. Perhaps the most important finding from NDS, is the most recent conclusion emerging from the largest of its kind ever study of crash causation that demonstrated that even today the human factor is a critical element in over 90 percent of traffic crashes (Dingus *et al.*, 2016). In a way this provides *prima facie* justification for this updated text.

This second edition has the same organization as the previous one, but every chapter has been expanded to include the current relevant issues and the theoretical and empirical research to substantiate them. This edition has over 100 tables and over 200 figures, and cites over 2,500 research papers. Yet even this compendium of approximately 1,200 pages only provides a sample of the studies in this domain. The second edition provides updated research that supports and augments our knowledge of safety-relevant human limitations and capabilities (e.g., in terms of visual perception, and information processing), discusses new research methods and new findings that challenge our previous assumptions and conclusions (e.g., the nature and role of distraction, the risk of drugs, and the safety of older drivers), and discusses new topics that a decade ago did not seem as important (to me at least) as they are today (e.g., bicycling behavior and safety, and in-vehicle driver assistance systems and the autonomous vehicle). For this edition, I have significantly expanded all the chapters of the previous edition and added a chapter on bicycling. Although in the process some of the material of the previous edition was deleted, the new edition is still 50 percent longer than the first edition.

A work of this scope is rarely done without help, and this case was no exception. I would like to thank Tamar Ben-Bassat, John Eberhard, Tsippy Lotan, Ilit Oppenheim, Mike Perel, Edna Schechtman, and my wife Eva Shinar for reading and commenting on the drafts of one or more chapters. They were instrumental in forcing me to clarify some points and in uncovering and helping me correct multiple typographical, syntax, and substantive errors. The ones that remain are obviously mine to own. Finally, I thank the staff of Emerald Publishing, in particular Cristina Irving Turner, Emma Stevenson, Charlotte Hales, Nicki Dennis, and Jen McCall. Their consistent support over the past 3 years made this volume a reality.

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PART A
BACKGROUND, METHODS,
AND MODELS

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INTRODUCTION AND BACKGROUND

“Citizens care about safety. There was a time when we had to force people to be safe, when regulation was the only way. The failed Ford safety campaign of the 1950s is still cited as proof that ‘safety doesn’t sell’, but I’m here to tell you that today safety does sell. We have moved on to market-driven development, with car makers now competing for top safety scores and consumers making real buying decisions based on these scores.” (Claes Tingvall, President of European New Car Assessment Program – EuroNCAP – at Transport Research Area – TRA 2006 Conference Göteborg, Norway). (http://ec.europa.eu/research/transport/news/article_4271_en.html)

“Although road traffic injuries have been a leading cause of mortality for many years, most traffic crashes are both predictable and preventable.” (WHO, 2015).

BACKGROUND

On August 17, 1896, Bridget Driscoll, a 44-year-old mother of two, became the first road fatality in the world from a collision with a vehicle powered by an internal combustion engine. She was hit by a car that – according to witnesses – was going at a “tremendous speed” (reported to be 4 mph). The driver of the car was Arthur Edsell who had been driving for only 3 weeks (no driving tests or licenses existed at that time). He was also said to have been talking to the young lady passenger beside him. After a 6-hour inquest, the jury returned a verdict of “Accidental Death.” At the inquest, the coroner said: “This must never happen again” ([Road Peace, 2004](#)).

4 Traffic Safety and Human Behavior

Whether or not Bridget Driscoll was indeed the first (true) automobile crash victim is arguable (Fallon and O'Neill, 2005), as Mary Ward was killed 27 years earlier when she fell under the wheels of an experimental steam car in 1869 (Wikipedia, August 26, 2014). The important issue is that in the course of the past 120 years, highway traffic safety has come a long way. Or has it? The purpose of this book is to describe the complexity of the issue of highway safety and the advances and difficulties encountered in this area in the past half century, from the perspective of the driving task. As will be shown in the following chapters, issues that were brought out in the above description of the first traffic accident are remarkably similar to some of the issues plaguing highway safety today: inexperience of novice drivers, speeding, distraction from non-driving tasks, vulnerability of pedestrians, labeling traffic crashes as “accidental,” and – most importantly – the desire of everyone involved to eradicate highway traffic injuries and fatalities.

Highway safety and driving behavior as topics of research are much younger than the history of traffic accidents or crashes. Crashes were a very early by-product of the automobile, as illustrated in Figure 1-1, for the first driver fatality crash in England. In fact, crashes and collisions were prophesied long before the automobile actually appeared on our streets. Nearly, 500 years ago the prophetess Mother Shipton proclaimed “A Carriage without a horse shall go/Disaster fill the world with woe” (Wikipedia, 2014). Some early analyses of traffic crashes were published already in the 1930s, but they were limited to technical reports of limited circulation and remained essentially obscured (e.g., Gilutz, 1937). Arguably, the first book on the topic of traffic psychology was the *Psychology and the Motorist* by Toops and Haven, published in 1938. This book cited only three references, and only two of those dealt with driving behavior. Yet, the situation as the authors noted was already alarming. In the U.S., the authors write “some thirty nine thousand Americans annually are killed by the auto.” And this was at a time when the U.S. population was below 130 million. In contrast, in 2015 there were 35,200 traffic fatalities (NHTSA, 2016a), and the U.S. population doubled to more than



Figure 1-1. Wall plaque commemorating the site of the first motor vehicle accident in which the driver was fatally injured (courtesy of author).

322 million. Despite the magnitude of the problem, the issue was largely ignored by the academic world at that time. To wit, Toops and Haven's book has been cited only three times since its publication (according to Google Scholar).

Possibly, the first commercially published monograph to focus exclusively on driver and driving behavior was Lauer's (1960) book: *The Psychology of Driving: Factors of Traffic Enforcement*. Since then the number of books and articles have increased in an exponential manner. Books on traffic safety and various aspects of driver behavior that appeared since then include *Aggression on the Road* by Parry (1968), *Vision and Highway Safety* by Allen (1970), *Human Factors in Highway Traffic Safety Research* by Forbes (1972), *Road User Behavior and Traffic Accidents* by Näätänen and Summala (1976), *Psychology on the Road: The Human Factor in Traffic Safety* by Shinar (1978), *Human Behavior and Traffic Safety* by Evans and Schwing (1985), *Traffic Safety and the Driver* by Evans (1991), *Automotive Ergonomics* by Peacock and Karwowski (1993), *Ergonomics and Safety of Intelligent Driver Interfaces* by Noy (1997), *Forensic Aspects of Vision and Highway Safety* by Allen et al. (1998), *Understanding Driving: Applying Cognitive Psychology to a Complex Everyday Task* by Groeger (2000), *Human Factors for Highway Engineers* by Fuller and Santos (2002), *Traffic Safety* by Evans (2004), *Handbook of Road Safety Measures* by Elvik and Vaa (2004), *Human Factors of Transport Signs* by Castro and Horberry (2004), *Human Factors in Traffic Safety* by Dewar and Olson (2007), *Traffic Safety and Human Behavior* by Shinar (2007), *The Multisensory Driver: Implications for Ergonomic Car Interface Design* by Ho and Spence (2008), *In the Company of Cars: Driving as a Social and Cultural Practice* by Redshaw (2008), *The Handbook of Road Safety Measures* (2nd edition) by Elvik et al. (2009), *Human Factors of Visual and Cognitive Performance in Driving* by Castro (2009), *Maintaining Safe Mobility in an Aging Society* by Eby, Molnar, and Kartje (2009), *Driver Distraction: Theory, Effects, and Mitigation* by Regan, Lee, and Young (2009), *Driver Behaviour and Accident Research Methodology: Unresolved Problems* by Wåhlberg (2009), *Motorcycling and Leisure: Understanding the PTW Rider* by Broughton and Walker (2009), *Forensic Aspects of Driver Perception and Response* by Olson, Dewar, and Farber (2010), *Driver Behaviour and Training* by Dorn (2010), *Handbook of Traffic Psychology* by Porter (2011), *Human Modelling in Assisted Transportation* by Cacciabue et al. (2011), *The Safety of Intelligent Driver Support Systems* by Barnard, Risser, and Krems (2011), *The Fast and the Furious: Drivers, Speed Cameras and Control in a Risk Society* by Wells (2011), *Handbook of Driving Simulation for Engineering Medicine and Psychology* by Fisher, Rizzo, et al. (2011), *Ergonomics in the Automotive Design Process* by Bhise (2012), *Driver Behavior and Accident Research Methodology* by af Wåhlberg (2012), *Advances in Traffic Psychology* by Sullman and Dorn (2012), *Designing Safe Road Systems: a Human Factors Perspective* by Theeuwes, van der Horst, and Kuiken (2012), *Advances in Human Aspects of Road and Rail Transportation* by Stanton (2013), *Behavioural Adaptation and Road Safety* by Rudin-Brown and Jamson (2013), *Automotive Ergonomics: Driver-Vehicle Interactions* by Gkikas (2013), *Eliminating Serious Injury and Death from Road Transport* by Johnston, Muir, and Howard (2014), *Driver Acceptance of New Technology* by Regan, Horberry, and Stevens (2014), *Communication, Public Discourse, and Road Safety Campaigns* by Guttman (2014), *Driving with Music: Cognitive-Behavioral Implications* by Brodsky (2015), *Increasing Motorcycle Conspicuity* by Rößger, Lenné, and Underwood (2015), *Human Factors in*

Automotive Engineering and Technology by Walker, Stanton, and Salmon (2015), *Human Factors in Traffic Safety* (3rd edition) by Smiley (2015), *Handbook of Driver Assistance Systems* by Winner *et al.* (2016), and *Handbook of Teen and Novice Drivers: Research, Practice, Policy, and Directions* by Fisher, Caird, *et al.* (2016).

Thus, more books have been published in the past decade – since the publication of the first edition of this book – than in all of the previous century and first 7 years of this century! A similar trend also exists in the number of published scientific studies. In an interesting quantitative summary of articles published in the open literature, Hagenzieker, Commandeur, and Bijleveld (2014) found that up until 1950 the total number of journal articles on road safety research was in the single digit range. But since then, there has been an exponential explosion such that by 2010, there were over 2,000 articles in English language alone. Furthermore, the growth was accompanied by a shift in focus from that of accident prone drivers, through multiple crash causes and systems analysis, to today’s focus on theories and models of driver behavior in the context of new intelligent transport systems (ITS) and autonomous driving. It is therefore not surprising that the role of psychology and psychological concepts such as risk taking and behavioral adaptation have assumed a central role in this area (Hakkert and Gitelman, 2014; Vaa, 2014).

