SAFE MOBILITY: CHALLENGES, METHODOLOGY AND SOLUTIONS

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TRANSPORT AND SUSTAINABILITY
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SAFE MOBILITY: CHALLENGES, METHODOLOGY AND SOLUTIONS

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For Dominique Lord:

"For my wife Leah and our son Javier, and to my mother Diane and my brother Sébastien and his family.

And especially for my father Laurent, who sadly passed away shortly before this book was finished."

For Simon Washington:

"I'd like to dedicate this book to my sister Karen, who is the most kind, compassionate, and loving sister–thank you for your unwavering support and encouragement over my career and life."

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Tom Brijs
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Rune Elvik
Per Gårder
Mazharul Haque
Narelle Haworth
Paul Jovanis
Francesca La Torre
Jianming Ma
Fred Mannering
Bhagwant Persaud

Ali Pirdavani
Mohammed Quddus
Michael Regan
Nicholas Saunier
Venky Shankar

The constructive comments provided by these individuals surpassed our expectations and reminded us of what a wonderfully supportive and collaborative discipline to which we have chosen to associate ourselves.

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CHAPTER 1

INTRODUCTION

Dominique Lord and Simon Washington

ABSTRACT

Purpose – *This chapter first provides the motivation for writing this book. It then describes the challenges involved with assessing societal safety through the analysis of transport system crashes. It concludes with a summary of the contents of the remainder of the book, identifying how various dimensions of the transport system challenges are addressed.*

Methodology/Approach – *This chapter discusses important real-world and methodological challenges that practitioners, academics and researchers face in making a more sustainable highway system through a reduction in the number and severity of transport network crashes resulting in fatalities, injuries and property damage.*

Findings – *The chapter first describes important challenges, such as complexity of the driving task, the challenges of engineering transport systems for humans, unanticipated effects that arise from differences between driver safety and security, the co-mingling of mobility modes of travel, and challenges in evaluating road safety. The chapters are separated into five general themes: driver behaviour, the transportation network, vulnerable road users, methods for understanding and predicting safety performance, and methods for evaluating safety impacts of countermeasures.*

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Practical Implications – *Comprehending the challenges associated with road crashes is a first step in making the roadway system more sustainable. This book provides a broad and understandable description of these challenges and how they can be overcome by academics and practitioners working in transport network safety management.*

Originality – *This book presents a clear understanding and offers insights about the challenges and potential solutions that can be brought to bear to make a more sustainable and safe transport system, whether it is located in an urban or rural area, and for a wide variety of functional classifications and designs. The topics covered in this book are intended to be useful and applied to tackle transport system management anywhere in the world.*

Keywords: Road crashes; road safety; societal risk; risk management; transport engineering; driver behaviour; pedestrians; transport network management; bicyclists

MOTIVATION FOR THE BOOK

Injuries to people and property arising from crashes on road transport networks around the world are staggering by any measure. Road crashes result in 1.33 million deaths annually and 78.2 million non-fatal injuries warranting medical care (Global Road Safety Facility at the World Bank & the Institute for Health Metrics and Evaluation, 2014). Road crashes are among the top 10 leading causes of death between the age of 1 and 59 – and exceed those arising from HIV, tuberculosis and malaria. Pedestrians using the transport network represent 35% of road injury deaths globally. The economic burden of crashes is astonishing. In the United States alone, for example, road crashes are estimated to have caused more than US$871 billion in economic loss and societal harm in 2010 (Blincoe, Miller, Zaloshnja, & Lawrence, 2015). Globally, it is estimated that 3% of gross domestic product (GDP) is lost to road crashes (fatal and non-fatal) and can be as high as 5% for low- and middle-income countries (WHO, 2015). Finally, road crashes have increased by 46% over the most recent two decades, highlighting the growing importance of the global road safety problem, reflecting in part increased mobility in developing countries and emphasising the importance of doubling down to tackle the problem (Global Road Safety Facility at the World Bank and the Institute for Health Metrics and Evaluation, 2014).

As a result of the health burden on global societies, significant questions arise about the sustainability of transport networks as they are currently built, operated and managed. This book is devoted to presenting a thorough review of what is currently known about global road safety and is authored by invited road safety experts from around the world with expertise in their targeted chapters. The intent of the book is to provide a broad, yet detailed reference that presents state-of-the-practice guidance regarding both academic and practical knowledge in transport network safety. The book is intended to be used by practitioners, academics, researchers and students interested in transport system safety. The hopeful and intended outcome of the book is to increase the level of knowledge on road safety contexts, issues and challenges; share what can currently be done to address the variety of issues; and understand what needs to be done to make further gains in road safety.