Definitions: Safety, accidents, and crashes

It is interesting that safety in general and highway traffic safety, in particular, are most commonly defined by their negative outcomes: crashes or accidents. In this book, I will use the two terms interchangeably, though some researchers and safety organizations distinguish between the two and prefer the term “crashes.” It appears that even the public – at least the American public – does not view accidents as random uncontrollable events as the word implies. In a national U.S. survey of the term “accident” (and not just traffic accidents), Girasek (2015) found that over 80 percent of the respondents thought that accidents are preventable. Yet, only 25 percent thought that they are predictable and a similar percentage thought that they are controlled by fate. Clearly, at least in the domain of traffic safety, there is a need to distinguish between a neutral and purely descriptive term, like a crash that does not convey any preconceptions about its causes, and an accident that is a random event or an act of God. The term accident is more loaded than a crash and implies a chance event, one that is out of the driver’s control and in a sense almost an act of God. If a crash is a chance event (“there but for the grace of God...”), then by implication it cannot be foreseen, and therefore cannot be prevented. If traffic crashes are indeed accidents, then how can they be studied scientifically, and how can science improve traffic safety? As I hope to show in this book crashes most often are not accidents. A similar rationale led the U.S. National Highway Traffic Safety Administration (NHTSA) to replace the term “accident” with the term “crash” in all their official documents and communications in 1996 (NHTSA, 1996). According to the U.S. National Highway Traffic Safety Administration (NHTSA) office of the Historian, “accidents imply random activity beyond human influence and control,” whereas crashes are “predictable results of specific actions.” Five years later the editors of the *British Journal of Medicine* declared: “we are banning the inappropriate use of ‘accident’ in our pages ... in

favor of the descriptive and more neutral terms ‘crash’ and ‘collision’” (Davis, 2001). Thus, in the past 50 years the use of the term “accident” has been in constant decline in scientific papers, whereas the use of the term crash has been increasing consistently (Hagenzieker *et al.*, 2014). Nonetheless, since the term accident is still in common use, the two terms will be used interchangeably in this book.

Before we continue any further, we must agree on a definition of a crash or an accident. Unfortunately, this is very difficult. In the case of traffic accidents, perhaps the most commonly accepted definitions are the ones adopted by the U.S. NHTSA and the UN/ECE. According to NHTSA, a crash is “an unintended event resulting in injury or damage, involving one or more motor vehicles on a highway that is publicly maintained and open to the public for vehicular travel” (NHTSA, 1998). According to the UN/ECE accidents are events “which occurred or originated on a way or street open to public traffic; which resulted in one or more persons being killed or injured and in which at least one moving vehicle was involved” (Berns and Brühning, 1998). Although the definitions seem nearly identical, they are not, as each word that is in them – as well as every word that is not – is critical. For example, the NHTSA definition refers to “motor vehicles,” whereas the OECD definition does not mention the word “motor” but does specify “moving vehicles.” Thus, a collision between a bicyclist and a pedestrian would qualify as such for the OECD data, but not for the U.S. These kinds of differences create significant problems when we attempt to compare accident statistics across different countries, as done by the International Traffic Safety and Analysis Group that produces the International Road Traffic Accident Data Base (IRTAD) that includes data from all reporting OECD countries and some additional countries, which also vary slightly – but significantly – in their definitions (OECD, 1998). For example, most countries include only injury crashes in their database, but some include property damage crashes too (e.g., Denmark, Israel). However, these data are neither a complete census nor a representative sample. Also, even within countries there are inconsistencies in the inclusion criteria; for example, in cases of crashes resulting from police chases and suspected suicide or loss of consciousness prior to the crash. The similarity but non-identity in definitions means that when looking at international data, we may not be comparing apples and oranges, but we are definitely dealing with a wide variety of oranges (or apples). In addition, most countries do not include vehicle-related non-traffic fatalities on private properties. Thus, being crushed by a backing vehicle on a private driveway is not considered a traffic crash. Although, relative to other traffic crashes their number is small, they are still significant. In the U.S., for example, they claim the lives of approximately 500 people and injure over half a million people each year (NHTSA, 2015c). But because of their psychological impact – the victims being mostly small children – the NHTSA recently issued a regulation requiring a backup video camera and display in all vehicles produced after May 1, 2018.

Safety has come a long way in the past half century

In the western world, over the past 40 years the desire for greater traffic safety has fostered a dramatic social cultural change in norms. Forty years ago the U.S. nationwide front seat safety belt use was 15 percent, alcohol-related crashes accounted for over 50 percent of all fatal crashes, and safety was viewed by the automotive industry as

something the public did not care about. In contrast, in 2012 the U.S. safety belt use in the front seats reached 86 percent (NHTSA, 2012), and in some countries (e.g., Australia, Canada, Czech Republic, France, Germany, Japan, Israel, New Zealand, Netherlands, Norway, Sweden, and the United Kingdom) it had reached 95 percent or higher (IRTAD, 2013). In 2012, in the U.S. alcohol impairment was responsible for 31 percent of traffic fatalities (NHTSA, 2013). Not surprisingly, the U.S. Centers for Disease Control listed “increased awareness and response for improving global road safety” as one of the “Ten great public health achievements worldwide: 2001–2010” (CDC, 2011). Perhaps, the most notable change has been in the regulatory and industrial emphasis on safety. In its Research, Development, and Technology Strategic Plan, the U.S. Department of Transportation listed safety as the #1 priority for the fiscal years 2013-2018, ahead of reducing congestion, improving mobility, and preserving the environment (DOT, 2013). On the automotive industry’s front, Volvo has stated its safety goal as “no one should be killed or seriously injured in a new Volvo by 2020” (Eugensson, 2009; Eugensson *et al.*, 2011).

Yet, the public’s attitude toward traffic safety is complex. A nationally representative survey conducted in the U.S. in 2005 (Mason-Dixon, 2005) found that safety is the single most important feature that Americans value in their personal car. At the same time the majority of the respondents in the same survey also felt that “driving today is less safe than five years ago,” and that they are “more likely to be involved in a motor-vehicle collision today than five years ago.” Thus, either way one looks at it – from the consumer’s desires or the consumer’s concerns – and despite the great advances just noted, traffic safety is of great interest to most drivers today. Similarly, in an earlier analysis of a decade of annual polls of the U.S. adult population health habits between the years 1985 and 1995, we found a steady improvement in driving-related safety habits that included significantly fewer people admitting to drinking and driving and significantly more people reporting that they regularly use safety belts (Shinar, Schechtman, and Compton, 1999). The result of all of these changes in driver attitudes and behaviors is reflected in the ever decreasing rate of traffic fatalities, which in the U.S., dropped in one decade, 2004-2014, from 1.44 to its lowest level ever of 1.08 fatalities per million vehicles miles of travel (NHTSA, 2015a, 2015b, 2016b). A similar dramatic trend of increasing highway safety has been observed in the European Union (EU) countries, as reflected in Figure 1-2, where the number of people killed in traffic accidents decreased by nearly 20 percent in the first half of this decade. Though this may be an impressive decline, it falls short of the rate of decline that is needed to meet the EU goal of a 50 percent reduction by the end of the decade.

Traffic safety must come at a cost. While we all want safer cars, safer roads, and safer road users, we often ignore the cost involved. The cost may be in terms of convenience, money, and mobility. From the perspective of driver behavior the cost is most often in terms of mobility and comfort. For example, we would like to “get there” “now” and we would like to get there safely. Well, there is a mathematically simple inverse relationship between speed and the time it takes to get from point “a” to point “b.” And we are all aware of that. Unfortunately, there is also a relationship between speed and crash risk, and between speed and crash severity: the higher the speed, the higher the crash risk and crash severity (see Chapter 8). This relationship is more difficult to accept (or easier to

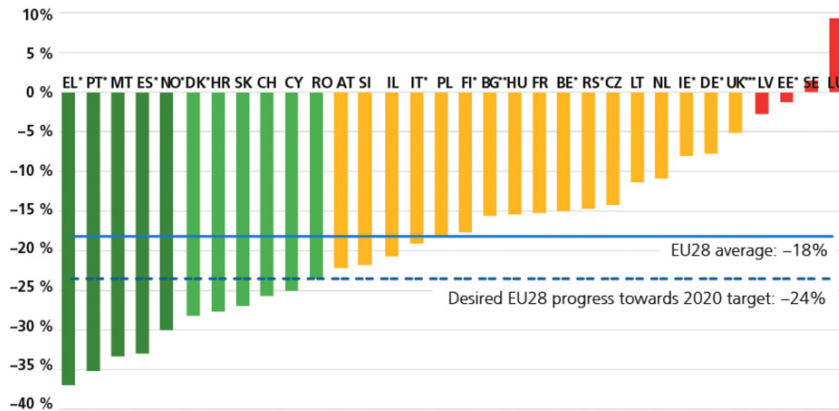


Figure 1-2. Percentage change in road traffic fatalities in 32 European Union and affiliated countries between 2010 and 2014. *Note:* Numbers for starred countries were based on estimates (from ETSC, 2015, with permission from the European Transport Safety Council, Brussels).

challenge) for many people. We can create safer cars with better energy absorption systems, better occupant protection devices (such as airbags), or occupant restraints (such as belts), but the first two cost more money and the third involves some inconvenience. Thus the claim that we all want maximum safety is really not tenable. Instead, what we all desire is to maximize other values, without exceeding a certain (hopefully low) level of crash risk (Evans, 2004; Wilde, 2002).

SCOPE AND MEASUREMENT OF TRAFFIC CRASHES AND INJURIES

The tremendous impact that crashes have on our society has attracted the attention of scientists, health officials, legislators, and policy makers to this issue, and in most countries significant advances have been made in curtailing accidents. However, to assess the scope of the problem and advances in safety, some standardized – or at least common – measures of the phenomenon must be agreed on.

The scope of the problem in terms of property-damage, injury, and fatal crashes

“Approximately 1.24 million people die every year on the world’s roads, and another 20 to 50 million sustain nonfatal injuries as a result of road traffic crashes” (WHO, 2013a, 2013b). Unfortunately, this number has not changed significantly over the past 10 years (WHO, 2015). In contrast, in 2013 terrorists killed approximately 18,000 people world-wide or about 1.5 percent of the number killed by traffic (Kuper, 2015). World-wide traffic accidents are also the leading cause of death for people 15-29 years old, and the ninth leading cause of death across all age groups (WHO, 2015). Thus, there is an elephant in our lives that most people tend to ignore.

Defining severe injury: MAIS3+

In contrast to the specific number of traffic fatalities cited, injuries are expressed in terms of an enormous range of numbers: 20-50 million. This is because documenting and applying a standard common measure for injuries in all countries is a formidable challenge that still has to be met (Tingvall *et al.*, 2013) and because relative to fatalities they are quite poorly documented (WHO, 2013a, 2013b). As a start, the EU has embarked on an effort “to devise harmonised methodologies to produce comparable data on serious injuries in due time; (because) only when their true character and frequency is assessed in a sound and uniform way, can effective road safety management mechanisms be employed (such as target setting, implementation, monitoring and evaluation)” (IRTAD, 2014, p. 25). A review of the current practices for documenting injuries in the EU countries revealed that the 23 participating countries had nearly 23 different definitions. Most of these were based on administrative criteria such as hospitalization for 24 hours or more (e.g., Belgium, France, Germany, Ireland, Israel, Portugal, Spain, Switzerland, the United Kingdom), 48 hours or more (Hungary), or overnight (Greece). In very few cases the criteria were actually based on medically accepted measures for injury severity (Finland, Netherlands, and Romania). In short, international comparisons at this stage are practically meaningless. Realizing this, the EU has adopted a common criterion of serious injury: $\text{MAIS} = 3+$. The MAIS is a medically determined evaluation of the Maximum Abbreviated Injury Scale. AIS scores are determined by the injury severity to nine different body regions (head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, and unspecified) on a 6-level scale of severity, ranging from 1 (minor) to 6 (maximal), where each level corresponds to a probability of death (0 at $\text{AIS} = 1$ and 100 at $\text{AIS} = 6$). The MAIS is the AIS score of the most severely injured body region. MAIS_3 , the level agreed on by the EU as the threshold for serious injury is associated with an 8-10 percent likelihood of death. As of 2015, most European countries have accepted this new definition of serious injury and are working toward integrating it into their crash documentation (ETSC, 2013, 2015). Once this becomes the norm, comparisons will be meaningful, and the full and true medical, societal, and financial burden will be measurable – and probably very disturbing. Nonetheless, once measured objectively and systematically, a goal for its reduction can be stated.

Consequently, for now at least, we must settle on fatalities as the common comparable measure of national and international road safety. Also, often ignored, but very relevant is the death toll from traffic-based pollution. According to the World Bank (2014), when added to the death toll from road injuries, the total toll of traffic in 2010 was 1.33 million people, making it the sixth leading cause of death.

It is important to refrain from generalizing from fatal crashes to injury and non-injury crashes, as their characteristics are quite different in speed, location, time-of-day, and the people involved. This also means that efforts at reducing traffic fatalities will not necessarily reduce traffic injuries. Because most countries focus on reducing fatalities, the trends are also different. Over long periods of time, the difference is quite dramatic. In the U.S., in the past half century (1964-2013) the death rate per vehicle miles traveled decreased by 80 percent, whereas the number of people injured decreased by 50 percent. The differences in some of the European countries are even more dramatic. For example, in the two decades from 1990 to 2009 the number of fatalities in Spain decreased by approximately

65 percent whereas the number of injuries fluctuated greatly and decreased by approximately 25 percent. In Sweden, a country known for its excellent traffic safety record, over the same period fatalities decreased by approximately 45 percent, whereas the number of injuries actually *increased* by close to 10 percent (OECD, 2010).

As the world population grows, and as cars become more and more commonplace, the number of accidents worldwide increases. According to the World Health Organization (WHO, 2005), worldwide motor vehicle accidents are the second most frequent cause of death for people 5-29 years old and “projections indicate that these figures will increase by about 65 percent over the next 20 years unless there is new commitment to prevention” (WHO, 2004). Also because traffic crashes hit people of all ages, especially young inexperienced drivers, the rising cost of crashes is also reflected in the reduced quality of life as measured by disability-adjusted life years (DALYs – see Table 1-2 for a definition). Using this measure, traffic accidents were ranked as the ninth leading cause of this global burden of disease in 1990, but was projected to become the 3rd by the year 2020 if the trend is not changed (WHO, 2004). So far this prediction seems to be valid, as in 2010 road injuries were the eighth leading cause of deaths worldwide, responsible for the loss of over 75 million DALYs (World Bank, 2014). Furthermore, while the death rate from road crashes has been constantly decreasing in the developed world (Europe and Israel, North America), in the rest of the world it is either stable (Latin America, North Africa, and the Middle East – excluding Israel) or actually increasing (Southeast Asia, Sub-Saharan Africa), as can be gleaned from Figure 1-3.

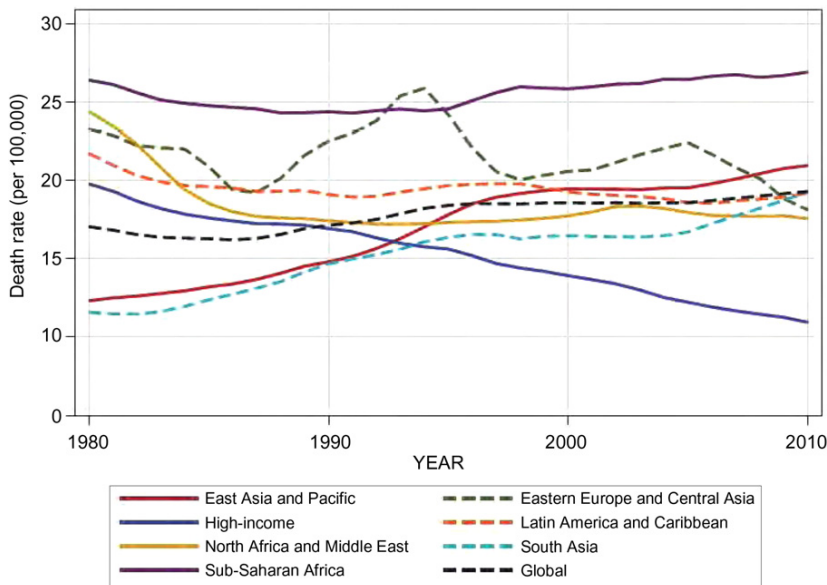


Figure 1-3. Worldwide trends in road injury death rates from 1980 to 2010 (from World Bank, 2014, p. 29, with permission from the World Bank).

Some people see this tremendous and increasing toll as an unavoidable cost of “progress.” As the number of cars increases and as the world population increases, so will the number of crashes and victims. Thus, given the current trends, death from a motor vehicle crash worldwide was projected to become the fifth most common cause of death by 2030, versus its 10th place in 2015 (WHO, 2016). The data in [Table 1-1](#), of the leading causes of death in the U.S., show that in the U.S., in terms of estimated years of life lost, this future is almost here. In fact, in 2011 motor vehicle crashes were the number one cause of death in the U.S. for people of ages 8-24 and the seventh leading cause in terms of years of life lost. The measure of “years of life lost” also has significant economic implications, especially when calculated in terms of composite measures that include the quality of life (such as DALY). Furthermore, when the analysis is restricted to unintentional injuries only, then death from motor vehicle crashes rises to the first or second leading cause of death for all age groups! (CDC, 2015).

Finally, though in this book the primary distinction is between crashes of different injury severities, it is important to acknowledge that there are other factors that define crashes, and they have critical implications for crash and injury reductions. Thus, the American National Standards Institute (ANSI, 2007) also classifies (and defines) motor vehicle traffic accidents in terms of damage severity, vehicle type, number of vehicles involved, first harmful event, location, and other variables.

Measuring safety

Since — all other things being equal — the absolute number of crashes is expected to increase over time (as the number of cars and drivers increase), trends in road fatalities are typically measured and tracked in terms of *rates* of crashes and injuries. When rates are used, the number of crashes or injuries is divided by some measure of exposure. Several different rates are often used to track changes in safety over time, each with a different exposure measure, and each providing a different measure of risk. Unfortunately, these measures of risk are often at variance with each other. This is where the use and abuse of statistics can come into play. A simple measure available in most countries is the number of crashes (or injuries or fatalities) divided by the size of the population. This measure gives the average risk per person. Another measure considers the risk per driver, and therefore uses only the number of licensed drivers in the population. However, because not all drivers have cars and by definition (in most countries at least) a traffic accident must involve a motor vehicle, a third exposure measure is the number of registered vehicles (after all, a driver without a car cannot cause a traffic accident). Finally, because only vehicles that are actually moving on the road can be involved in crashes, a fourth common measure of crash rate uses the total number of miles or kilometers driven as the denominator. With four potential denominators and at least three qualitatively different numerators — number of crashes, number of people injured, and number of fatalities — we now have 12 different indices with which we can describe the state of traffic safety in any one country. This gives policy makers a lot of room to either denounce the state of traffic safety or to congratulate themselves for the great improvements achieved on their watch. [Table 1-2](#) provides a list of some of the

Table 1-1. Leading causes of death in the U.S. as a function of age, based on National Center for Health Statistics Mortality Data. Traffic Crashes are highlighted (from Liu, Singh, and Subramanian, 2015).

★★★★★

NHTSA

www.nhtsa.gov

Top 10 Leading Causes of Death in the United States in 2011, by Age Group¹

National Highway Traffic Safety Administration's National Center for Statistics and Analysis

R A N K	Cause and Number of Deaths											Years of Life Lost ²
	Infants Under 1	Toddlers 1-3	Young Children 4-7	Children 8-15	Youth 16-20	Young Adults 21-24	Other Adults			Elderly 65+	All Ages	
							25-34	35-44	45-64			
1	Perinatal Period 11,931	Congenital Anomalies 448	Malignant Neoplasms 381	MV Traffic Crashes 785	MV Traffic Crashes 3,424	MV Traffic Crashes 3,300	Accidental Poisoning 7,652	Malignant Neoplasms 11,717	Malignant Neoplasms 161,469	Heart Disease 475,100	Heart Disease 596,577	Malignant Neoplasms 24% (9,188,476)
2	Congenital Anomalies 5,013	Accidental Drowning 308	MV Traffic Crashes 287	Malignant Neoplasms 693	Suicide 2,167	Homicide 2,449	Suicide 6,100	Heart Disease 10,635	Heart Disease 105,842	Malignant Neoplasms 397,107	Malignant Neoplasms 576,691	Heart Disease 19% (7,291,475)
3	Heart Disease 309	Homicide 363	Congenital Anomalies 158	Suicide 492	Homicide 2,154	Accidental Poisoning 2,301	MV Traffic Crashes 5,569	Accidental Poisoning 8,075	CLRD ⁶ 19,678	CLRD ⁶ 121,869	CLRD ⁶ 142,943	CLRD ⁶ 4% (1,714,895)
4	Homicide 290	Malignant Neoplasms 259	Accidental Drowning 151	Homicide 303	Accidental Poisoning 1,109	Homicide 2,300	Homicide 4,185	Suicide 6,599	Chronic Liver Disease 19,613	Stroke 109,323	Stroke 128,932	Stroke 4% (1,429,919)
5	Influenza/ Pneumonia 204	MV Traffic Crashes 247	Homicide 129	Congenital Anomalies 281	Malignant Neoplasms 690	Malignant Neoplasms 801	Malignant Neoplasms 3,499	MV Traffic Crashes 4,425	Diabetes 18,700	Alzheimer's 84,032	Alzheimer's 84,974	Accidental Poisoning 4% (1,394,750)
6	Septicemia 178	Heart Disease 138	Exposure to Smoke/Fire 96	Heart Disease 169	Heart Disease 403	Heart Disease 564	Heart Disease 3,301	Homicide 2,519	Stroke 16,910	Diabetes 52,402	Diabetes 73,831	Suicide 4% (1,393,748)
7	Stroke 134	Influenza/ Pneumonia 101	Heart Disease 92	Accidental Drowning 163	Accidental Drowning 173	Accidental Drowning 249	HIV 636	Chronic Liver Disease 2,449	Suicide 15,427	Influenza/ Pneumonia 45,363	Nephritis/ Nephrosis 53,609	MV Traffic Crashes 3% (1,297,257)
8	MV Traffic Crashes 93	Exposure to Smoke/Fire 89	Influenza/ Pneumonia 52	CLRD ⁶ 113	Congenital Anomalies 212	Congenital Anomalies 184	Diabetes 666	Diabetes 1,842	Accidental Poisoning 15,379	Nephritis/ Nephrosis 37,796	Nephritis/ Nephrosis 45,591	Diabetes 3% (1,119,576)
9	Nephritis/ Nephrosis 76	MV Nontraffic Crashes ⁴ 79	CLRD ⁶ 49	MV Nontraffic Crashes ⁴ 84	Accidental Falls 86	Pregnancy, Child Birth 119	Influenza/ Pneumonia 530	Stroke 1,718	MV Traffic Crashes 9,424	Septicemia 26,746	Suicide 39,518	Perinatal Period 2% (942,864)
10	Malignant Neoplasms 70	Septicemia 55	MV Nontraffic Crashes ⁴ 37	Influenza/ Pneumonia 79	Influenza/ Pneumonia ⁵ 81	Influenza/ Pneumonia 116	Stroke 505	HIV 1,619	Nephritis/ Nephrosis 7,414	Hypertension Renal Disease 23,272	Septicemia 36,280	Chronic Liver Disease 2% (761,320)
ALL ³	23,985	3,572	2,205	4,885	12,983	15,669	43,748	69,893	505,562	1,831,844	2,515,458	All Causes 100% (38,536,588)

Table 1-2. Commonly used measures of crash and injury rates (from WHO, 2004, p. 57, with permission from the World Health Organization).