CHALLENGES IN REDUCING ROAD CRASHES

Improving road safety, or reducing the number of injuries and fatalities that arise during the pursuit of mobility on the transport network, is an enormous challenge. There is a large number of reasons why practitioners and academics struggle to reduce the negative societal impacts of road crashes. These challenges include the complexity of the driving task, the challenges of engineering transport systems for humans, the unanticipated effects that arise from differences between driver safety and security, the co-mingling of mobility modes of travel, and challenges in evaluating road safety. While all of these challenges are briefly discussed below with the intent to provide an introduction to these topics, additional detail is provided in the relevant chapters within the book.

Complexity of Driving Task

Driving is a phenomenally complex task. Driving requires that we are not impaired in any way, that we employ the use of all of our senses, that attention is paid at precisely all of the key moments, that we accurately predict what those around us are intending to do, and we possess sufficient coordination and manual dexterity leading to appropriate driving inputs. It requires us to continually monitor an extremely large number of inputs and not be distracted by things that may be unhelpful to the driving task. It requires us to appropriately manage the effect of our moods while driving, and to

responsibly manage the use of prescription drugs, alcohol and illegal drugs. Because driving demands are proportionate to the complexity of the driving environment, drivers are not required to provide constant vigilance – leading to a requirement for drivers to correctly anticipate when cognitive loads and subsequent driving inputs are relatively high or low. Different segments of the network also require different levels of skills and vigilance. High-speed highways are very different than parking lots, while urban city driving is different than driving near to schools. Driving also requires constant monitoring and prediction of the behaviour of other drivers, pedestrians and cyclists. Considering the routine activities of life, driving is very likely to be the most complex activity undertaken by the majority of people on a regular basis.

Engineering Transport Systems for Humans

A high level of safety is not the only attribute of a transport system that engineers strive to deliver through design. Transport systems are also designed to deliver efficient throughput, minimise congestion, support multiple users, link multiple modes of travel, provide equity of mobility and link important transport destinations. Designing all elements of these systems to be as safe as possible while simultaneously delivering other performance indicators often places road designers into difficult trade-off decision contexts regarding safety. As an example, providing efficient access for pedestrians and cyclists on transport networks is likely to put more cyclists and pedestrians at risk of conflict with motor vehicles. Similarly, providing high-speed travel on high-capacity roads increases the risk of injury and death when crashes occur. These trade-offs in transport network design cannot be ignored, as they govern the context of decision making with regard to major transport investments.

Differences between Driver Safety and Security

How drivers interpret and assess crash risk is complex, with large variability in driver responses to the designed road network. One driver may perceive crash risk as low while driving at night, maintaining posted speeds, while another driver may assess crash risk as high and select much lower driving speeds. Some drivers feel secure (with respect to risk assessment) following other drivers according to a 1-second time headway, while others feel secure driving with 2-second headways. When encountering reduced visibility, some drivers

may slow their speeds significantly, while others may only slightly adapt their driving to the changed conditions. These differences in driver responses to risk have been noted in a large number of observational and simulator studies and create challenges in the smooth operation of transport networks.

Co-Mingling of Mobility Modes

Transport systems are meant to serve a variety of users, including pedestrians, cyclists, motorists, motorcyclists and public transport users. The crash risk of these user groups varies drastically across the network and network design features. Fundamentally, pedestrians and cyclists lack the safety features that adorn modern vehicles. Safety features like airbags, dynamic stability control, anti-lock brakes and safety restraints work collectively and aggressively to protect motor vehicle occupants in crashes, yet do little to protect pedestrians and cyclists. The newest vehicles are designed to minimise injury risk with pedestrians, whilst some vehicles have pedestrian and cyclist warning detectors built into their systems. By and large, however, most vehicles on the road do little to assist in the protection of the transport system's vulnerable road users and are formidable obstacles when collisions do occur.

Challenges in Evaluating Road Safety

While operating transport systems safely is difficult enough, conducting rigorous scientific studies to quantify and understand crash risk in the transport network is fraught with challenges. The following partial list highlights some of the many challenges confronting the evaluation of road safety:

1. Road crashes are relatively rare events with respect to how much time is spent driving. In essence, this rarity translates to a difficulty in establishing crash trends that are reliable. Moreover, crash causes are quite varied and thus further compound the difficulty in establishing recognisable trends.
2. It is difficult to determine the actual causes of crashes. While most crashes will have a 'critical event' that triggers a sequence of events, it is often difficult to identify the 'trigger' and all of the essential events that followed. Without a reliable explanation of crash causes available at the 'scene of the crash', most of the conclusions drawn are extracted from statistical analysis of readily available site and driver features, which may or may not be directly related to a crash cause.