Measure	Description	Use and Limitations
Number of injuries	Absolute figure indicating the number of people injured in road traffic crashes. Injuries sustained may be serious or slight.	Useful for planning at the local level for emergency medical services. Useful for calculating the cost of medical care. Not very useful for making comparisons. A large proportion of slight injuries are not reported.
Number of deaths	Absolute figure indicating the number of people who die as a result of a road traffic crash.	Gives a partial estimate of magnitude of the road traffic problem, in terms of deaths. Useful for planning at the local level for emergency medical services. Not useful for making comparisons.
Fatalities per 10,000 vehicles	Relative figure showing ratio of fatalities to motor vehicles.	Shows the relationship between fatalities and motor vehicles. A limited measure of travel exposure because it omits non-motorized transport and other indicators of exposure. Useful for international comparisons.
Fatalities per 100,000 population	Relative figure showing ratio of fatalities to population.	Shows the impact of road traffic crashes on human population. Useful for international comparisons.
Fatalities per vehicle-km traveled	Number of road deaths per billion kilometers traveled.	Useful for international comparisons. Does not take into account non-motorized travel.
DALYs (Disability-Adjusted Life Years)	Healthy life years lost due to disability and mortality. 1 DALY lost = 1 year of healthy life lost, due to premature death/disability.	DALYs combine both mortality and disability.

more common measures and their uses. The important point is not that one measure is better than another, but that each statement of traffic safety has to specify the type of measure used. The intelligent reader can then interpret its meaning. This is not always easy because different measures are affected by different variables that by themselves have no bearing on safety policy. For example, [O'Neill and Krychenko \(2006\)](#), demonstrated that the number of deaths per distance traveled is greatly affected by the level of urbanization and demographic characteristics of the road users. Thus, in the U.S. where the fatality rates differ greatly among the 50 states, almost 70 percent of the variance is accounted for by differences in these two factors. The use of the different measures is illustrated below for crash and injury trends over time for specific countries, and at a given time for comparisons among countries.

The choice of a preferred rate goes beyond the immediate meaning of the measure. In recent years, with the dramatic increase in traffic accidents worldwide, traffic safety has come to the attention of health officials, who are now attempting to address it as they would any other disease. From the perspective of public health, traffic accidents are *the* disease of our time, and they are projected to remain in that dubious place of honor in the next few decades at least. As a public health issue the situation is not only grim, but has not improved at all over the past decades. An interesting illustration of this is provided by [Sivak \(1996\)](#) who notes, based on data provided by the U.S. National Safety Council, that between 1923 and 1994 the total number of people killed in the U.S. from traffic accidents annually more than doubled: from 18,400 to 43,000. However, the death rate per million vehicle kilometers decreased by 92 percent (!): from 13.4 to 1.1. During that time, at least part of the reason for the increase in the first measure and the decrease in the second measure was due to the increase in the size of the U.S. population, the number of licensed drivers, and the number of registered vehicles. With all these critical factors affecting the likelihood of traffic accidents, the fatality rate per 100,000 persons living in the U.S. remained essentially unchanged: at 16.5 in both periods. Thus, if we are to treat crashes as a modern day disease, we must look just as epidemiologists evaluate the risk of diseases and epidemics: at its impact relative to the number of people in the affected population; and the news concerning the traffic accident “disease” is not good. Incidentally, despite significant reductions in the U.S. traffic fatality rates, the U.S. is far from being a leader in this domain. Based on data collected by the IRTAD for 2013, the U.S. had 10.3 fatalities per 100,000 inhabitants while seven OECD countries – Denmark, Israel, Netherlands, Norway, Sweden, Switzerland, and the United Kingdom – led the pack with less than four fatalities per 100,000 inhabitants ([IRTAD, 2015](#)).

If we look at traffic accidents from the perspective of highway safety administrators and policy makers then we make allowance for all the factors for which the engineers – justifiably – cannot assume responsibility and these include the number of people and vehicles moving on the roads. The differences in philosophies concerning the place of traffic safety – as a unique safety phenomenon versus a public health concern – are also reflected in the different goals set by different countries. Of course, to be immune from criticism for biasing the safety picture, a country can strive to lead on all three rate measures of fatalities: per population, per vehicles, and per kilometers driven. Worldwide as

of 2013, three countries excelled and led the rest of the world on all three measures: Sweden (with 27 fatalities per million inhabitants; 58 per million passenger cars, and 2.4 fatalities per billion vehicle kilometers), the United Kingdom (with 28, 59, and 2.8, respectively), and Netherlands (with 28, 60, and 3.3, respectively) (EC, 2015). By comparison, the U.S. which up to the 1970s led the world in traffic safety had 103.5 deaths per million inhabitants, 122.6 per million registered vehicles, and 17.5 per billion vehicle kilometers (NHTSA, 2015a).

The importance of setting measurable goals – regardless of the terms in which they are defined – is well established as a means of improving performance (Locke and Latham, 2002). Setting tough but achievable goals is a great motivating force. Once stated, a goal becomes a measure against which nations, governments, and other institutions can evaluate their performance, and be held accountable. Most European countries – where the population size is relatively stable – set their traffic safety goals in terms of reductions in either absolute number of fatalities or in terms of the rate of fatalities per population (IRTAD, 2015). The most ambitious and challenging goal phrased in absolute terms is the “Vision Zero” adopted by the Swedish parliament in 1997: “that no one would be killed or seriously injured in the road transportation system.” This approach explicitly states that “the system designers are invariably ultimately responsible for the design, management and use of the road transport system and thus, they are jointly responsible for the level of safety of the whole system. The road users are obliged to abide by the rules that the system designers decide on for the use of the road transport system. If the road users fail to abide by the rules – for example, due to lack of knowledge, acceptance or ability – or if personal injuries occur, the system designers must take additional measures to prevent people from dying or being seriously injured” (Fahlquist, 2006, p. 1113, quoting the Swedish law).

In contrast, the U.S. Department of Transportation sets its safety goal in terms of the fatality rate per 100 million vehicle miles traveled. The strategic goal that was set in 2003 for 2008 was “not more than 1.0 per 100 million vehicle miles traveled” (U.S. DOT, 2003) or 0.62 deaths per 100 million vehicle kilometers traveled. Unfortunately, this goal was not achieved and instead a new more modest goal was set to “reduce the rate of roadway fatalities per miles traveled from 1.25 per million vehicle miles traveled (VMT) in 2008 to 1.03 per 100 million VMT in 2013” (i.e., 0.64 fatalities per 100 million vehicle kilometers traveled) (U.S. DOT, 2012), and that goal too has not been met (NHTSA, 2015a). In 2015, the fatality rate was 1.12 (NHTSA, 2016a) or 6.96 fatalities per billion kilometers traveled. Note that this is significantly worse than the rate of nearly all Western European countries (Figure 1-5).

Another caveat is the definition of a crash or an injury. For example, one of the more common definitions, used in the U.S. Fatal Analysis System, for a fatal traffic accident is “a police-reported crash involving a motor vehicle in transport on a trafficway in which at least one person dies within 30 days of the crash” (NHTSA, 2000). Not all countries limit recorded crashes in their data files to ones occurring on public roads (by including crashes off the road and on private roads) and motor vehicles in motion (by including crashes involving bicyclists and a parked car), and not all countries use the same time

limit of 30 days (the range varies from 24 hours to no time limit at all) to note a fatality or a fatal crash. These differences in definitions make cross-cultural and international comparisons a little more uncertain than they appear. However, some approximations can be derived by factoring some of the differences. For example, the World Health Organization uses a 12-month rule for counting fatalities for vital statistics reporting. In the U.S. according to [ANSI \(2007\)](#) “experience indicates that, of the deaths from motor vehicle accidents which occur within 12 months of those accidents, about 99.5 percent occur within 90 days and about 98.0 percent occur within 30 days” (Section 3.1.3). This difference of 2.0 percent between 30 days and “anytime” (equivalent for all practical purposes to 1 year) has also been obtained for traffic fatalities in Israel (NRSA, 2010).

Perhaps, the most common rate used by traffic safety engineers and transportation experts is the number of crashes or fatalities per total vehicle miles (or kilometers) driven by all cars; that is, the risk per miles or kilometers of driving in any one country. Obviously, a registered vehicle that is not moving, cannot strike anyone, and the more time and distance a vehicle travels on the road the more it is at risk of being involved in an accident. But time-on-the-road is very difficult to evaluate, and we therefore resort to the estimate of total mileage driven. Unfortunately, the measure itself is not as accurate as we would like it to be because it typically depends on survey reports of people’s estimates of their driving distances. Distance traveled can be accurate in countries with annual motor vehicle testing, where based on the odometer readings from all vehicles the aggregate measure of the total distance traveled by all vehicles can be calculated. However, this procedure is practiced in very few countries (e.g., Israel). Still, regardless of how it is calculated or estimated, when the change over time is great, the inherent inaccuracy of the measure is less important. Thus, as noted above, in the U.S. the risk of fatality per mile driven has decreased markedly over the half century by approximately 80 percent: from 5.5 fatalities per 100 million vehicle miles in 1966 to 1.1 fatalities per 100 million vehicle miles in 2012 ([Figure 1-4](#)). Statistically speaking, this means that in the U.S. a person would have to travel by car an average distance equivalent to over 460 round trips to the moon – which is on the average 238,855 miles from earth – before being killed in a traffic accident.

Using this rate, fatalities per total distance traveled, as a basis for international comparisons, it is easy to see from [Figure 1-5](#) that, in general, the more developed, and more motorized, countries have lower fatality rates, with England and some of the Scandinavian countries leading the way. Note, however, that the U.S., the most motorized country in the world (with approximately eight vehicles for every 10 residents, including infants and children) does not fare well as these countries. This chart, however, does not include countries with fatality rates significantly above 100 such as China (126) and Russia (598).

The rate per miles driven is also oblivious to the impact of alternative modes of transportation on overall travel safety. Public transportation by train or bus is typically safer than travel by car and shifting the public’s use to these modes can increase public safety without being reflected in the fatalities per miles driven. Thus, as comforting or disturbing as the rate of fatality per miles driven is (depending on where you live, of course),

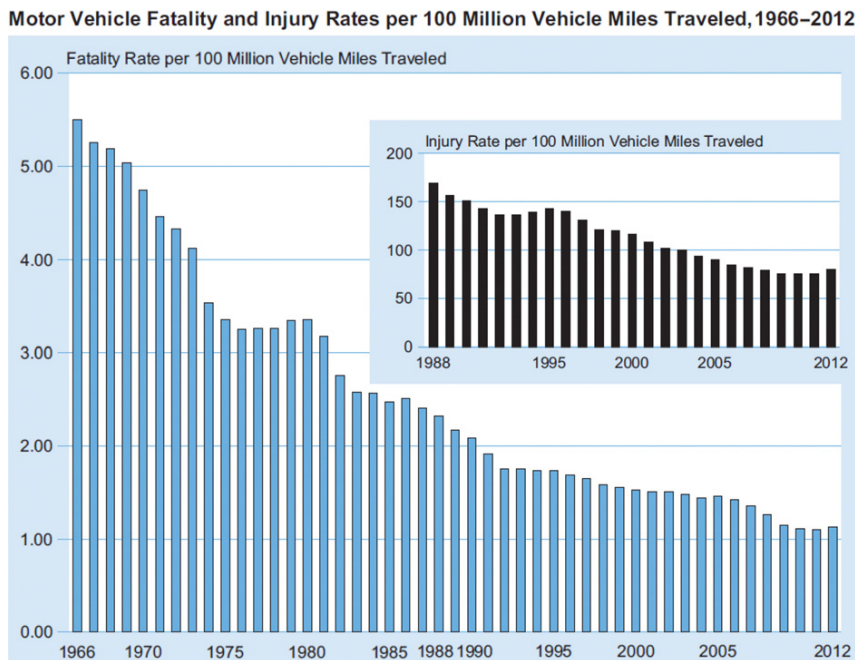


Figure 1-4. Trends in fatalities and injuries per 100 million vehicle miles of travel in the U.S., 1966–2012 (from [NHTSA, 2014](#)).

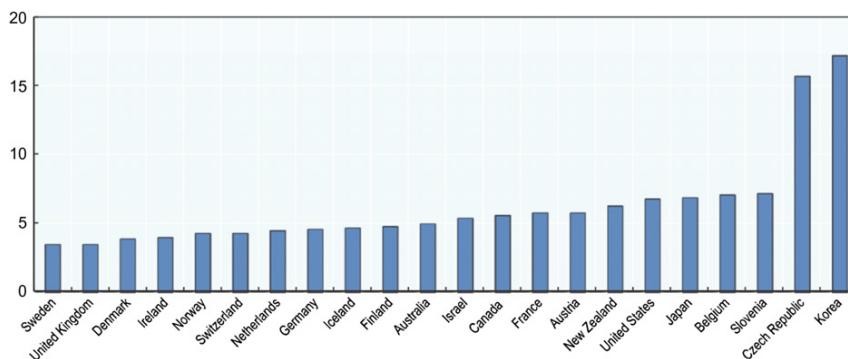


Figure 1-5. Fatalities per billion vehicle kilometers traveled in different countries in 2013. Data for Australia, Canada, Ireland, Lithuania and the U.S. is provisional. Data for the Czech Republic is from 2012 (from [IRTAD, 2015](#), with permission from the [OECD Publishing, Paris](#)).

the state of traffic safety looks very different if we consider another common rate: the rate of fatalities per number of people in the population. This is the typical measure used in health statistics to estimate the risk of a person of contracting any disease in any one country.

Unlike the rate per miles driven, in the U.S. the rate of fatalities per population has stayed fairly constant with only a 5 percent drop from 1923 to 2000. Why the great disparity in the behavior of the two statistics? One possibility is that most of the improvement in the rate per miles driven is due to an increase in travel rather than due to a reduction in the number of crashes. Thus, a road segment may be equally safe (or unsafe) regardless of the number of cars traveling on it (within limits) and a car may be equally safe (or unsafe) regardless of the miles driven. Another possibility, raised by Sivak (2002) is that a society has a certain tolerance to traffic injuries, not in absolute terms (because the absolute numbers keep increasing) but relative to population size.

While the rate of involvement per population is a common rate used in the health area, it does not account for the number of drivers or vehicles running on the roads and potentially having the crashes. Obviously, the likelihood of being in a crash should be related to these. Also — especially from the perspective of policy makers — there is very little one can do to control all citizens, but there are a lot of actions that can be taken to regulate and improve the vehicles and the drivers. Therefore, two other common rates are the rate of crashes or fatalities per number of licensed drivers and the number of crashes or fatalities per number of registered vehicles (Figure 1-6). Figure 1-7 demonstrates the difference in the rates of fatalities relative to the number of people and relative to the number of registered vehicles in different countries. Although the data are somewhat dated, they still illustrate the importance of having both measures, and the differences between them. As can be seen from this figure, in the more developed countries of the Western world (in income per capita and the number of vehicles per person),

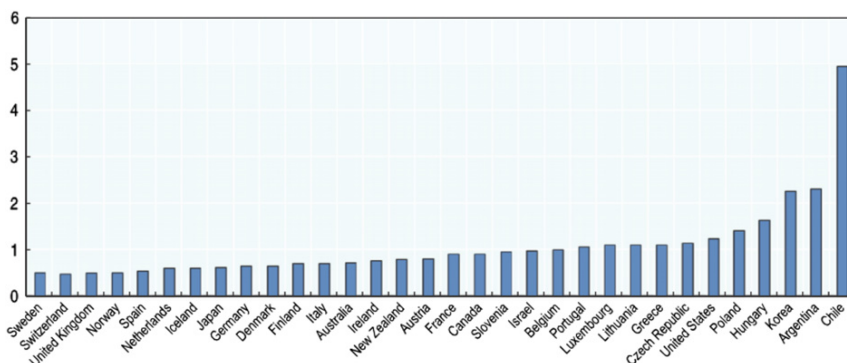


Figure 1-6. Road fatalities per 100,000 registered vehicles in 2013. (Total vehicles include mopeds for Argentina, Australia, Canada, Chile, Iceland, Ireland, Lithuania, and the U.S. Canada: 2012 data. Provisional data for Australia, Ireland, Lithuania, and the U.S.) (from IRTAD, 2015, with permission from the OECD Publishing, Paris).

both rates are relatively low, whereas in the less-developed countries such as Turkey and Korea, the rate per population is much lower than per vehicles. In general, the disparity between the two rates is even greater for poorer, less motorized countries. When we focus on rates per population only, finer distinctions among the countries become apparent, as can be seen for the EU countries in 2010 and 2014 (Figure 1-8).

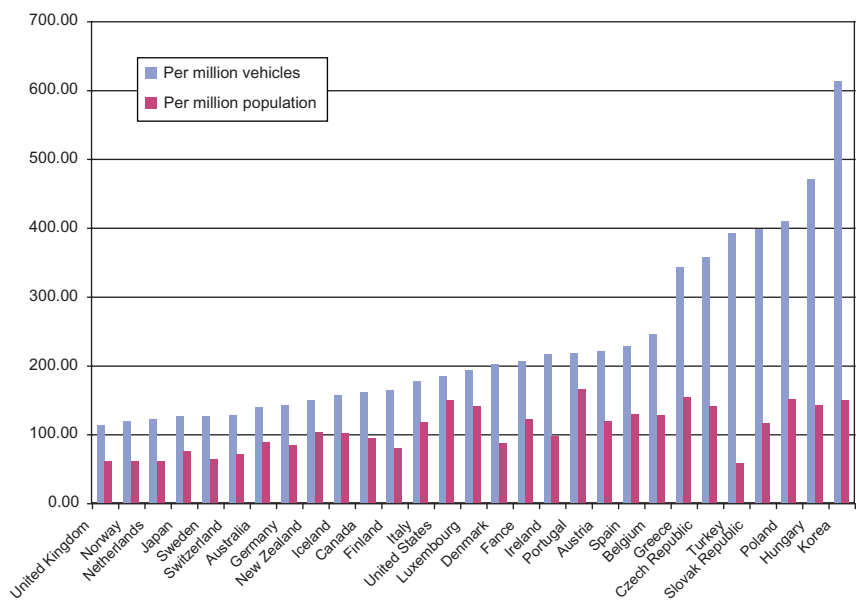


Figure 1-7. Traffic accident fatalities per population size and number of registered vehicles in different countries: 2002 (from OECD, 2006, with permission from the OECD Publishing, Paris).

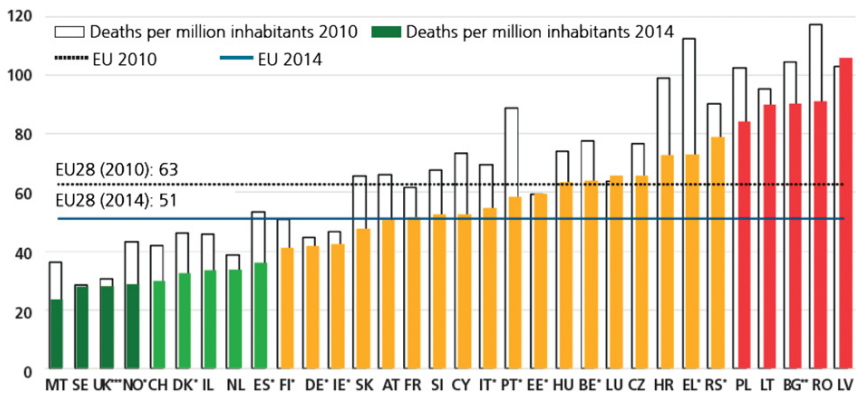


Figure 1-8. Road deaths per million inhabitants in 30 EU and affiliated countries in 2010 and in 2014. *Note:* Starred countries are estimates (from ETSC, 2015, with permission from the European Transport Safety Council).

Of the various measures described above, fatalities per vehicle miles/kilometers driven have evolved to become the gold standard of traffic safety measures. Yet, even for this measure (as well as the others) there are pitfalls in using aggregate data when comparing countries or states. The most common is the one known as “Simpson’s Paradox,” which states that “a trend that appears in different groups of data disappears when these groups are combined, and the reverse trend appears for the aggregate data” (Wikipedia). Stated with respect to international comparisons in fatality rates, it means that one country may appear safer than another when all of its regions are combined, whereas in fact, it is actually less safe when examined on a regional basis. An illustration from U.S. data is the comparison of the fatality rates of California and South Dakota (SD). California has a fatality rate of 1.27 fatalities per 100 million vehicle miles and SD has a fatality rate that is nearly 70 percent higher, 2.12 fatalities per 100 million vehicle miles. When the fatality rates are disaggregated by the types of roads, we get a completely different picture, as can be seen in [Table 1-3](#). When the data are disaggregated into urban and rural roads, it is obvious that SD is safer on both. Yet, because most of the driving in California is on urban roads (where fatality rates are lower because of lower speeds), while most of the driving in SD is on rural roads, we actually get the misconception that driving on California roads is safer than driving on SD roads.

Given these large differences between the various measures, and the pitfalls that abound in interpreting the aggregate data on each measure, is there a simple way to describe safety levels? The answer is yes and no. Perhaps, the most common way to evaluate safety is to consider change over time in a given country, state, or locality, and then justify the particular measure used. The particular measure used will then depend on the nature, mission, and policy of the institution making the comparison. Health organizations would be more likely to evaluate safety in terms of rates relative to population size, whereas transportation organizations would be more likely to consider rates relative to drivers, vehicles, or total kilometers traveled. Still there remains one caveat: the change in safety may be due to exogenous reasons (confounding factors) that may only surface in comparisons to other locations.

Table 1-3. Demonstration of Simpson’s paradox using California and South Dakota fatality rates (per 100 million vehicle miles of travel). Based on 2004 data (from [Hedlund, 2008](#)).