3. Road crashes are predominately caused by driver errors, which may inappropriately be attributed to roadway features upon subsequent analysis. It is estimated that about 93% of road crashes are caused by human error in part or in total (NHTSA 2008). Conversely, a crash where the primary trigger was inattention by inappropriately be attributed to a roadway design feature, as the *inattention* status of a driver is likely to be unavailable.
4. Because crashes are rare and analysts rely on detecting reliable trends to make safety recommendations, data are often aggregated and as such lose the resolution necessary to capture crash-specific conditions. Average annual daily traffic, for example, is often used to capture exposure to risk but rarely is indicative of the conditions at the actual times of crashes.
5. Evaluation studies aimed at assessing the impact on road safety before and after treatment are threatened by the lack of experimental control on the myriad of factors that can affect road crashes.
6. Simulator studies, while extremely useful for establishing relative risk (i.e., task A is riskier than task B), are notoriously difficult for establishing absolute risk. Moreover, there is not a straightforward method or theoretical underpinning for translating simulator risk to actual driving crash risk.
7. Crash surrogate measures that measure crash 'precursor' events, such as near-misses, are extremely promising tools for evaluating road safety, but are in their infancy in terms of relating crash surrogates to actual crash risk, are sometimes difficult to measure, and are likely to not be generalizable across countries, states and regions – and thus require local calibration.
8. Real-time crash prediction, with the aim of taking a proactive and immediate response to crash mitigation, struggles with the establishment of theoretical relationships between crash risk and microscopic traffic conditions. Moreover, while real-time prediction may become reliable in predicting conditions 'ideal' for crashes to occur, the methods suffer from high false-positive rates. The consequence of having many false positives is losing the confidence of the motoring public in assisting to mitigate traffic risk.

STRUCTURE OF THE BOOK

Chapters are grouped into both human behaviour and engineering design aspects of transport network operation, and road crash evaluation methodologies. All chapters aim to provide current state-of-the-practice knowledge on several questions: what do we know, what do we not know, and how we are going to find out? The chapters are grouped under five general themes: driver behaviour, the transportation networks, vulnerable road users, methods for

understanding and predicting safety performance, and methods for evaluating safety impacts of countermeasures.

Because the transport network is an engineered facility that relies on the diligent, consistent behaviour of pedestrians, cyclists and people operating motor vehicles (e.g., cars, motorcycles, buses, commercial vehicles, etc.), there are predictable and often undesirable behaviours that contribute to the road toll. Some of the behaviours are intentional, while others are unintended but are often equally risky. The transport systems we build also influence behaviour and safety performance. Some portions of the network are easier to navigate safely compared to others, and much is known about the traffic and design influences of the network on safety. The chapters that constitute the remainder of this book are organised as follows.

Opening the theme on driver behaviour, Chapter 2 discusses the role of driver licensing on motor vehicle crashes, covering a variety of topics, including graduated driver licensing programs, the role of parents in licensing, compliance and enforcement of licensing, driver testing and unlicensed driving. Graduated driver licensing programs have been shown to be effective, unlike many other driver training programs. Best practice in graduated driver licensing can assist in mitigating the risk of the young and inexperienced driving cohort.

Chapter 3 examines the role of aggressive driving and speeding in motor vehicle crashes, and the role that speeding-related crashes play in the global crash picture. How public attitudes, personal behaviours, vehicle performance, roadway design and laws and policies influence speeding and speed-related crashes are also discussed. Solutions to aggressive driving may include practical enforcement, intentional speed-related roadway design elements, education campaigns and automated driving.

Chapter 4 examines the role of driver distraction in motor vehicle crashes. Driver distraction may lead to reduced driving performance, detracting from the essential driving task and leading to increased crash risk. Empirical research supports the risk associated with some types of distraction – such as mobile phone use whilst driving that is rampant in many parts of the world – requiring an improved understanding of distraction. The links between distraction research and crashes are sparse and require further research. Solutions to distraction offering promise may include the use of technology, driver licensing, and education and training.

On the transport network theme, Chapter 5 presents the evidence around the safety performance of suburban and urban arterial roads – where a large proportion of motor vehicle crashes occur. Traffic characteristics and design features affect the performance of these facilities. While some of the features have known effects, others are inconsistent and are counter-intuitive.

Chapter 6 presents the collective knowledge around controlled access, typically high-speed facilities. While these facilities typically enjoy the highest design-standards of all roads, and also are typically prohibited from use by pedestrians and cyclists, crashes on these facilities tend to be severe.

Rural and urban intersection crashes are described in Chapter 7. The factors contributing to crashes at these locations are diverse and complex. Despite a large number of quantitative studies looking at these network locations, some factors reveal inconsistent effects on safety. Engineering design treatments need to be examined holistically to understand potential unintended effects and should be designed to satisfy Pareto improvement social equity criterion.