State	Fatality Rate (per 100 Million? VMT)			Distribution of VMT	
	Rural	Urban	Total	Rural	Urban
California	2.68	0.92	1.27	20%	80%
South Dakota	2.49	0.87	2.12	77%	23%

MOTORIZATION AND CRASHES — SMEED’S LAW

Contrary to appearance, the data in [Figure 1-7](#) do not reflect independence of the two measures of safety. There is another measure that seems to mediate the relationship between safety per population size and safety per number of vehicles: the level of motorization. The level of motorization as an intervening variable was first proposed by Smeed in 1949 and is now known as Smeed’s law. According to this “law” the rate of fatalities per number of vehicles decreases exponentially as a function of the number of vehicles per the size of the population. Stated in more intuitive terms, the involvement of each vehicle in a fatal crash decreases as the number of cars in a country increases. Although first formalized by Smeed on the basis of 1938 data from only 20 countries, it has since been validated repeatedly on more recent and larger samples of different countries based on annual statistics from different years ([Adams, 1985](#); [Evans, 2004](#); [Smith, 1999](#)). A relatively recent evaluation of this relationship is depicted in [Figure 1-9](#), and it is based on mostly 2002 and 2003 data from 62 countries gathered by [Link \(2006\)](#). When Link’s fatality rates (per million vehicles) are plotted relative to the level of motorization (vehicles per 1,000 people), we obtain the typical negative power relationship demonstrated by Smeed on data more than three quarters of a century ago. Further demonstration of the strength of this relationship was shown by [Adams \(1985\)](#) and [Evans \(2004\)](#) when they plotted the data for individual countries over the course of several years.

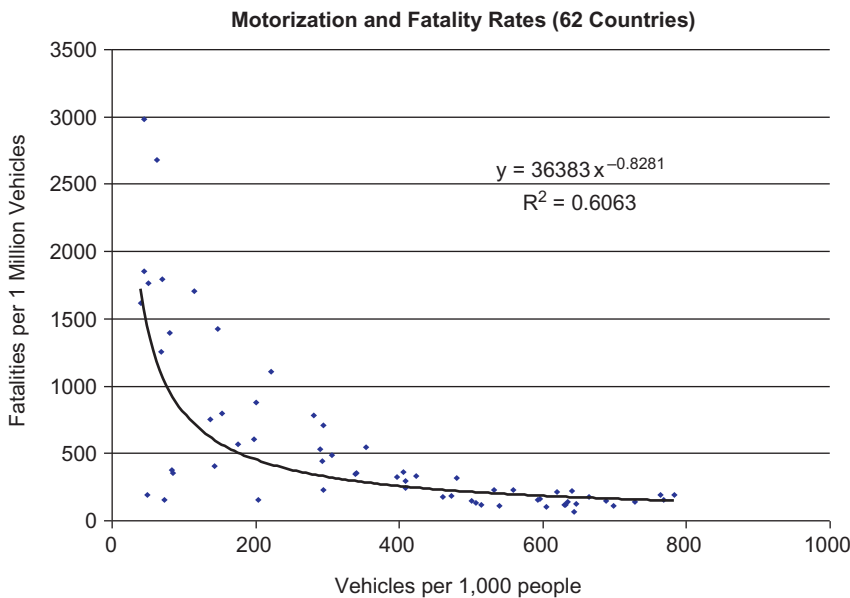


Figure 1-9. Smeed’s Law based on data from 62 countries (collated by [Link, 2006](#), with permission).

Various explanations have been offered for the relationship between fatalities per vehicles and the level of motorization (Näätänen and Summala, 1976). Because the relationship is one of association, it is likely that there are multiple factors that together contribute to this phenomenon, and it is their combined effects that are most likely responsible for the stability in this function across countries and across time. Other variables that covary with increasing motorization and that may directly or indirectly influence traffic safety include the increasing proportion of trips taken in motorized vehicles relative to trips taken by walking or bicycling (see Chapters 15 and 17); improvements in the transportation infrastructure (including divided highways, hard shoulders, barriers, etc.) that accompany the increase in vehicles; demographic shifts toward urbanization, where accidents are less severe; increasing traffic density and congestion, leading to reduction in high-speed crashes; improvements in emergency medical services; reductions in the exposure (kilometers driven) of each vehicle as the number of vehicles increases (we can accumulate vehicles, but we still cannot drive more than one vehicle at a time); increases in population risk awareness; and greater level of motorization due to greater government investment in safety in general, including education. Perhaps the most important implication of Smeed's law and the explanations offered for it is that because accidents and highway safety are affected by multiple factors, addressing any one of them without consideration for the others will only constitute a small part of the solution for a complex problem.

For example, we can illustrate the relationship between motorization and the mix of vehicles. The argument is that as the level of motorization increases, the mix of protective vehicles (cars), non-protective vehicles (motorcycles and bicycles), and vulnerable road users (pedestrians) changes, so that there are more of the former and fewer of the latter on the streets and highways. This is illustrated in [Figure 1-10](#) that graphically displays the relative proportions of people killed in motor vehicle crashes as pedestrians, bicyclists, motorcyclists, and occupants of cars and trucks in different countries. [Figure 1-11](#) displays the relevant data collapsed across countries but disaggregated by gross levels of income (which correlates highly with the level of motorization). The differences between highly motorized and high-income countries and the countries with low levels of motorization and income are striking. In motorized countries most of the people killed are car occupants. For example, in the EU countries the range is from close to 70 percent in Norway, Finland, and Sweden, to approximately 50 percent in Cyprus, Romania, and the Czech Republic ([ETSC, 2011](#)). In contrast, in low-income countries (especially in Sub-Saharan Africa), pedestrians account for more fatalities than any other mode of transportation ([Figure 1-11](#)). Obviously, once a collision occurs, the likelihood of an unprotected pedestrian being killed in a crash is much greater than that of a car driver or a passenger who is protected by their vehicle frame, a safety belt, and an airbag. For example, as detailed in Chapter 15, an analysis of the data from 62 countries revealed that the proportion of pedestrian fatalities is inversely related to the level of motorization ($r = -0.72$) and the level of affluence (gross domestic product/person, $r = -0.71$), which are positively related to each other ($r = 0.82$).

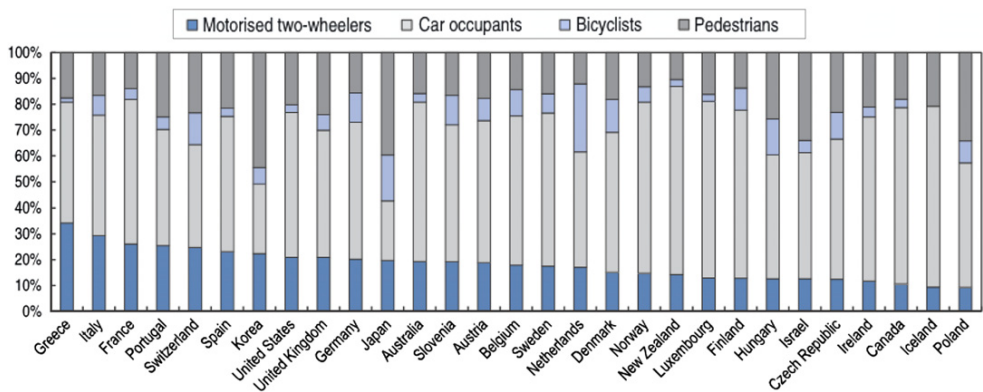


Figure 1-10. Percentage of different types of road users in fatalities (average 2009-2013) share of different road user classes in OECD countries. *Note:* in the U.S. sport utility vehicles are not included in the “car” category, and hence the large proportion of others (from IRTAD, 2015, with permission from the OECD Publishing, Paris).

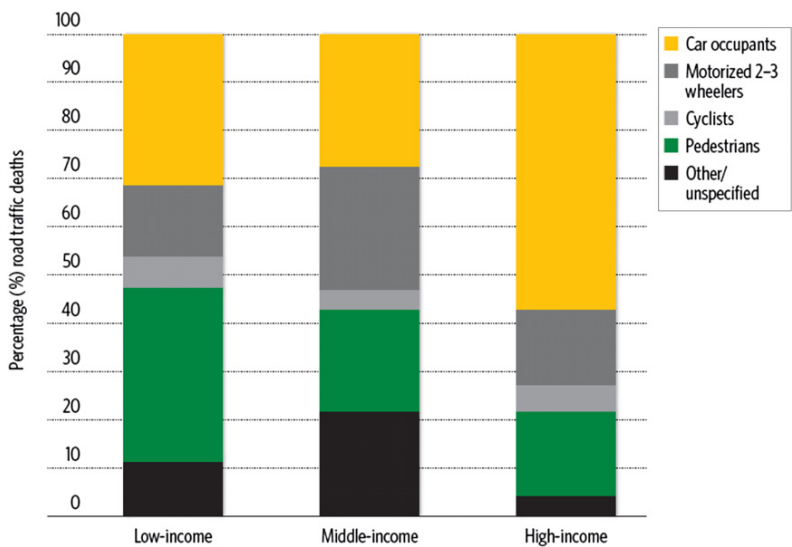


Figure 1-11. Percentages of road users killed as pedestrians, cyclists, mopeds and motorcycles, and cars and trucks, in different countries with different income levels (reprinted from Global Status Report on Road Safety 2013 (p. 7, Copyright World Health Organization, <http://apps.who.int/iris/handle/10665/78256>).

THE RELIABILITY AND VALIDITY OF CRASH DATA

Even when crashes are well defined in identical terms, there are significant variations in crash data among sources. Various state agencies, such as police, licensing agencies, safety divisions, insurance companies, trauma centers, and bureaus of statistics do not always agree with each other. Furthermore, in many traffic safety studies, the crash data are based on the drivers' own reports. Needless to say there are many reasons for discrepancies between self-reports of crashes, reports from hospital trauma centers, and police reports.

The most ubiquitous source of crash data is police reports, which constitute the basis for national crash statistics in over 70 percent of the countries surveyed by the World Health Organization (WHO, 2013a, 2013b). However, for various reasons, listed in Table 1-4 (Elvik *et al.*, 2009), there are limitations to police reports.

It is worthwhile to dwell on the reasons for the data loss as they can introduce some significant biases in the data analysis, interpretation, and recommendations based on them. To start with, some accidents are simply not reported to the police for various reasons: poor communications (mostly in remote areas and in less-developed countries) and inadequate police force to record and investigate all crashes. Next, some accidents are "not reportable" according to the police definitions, such as minor injury and property-damage-only crashes. Some of these crashes are actually misclassified because of initial underestimation of injuries (such as those from internal bleeding). For these reasons and others, police records often underreport accidents relative to hospital records, especially pedestrian and bicycle accidents (Derriks and Mak, 2007). Thus, in a cross-country comparison, Elvik and Mysen (1999) estimated that global crash recording rates include only 95 percent of all fatal crashes, 70 percent of serious injury crashes (where at least one person was admitted to a hospital), 25 percent of slight injury crashes (where no one was treated at a hospital), 10 percent of very slight injury crashes, and 25 percent of

Table 1-4. Reasons for incompleteness and inaccuracy of police accident data in the various stages of information transmission (from Elvik *et al.*, 2009, with permission from Emerald Group Publishing).

Stages in the Recording of Accidents	Reasons for Lost or Inaccurate Information
All accidents on public roads	Not reported to the police
Accidents defined as reportable	Not reportable accidents
Accidents reported	Incomplete reporting
Data elements recorded	Missing data elements
Accuracy of recorded data	Inaccurate data

property-damage-only crashes. In fact in some countries and jurisdictions, police, as a matter of policy, do not become involved in the recording or investigation of property-damage-only crashes (e.g., Israel). Next, even when a crash is investigated some of the needed information may be missing. Finally, clerical and judgment errors often lead to inaccurate data in the final data set. Evaluations of the accuracy of police reports – even those of well-trained officers – often reveal some gross inaccuracies in data recording and interpretation of the evidence. Errors are most common when it comes to attributing the cause of the accident (Shinar, Treat, and McDonald, 1983), exact location, time, and speed (Chung and Chang, 2015). It is important to emphasize that underreporting and errors are not a random process or one that is the same for all countries. The greatest amount of underreporting occurs in the poorest countries where the death toll from road traffic crashes is the greatest (World Bank, 2014). But even in the developed world, underreporting is a significant problem for pedestrian and bicyclist crashes as these often occur on the sidewalk or on foot paths off the road and often do not involve a motorized vehicle (Turner, Roozenburg, and Francis, 2006).

Interestingly, there is no convincing argument for the preference of one data source over the other as they all have some advantages and disadvantages. The intuitive appeal of police reports as a data source for crash involvement is that they are based on police-observed facts. The appeal of self-reports is that they can supply details that police reports often lack. On the other hand, drivers suffer from memory failures and bias and are less reliable in recalling crashes from several years ago. Drivers are also probably less likely to report crashes in which they were culpable, especially if they involve socially unacceptable behaviors such as being intoxicated.

Overall, there is a moderate agreement between the total numbers of police-reported crashes and self-reported crashes, although the two definitely do not provide identical sets of cases. Marottoli, Cooney, and Tinetti (1997) consider the two sets complementary, but others are more skeptical. Owsley *et al.* (1991) compared crash frequencies in state records and self-reports and found a near zero correlation between the two sources ($r=0.11$), although when the frequencies were grouped, and the measure of association was changed (to Kappa coefficient of agreement) a greater – although still low – level of agreement was obtained ($K=0.40$). McGwin, Owsley, and Ball (1998) compared the two sources on a sample of 278 drivers 55+ years old and found a moderate agreement on whether or not the drivers had a crash in the past 5 years ($K=0.45$), but poor agreement in terms of the number of crashes a driver had ($K=0.25$). The discrepancies are not random, but biased in a specific manner. In their sample McGwin and his associates found that the amount of discrepancy depended on the driver demographics, driving exposure, and visual impairments. This creates a caveat that may account for some of the inconsistencies among studies and even within a single study. Thus, in their own study McGwin *et al.* (1998) found that performance on some driving-related skills (such as “useful field of view,” discussed in Chapter 4) was associated with crashes on both data sets, whereas others (such as presence or absence of glaucoma) were significantly associated only with one only (police-reported crashes). In general, they also found that drivers tended to under-report crashes, omitting some of the crashes in the police-based files.

In many studies the source of the data is based on convenience. When available, police data are sought as the “more objective” source. But in some cases — such as the study by [Maycock, Lockwood, and Lester \(1991\)](#) on the relationship between age, experience, and crashes and the study by [McCartt, Shabanova, and Leaf \(2003\)](#) on the effects of graduated driver license on crash involvement — the researchers actually preferred to rely on drivers’ self-reports because they are considered to be more valid for the specific issues examined in these studies (both studies are described in detail in Chapter 6 on young drivers).

A third source of crash data are hospital records. Obviously, this applies only to injury crashes above a certain level of severity. Also, because hospital injury records are not typically centralized in a national data file, an accurate comparison is difficult. Still, hospital records can be indicative of lacunas in police data. Studies conducted in several countries have consistently shown that when compared to hospital data, there is fairly a good agreement on fatalities, but an underreporting by the police, especially in accidents involving bicyclists ([Amoros, Martin, and Laumon 2006](#); [Broughton *et al.*, 2010](#); [Rosman, 2001](#)). Some of the underreporting stems from different definitions of “road accident” (police typically require the involvement of a motor vehicle) and injury severity (police use administrative criteria such as length of hospitalization, whereas hospitals use medical criteria such as the MAIS based on actual injury severity) ([Broughton *et al.*, 2010](#)). Still some of the discrepancies stem from differences in actual reporting where the driver fails to stop and the bicyclist is taken (or goes himself/herself) to the hospital without anyone notifying the police. These shortcomings of the police data relative to data from hospital records do not imply that the latter should substitute for the former, but that “because of underreporting problems and possible bias (e.g., with differing rates of reporting by vehicle type), police data should be complemented by hospital data, which are the next most useful source” ([OECD, 2010](#), p. 8). Unfortunately, most countries do not have linked hospital, vital registry, and police data on traffic fatalities. When data from all sources are available, the police data often underestimate the scope of the problem ([WHO, 2015](#)).

THE CONCERN FOR TRAFFIC SAFETY

Despite the statement by Tingvall (quoted at the beginning of this chapter), the concern about traffic safety is not shared by all road users everywhere. A multi-nation Social Attitudes to Road Traffic Risk in Europe (SARTRE) ([SARTRE 4, 2012](#)) conducted in 2010 on a representative sample of 1,000 adults in 19 countries (17 European countries plus Cyprus, plus Israel) demonstrated very large differences among the people of different countries in their concern about traffic safety. [Figure 1-12](#) shows the percentage of respondents who expressed different levels of concern about the road safety in their country. Although there were very large differences in the percentage of people who were “very concerned” — ranging from less than 20 percent in Germany to over 75 percent in Israel — only a very few people in all other countries stated that they were not concerned at all. Interestingly, the level of concern did not parallel the level of traffic

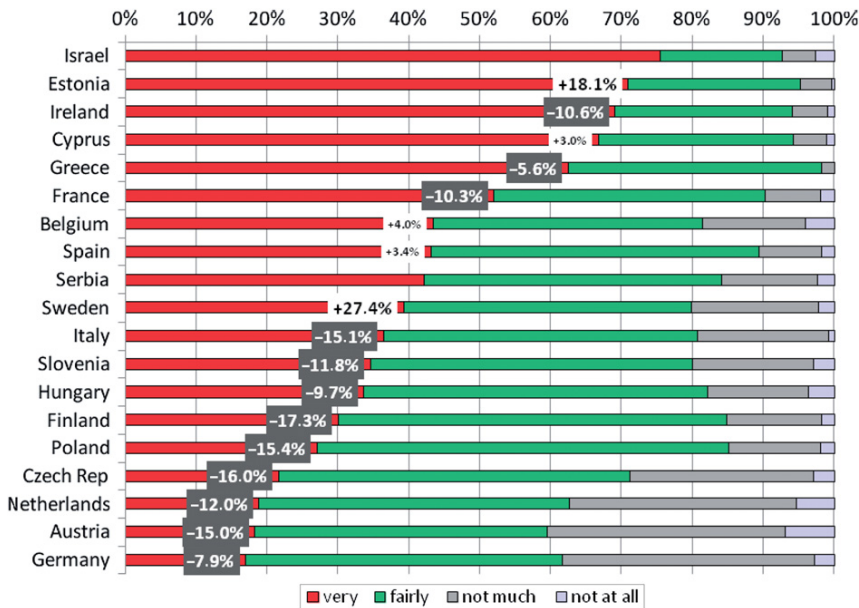


Figure 1-12. Concern about road safety in 2010. Frequency distribution in percentage of road users who are “very concerned” in 2010 (SARTRE 4) and the change from 2001 (SARTRE 3) noted in percentage points to SARTRE 4 (significant changes in bold) (from SARTRE, 2012, p. 47, with permission from J. Cestac, SARTRE 4 Coordinator and Final Report Editor).

safety: $r=0.07$. It was highest (Israel) and lowest (Germany, Austria, Netherlands) in countries that rank quite high on most measures of traffic safety (as reflected in Figures 1-5 to 1-8). The absence of such a relationship is underscored when the concern for safety is plotted against the fatality rate relative to the number of people in the country (Figure 1-13). Sweden is quite consistently ranked as the safest country, yet it was in the middle in the ranking on “very concerned.” Thus, it appears that concern for safety is not closely related to the actual level of safety. To the extent that being concerned drives the behavioral norms and the governments’ investment in safety, it is a good thing to be very concerned. In Israel there is a false public perception – often shared by tourists who view Israelis as very aggressive drivers – that the road safety level in Israel is low, and definitely lower than it should be relative to other OECD countries, independently of all objective data (Figures 1-5 to 1-8). Relative to the previous SARTRE survey conducted in 2001, the change in the percentage of people who were “very concerned” was mostly negative (although not statistically significant). Thus, as road safety increased in nearly all EU countries over that period, the level of concern declined. The most notable exception is Sweden, where there was a statistically significant *increase* in concern despite its excellent road safety records. This supports the speculation that heightened concern is a good thing in a country where the government is attentive to the concern of its constituents. One of the most visible means of that attentiveness is the state of the country’s roadway infrastructure. Thus, it should be no surprise that when

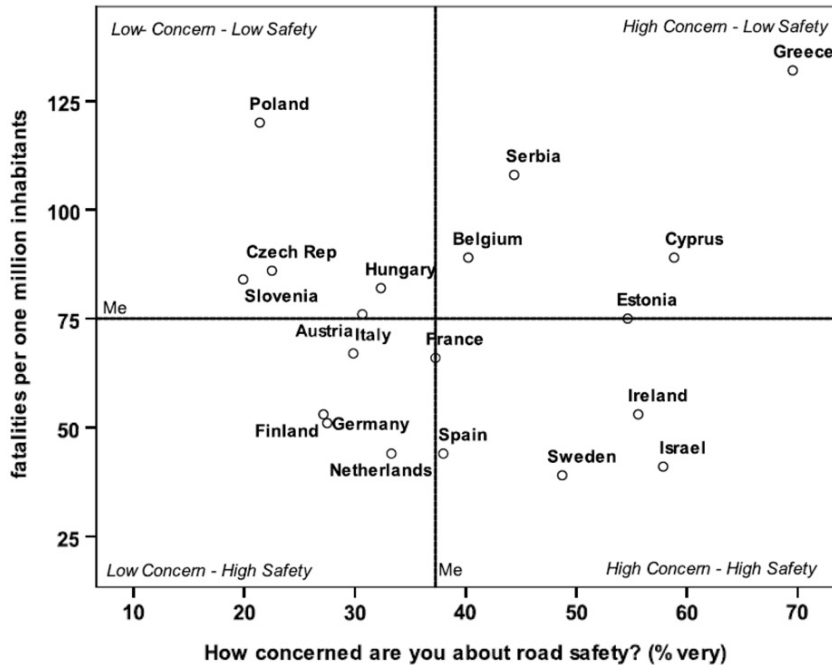


Figure 1-13. Personal concern about road safety versus fatality rate. The center lines indicate the medians of percentage of people who are “very concerned” and the fatality rate (from SARTRE 4, 2012, p. 49, with permission from J. Cestac, SARTRE 4 Coordinator and Final Report Editor).

the fatality rate was plotted relative to the percentage of people who rated the roads as “very” or “fairly” safe, a strong negative relationship emerged ($r = -0.72$). The higher the fatality rate the lower the percentage of people satisfied with their roads, with Sweden having the lowest fatality rate and highest level of satisfaction (Figure 1-14). It is probably also relevant to note that Volvo – that has always carved safety on its mission – is a dominant factor in the Swedish economy.