Chapter 8 focuses on the safety performance of roundabouts, which offer operational and environmental advantages, but may pose challenges to different road users. Specific features of roundabouts are very important in determining the way they operate, particularly with respect to pedestrian and cyclist safety.

Chapter 9 focuses on progress and issues remaining with real-time traffic operations and safety. The chapter focuses on the methods used to make sense of real-time traffic operations as they relate to safety, the limitations on data sources for implementing such programs and issues of inter-jurisdictional transferability.

Pedestrians, accounting for 35% of persons killed on transport networks globally, are the topic of Chapter 10, which opens the theme on vulnerable road users. Sidewalks are needed on all arterials and collector roads with pedestrian traffic greater than 50 per day to achieve acceptable levels of road safety. Elderly pedestrians require lows speeds and narrow streets to cross safely. Posted speeds yielding 90% speeds of no more than 30 km/h are a target for pedestrian-friendly and safe environments. While pedestrian travel is highly desirable from health liveability perspectives, we need to design more conducive and safe environments for pedestrians.

Another vulnerable road-user group is cyclists, the topic of Chapter 11. While cycling offers a sustainable and affordable solution for fulfilling mobility needs it poses some challenges with respect to safety – particularly when mixed with motor vehicle traffic. A variety of cycling infrastructure treatments are shown to be effective in improving cycling safety, including both on-road and off-road treatments. Getting the infrastructure right is critical for increasing cycling participation rates.

Chapter 12 is the first chapter to focus on crash evaluation methodologies. Cross-sectional data based on information gleaned from crash reports form the basis of many safety studies and require careful guidance on how these

data should be analysed. Commonly applied methods are presented in this chapter, along with important data features that represent more pesky yet important features of cross-sectional crash data analysis.

Time-series methods for assessing crash data are presented in Chapter 13. Because crashes are often observed over time, and safety investments often take time to accrue benefits, time-series methods can be extremely useful. While much of the book is focused on road safety, air travel as a transport mode is also of significant importance with respect to risk management. Examples in air safety are provided in this chapter to illustrate the state-of-the-practice techniques in time-series methods applied to assess crashes.

Because crashes are rare events, crash data often are characterised by many zeroes (lots of sites observed in a sample record zero crashes during the observation period). Characterising these data well is important to draw correct inferences from the data. Chapter 14 describes the most current thinking around dealing with these challenging crash datasets, and recommends methods for making sense of crashes from datasets with many zero responses.

Crash severity is an important characteristic of crashes. Because crash severity is the most accurate indicator of the societal harm caused by road crashes, methods designed to model and understand crash severity are discussed in Chapter 15. Data limitations hinder the ability to undertake large and accurate severity analyses. Several different methods explained in this chapter are useful for modelling and understanding what transport network features are related to road crash severity.

Chapter 16 presents the underpinnings of transport network screening, or safety management practice. This practice involves a large number of assumptions and makes significant use of crash modelling discussed in Chapters 12, 14 and 17. A variety of methodologies have been used over the years, with the Empirical Bayes method for identifying hot spots the most reliable.

Surrogate measures of safety are discussed in Chapter 17. Surrogate measures of safety are a rapidly growing subfield in transport safety. The fundamental dilemma of needing to wait for crashes to occur to gain information about how to prevent them is a primary motivator for developing this subfield of research. Identifying the pre-crash movements of vehicles (and other vehicles, pedestrians, cyclists, etc.) that relate to crashes that are expected to eventuate is the goal of this approach. Much of the current work in this area is described, along with where this subfield is headed.

In the last theme related to the safety impacts of countermeasures, Chapter 18 focuses on before–after safety evaluations. These types of investigations are thought to be the most reliable of all safety investigations, yet remain fraught with challenges. The chapter outlines the methods used to

conduct these studies, and identifies the salient features of these studies and solutions to overcome their technical difficulties.

Chapter 19 concludes the book, appropriately, with an overview of meta-analytic methods. These methods are used to make sense of a body of research – capitalising on the enormous resources that have already been invested to study a particular safety feature or problem. It presents the methodologies used to compile, assess and make sense of a sample of studies with varied findings across the studies. Because the overall sample size grows with multiple studies, there can be significant benefit in pooling the results to draw meaningful safety conclusions. This chapter provides a roadmap for conducting such studies in a rigorous way.

Overall, this book offers students, practitioners, academics and researchers both an in-depth and broad understanding of the issues and challenges related to road crashes and provides solutions that can be used to overcome these limitations in order to promote a more sustainable transport system by reducing the number and severity of road crashes.

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