ORGANIZATION OF THIS BOOK, ADDITIONAL RESOURCES, AND THE RATIONALE FOR THE NEW EDITION

Book organization

In the remainder of the book, I will explore the reasons why highway safety is improving – and the reasons why it isn’t, especially from the perspective of the road user behavior. Because the road user – driver, cyclist, or pedestrian – has been historically viewed as the only decision maker in the driver-vehicle-highway system, his or her role is critical. But the driver does not behave in vacuum. The roadway environment and the vehicle characteristics are crucial components in the highway traffic system as are other vehicles and road

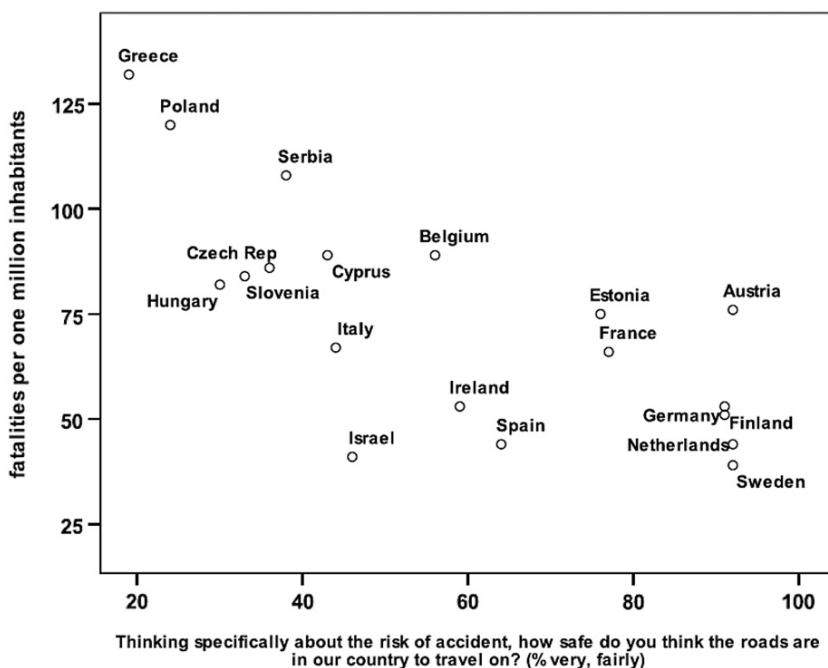


Figure 1-14. Perception of the safety of the roads versus the fatality rates (per one million in population) (from SARTRE 4, 2012, p. 51, with permission from J. Cestac, SARTRE 4 Coordinator and Final Report Editor).

users, the legal and social environment, and the enforcement that is or is not applied. When a crash occurs, it is not necessarily the “nut behind the wheel” that is responsible for it but many other “nuts and bolts” in this complex system that may be loose or missing at the critical moment. Nonetheless, the focus of this book will be on the driver and the driver’s behavior as the significant element in highway safety.

The contents of the book are divided into six major parts, each further divided into 2-4 chapters, totaling 19 chapters. The first part, Background, Methods, Models (Chapters 1-3), essentially sets the stage for discussing the substantive issues of this book. Like any discipline, traffic safety has its own jargon, its own measures, and its own theoretical models within which the discussion of the issues is framed. The Methods chapter provides some very basic information on research design, independent and dependent measures, and statistics that are commonly used in behavioral research on highway safety.

The remainder of the book focuses on specific safety-related issues and, as much as possible, defines the nature of the issue, problem, or behavior, its scope and impact on traffic safety, and potential countermeasures that can reduce the magnitude of the problem.

The second part, Driver Capacities and Individual Differences (Chapters 4-7), focuses on four aspects of driver characteristics that have been studied extensively in

their relation to safety: driver vision, driver information processing, and driver age. Age-wise the two groups that have received most of the attention – although they definitely constitute a minority of all drivers – are the young drivers (typically under 25 years) and the older drivers (typically 65 years old and older). Because the nature of their crash involvement differs and because they differ greatly in their experience, skills, and information processing abilities, they are treated separately in two chapters.

The third part, *Driving Style*, (Chapters 8-10) focuses on two aspects of driving style: speeding behavior and aggressive driving. Obviously, as most people would suspect, the two are related to other driver characteristics such as age and gender, and therefore the relationship of speeding and aggressive driving to age and gender is discussed in this context. In addition, this section also discusses the benefits of occupant protection and the road-users' tendencies to use them.

The fourth part, *Driver Temporary Impairments* (Chapters 11-14), focuses on the four types of impairments that most researchers associate with the greatest involvement in crashes: impairments from alcohol, impairments from (other) drugs, impairments from fatigue, and impairments from distraction and attentional lapses. Unlike the more stable individual differences of personality, gender, age, and visual and information processing abilities, these can change drastically within short intervals (on the order of minutes), and then their effects are often interactive with the person's more stable characteristics. When such interactions have been studied they will be discussed in these chapters.

The fifth part, *Vulnerable Road Users* (Chapters 15-17), implicitly acknowledges that most of the previous discussion was focused on car drivers and occupants. But these are not the only road users that contribute to and suffer from crashes. The others, often labeled as the “vulnerable” road users, consist of primarily riders of powered two-wheel vehicles (mopeds and motorcycles), bicyclists, and pedestrians. They are considered vulnerable for an obvious reason: They do not have the protective seat belts and shield of the car. Although most of the readers of this book probably think of themselves primarily as drivers of passenger cars, we are all at times vulnerable road users as well. In many countries the combined “contribution” of the vulnerable road users to the traffic death toll is greater than that of all car occupants (drivers and passengers). According to the World Health Organization “Half of the world's road traffic deaths occur among motorcyclists (23 percent), pedestrians (22 percent), and cyclists (5 percent).” Car occupants constitute (only) 31 percent of the deaths and the remaining 19 percent are “unspecified road users” (WHO, 2013a, 2013b, p. 6). The three groups making up the vulnerable road users are also distinctly different from each other on at least two dimensions. These include regulation: motorcyclists are regulated through licensing, whereas bicyclists and pedestrians are not, and age: motorcyclists essentially mimic the driver population in their age distribution (with greater frequencies of young riders), whereas bicyclists extend to much younger age groups (teens and preteens) and pedestrians – at least in terms of their crash involvement tend to concentrate on the very young and very old. Consequently, these three types of road users are treated in separate chapters.

The last part, Crash Causation and Countermeasures (Chapters 18 and 19), focuses on what we have learned over the past 100 years — and especially over the past few decades — about the causes of traffic accidents, their relative frequencies, and the means that have proven successful in combating accidents. The crash causation chapter also has a methodology component because often the relative frequency of various causes of traffic accidents is methodology-bound, meaning that different methods of analyses yield different conclusions. The countermeasures chapter is divided into four domains in which countermeasures can and have been applied: organizational actions (such as “Vision Zero” mentioned above), behavioral changes in drivers and other road users, environmental treatments of the roadway and its “furniture,” and vehicular changes in both crash prevention and injury reduction. A significant conceptual change that has occurred over the past decade is reconsideration of the role of the driver as the controlling element in the vehicle. Recent innovations in in-vehicle safety systems transform the driver more and more into a monitor of the car and traffic and less of a continuous controller of the vehicle. In its most extreme form, we see the autonomous vehicle (often known as the Google Car, http://en.wikipedia.org/wiki/Google_driverless_car) that, within some limitations, can safely navigate itself in traffic. This approach involves numerous systems that regulate the speed and lateral control of the car while responding to various crash-related sensors that are sensitive to the prevailing roadway and traffic conditions. While autonomous vehicles would seem to negate even the presence of the driver (let alone the need to change the name), they do involve multiple aspects of the human driver and vehicle interactions that are critical to safety. These issues are discussed in the last part of Chapter 19.

Additional resources

Nearly 40 years ago, I published a small (212 pp.) book on this topic entitled *Psychology on the Road: The Human Factor in Traffic Safety*. At the time, the challenge was to find scientifically valid published research in this area. Ten years ago, while working on the first edition of this book, the challenge was to select the most pertinent research from a wealth of scientific reports published in refereed journals and other technical publications that cover the field. By that time the emphasis in reviewing the state-of-the-art shifted from searching for literature to selecting the most relevant literature. The emphasis in the current version was again on selection. But it was much more difficult now. As noted in the beginning of this chapter, in the last decade alone there were more books written on the topic of human behavior and traffic safety than in all the previous years since the appearance of the motorized vehicle. The same applies to refereed articles of original research and to technical reports. Although most of the studies have been published in a few journals that focus on safety and road user behavior (for example, *Accident Analysis and Prevention*, *Applied Ergonomics*, *Ergonomics*, *Human Factors*, *Injury Prevention*, *Journal of Safety Research*, *Journal of Traffic Medicine*, *Traffic Injury Prevention*, *Transportation Research Part F*, and *Transportation Research Record*), the internet search engines now reveal additional studies published in medicine, engineering, law, policy, and public administration journals. In addition much of the research is only published as technical reports of government and public

research agencies, such as the NHTSA, the Federal Highway Administration (FHWA), and the Federal Motor Vehicle Carrier Safety Administration (FMVCSA) in the U.S.; the Road and Transport Research Institute (VTI) in Sweden; Institute for Transport Economics (TOI) in Norway; the Institute for Road Safety Research (SWOV) in Netherlands; the Department for Transport (DfT) in the United Kingdom; Institut Français Sciences et Technologies Transport a Ménagement Réseaux (IFSTAR) in France; and similar bodies.

There are also non-government organizations that are very active in research in this area such as the Insurance Institute of Highway Safety (IIHS) in the U.S., the Traffic Injury Research Foundation (TIRF) in Canada, and the Transport Research Laboratory (TRL) in England. Finally, there are university-based research centers that focus on highway safety such as the University of Michigan Transportation Research Institute, the Texas Transportation Institute at Texas A&M University, the Highway Safety Research Center of the University of North Carolina, the Institute of Transport Studies at the University of Leeds, the Monash University Accident Research Center, and the Centre for Accident Research and Road Safety at the Queensland University of Technology in Australia. All of these and many others have websites that describe their research activities and reports.

The rationale for a new edition

There were several reasons why I felt it was time to update the first edition of the book. First and foremost, the increasing interest in road safety beyond the domain of safety and into the domain of public health has generated an explosive growth in the number of research studies in this area. Second, the emergence of new study methods – specifically Field Operational Technique and Naturalistic Driving Studies – that brings research much closer to the actual driving context. Third, the plethora of electronic driver assistive systems that are designed to increase safety and infotainment systems that are designed to enhance the drivers' abilities to engage in non-driving tasks, at once improving and compromising driving safety. Fourth, the rapid shifting in urban transport from the car to the traditional and electric bicycles. Fifth, the shift toward sustainable lifestyle that is sweeping the world has also changed mobility patterns with a move toward cleaner vehicles, but more importantly with a shift toward alternative modes of transport such as bicycling, motorcycling, and walking, as well as combinations of the different modes of transport. All of these required updating all of the chapters in the first addition, as well as adding a chapter on the increasing role of bicycling (and electric bicycles) in the transportation system.

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