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Surrogate Methods of Road Safety

K.V.R. Ravi Shankar and
Bhadradri Raghuram Kadali

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This book provides a comprehensive understanding of accident data collection, analysis, and the use of surrogate safety measures (SSMs) from both vehicular and pedestrian perspectives. It discusses the application of simulation tools for surrogate safety analysis, with an emphasis on risk estimation and the integration of machine learning techniques. This book also explores the use of augmented and virtual reality for road user training and assessment, as well as safety concerns related to automated and connected vehicles. Field case studies offer a realistic view of on-site assessments, safety implications, and measures for safety enhancement.

- Explores surrogate safety methods in detail, including the identification of surrogate measures and their applications.
- Examines various SSMs, such as Post-Encroachment Time and Time-to-Collision, and identifies suitable SSMs for mixed traffic conditions, highlighting their strengths and weaknesses.
- Discusses international codes and standards at appropriate points in each chapter.
- Covers statistical methods, including Support Vector Machines, binary logit models, and ordered logit models, for estimating severity levels.
- Includes worked examples and numerical problems for practical understanding.

This book is intended for senior undergraduate and graduate students in road safety engineering, transportation, and civil engineering.

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This book is dedicated to all the victims of the road
who lost their valuable life in road accidents

Contents

Authors' Biography

K.V.R. Ravi Shankar is working as Associate Professor in the Department of Civil Engineering, National Institute of Technology (NIT) Warangal, Telangana, India. Ravi Shankar received his Ph.D. from the Indian Institute of Technology Bombay in 2011. He is having 20 years of experience in the field of teaching and research. His research interests center on innovative road safety strategies, machine learning application for traffic management and road safety, pedestrian behavioral analysis and modeling, and crowd behavior modeling. Ravi Shankar guided eight Ph.D. thesis works and four more are in progress. He also guided 64 M.Tech. project works. He is the author of about 90 publications in leading international journals and conferences. He was awarded the Young Researcher [Engineering] Award in 2020 by NIT Warangal Alumni Association. He is a recipient of research grants from SPARC, Department of Science and Technology, and Ministry of Road Transport and Highways and has a collaboration with Lund University, Sweden and UNSW, Australia. He worked on consultancy projects related to development of toolkits, traffic management planning, intersection design, and road safety improvement. He is a reviewer of several transportation-related journals and a prominent invited expert on road safety-related topics.

Bhadradri Raghuram Kadali is currently working as Assistant Professor in the Department of Civil Engineering, National Institute of Technology, Warangal (NITW). Raghuram obtained his Ph.D. degree from the Indian Institute of Technology Bombay in 2017 and Masters in Transportation Engineering from NITW. He has eight years of teaching and research experience. He has guided one Ph.D., 20 M.Tech. dissertations, five B.Tech. project works, and currently three research scholars are pursuing their Ph.D. Raghuram has successfully completed three externally funded R&D projects as principal investigator and associated with another two projects as co-principal investigator. He is currently working in traffic safety, pedestrian travel behavior, and transportation planning. He has published 50 papers in reputed journals and international conferences.

Preface

Road safety is one of the crucial challenges faced by the present road transportation sector across the world. At one or other point of time, everyone in this world was a mute victim to the ever-increasing burden of road accidents. Accident frequency and severity are direct measures of road safety and accident data are used to measure road safety. But accidents are rare events and sometimes collection of sufficient accident data is not possible. In the absence of accident data, surrogate safety measures (SSMs) are used to predict and analyze the frequency and severity levels of possible potential traffic conflicts using videography data. SSMs are indirect and complementary safety measures, and they don't rely on accident data. SSMs are more proactive, more accurate, more informative, and more time efficient. In the recent past, the use of SSMs has been widely spread across the world.

This book is intended as a one-stop reference for safe system concepts along with various SSMs adopted by various agencies across the world, data collection procedures, and methods of analysis. This book lays the foundation for the benefit of practicing road safety engineers, traffic engineers, and transportation engineers in adopting the safe system concepts for creating a safer road network. Through extensive real-world examples, case studies, and practical relevance, this book explains the intrinsic principles of safer system approach. Furthermore, pedestrian safety, use of simulation methods, and augmented and virtual reality considering the safe system concepts are further presented as a part of this book.

Acknowledgments

This book includes many ideas and concepts experienced and taught by the authors as an instructor and researchers on topics related to road safety. We would like to acknowledge the research scholars, students, faculty colleagues, and administration of National Institute of Technology Warangal, Telangana, India for their valuable support and encouragement. We are particularly thankful to all those who were courageous enough to allow to use draft sentences, paragraphs, or sections as examples or problems in this book. We are also thankful to our family members and friends for the encouragement provided at various stages of the book preparation.

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1 Introduction to Road Safety

1.1 CURRENT STATUS OF ROAD SAFETY

Road traffic safety involves the implementation of strategies and measures to prevent fatalities and serious injuries among individuals using roadways. Common road users include pedestrians, cyclists, drivers, vehicle occupants, horse riders, and passengers of on-road public transportation. Globally, approximately 1.19 million people lose their lives in road traffic accidents each year, and an additional 20–50 million suffer non-fatal injuries. Around 92% of the global fatalities occur in low- and middle-income countries, though these countries carry 60% of the world's vehicular population. Vulnerable road users, such as pedestrians, cyclists, and motorcyclists with their passengers, account for more than half of these accidents. Road traffic injuries are the leading cause of death for individuals aged between 16 and 29 years, particularly affecting males under 25 years, who represent 73% of road traffic deaths. Developing economies, particularly low- and middle-income countries, bear a disproportionate burden, contributing to 93% of fatalities. Beyond the human toll, road traffic injuries impose a significant economic burden, encompassing treatment costs for the injured and the loss of productivity for those killed or disabled. These injuries also have a substantial impact on national economies, causing countries to lose 3% of their annual gross domestic product. Recognizing the severity of the situation, established measures exist to mitigate the risk of road traffic injuries and fatalities. The 2030 Agenda for Sustainable Development has set ambitious targets to address and reduce road traffic injuries.

In India, road transportation emerges as the most cost-effective mode for both freight and passenger travel, especially given its extensive coverage in densely populated regions. The country confronts heightened exposure to challenging traffic conditions due to increased motorization and urbanization, driven by a robust economic growth rate. Consequently, the incidence of road accidents, traffic injuries, and fatalities remains notably elevated. Globally, road accidents stand out as a leading cause of death, with a significant concentration among individuals aged 15–49. In the year 2023 alone, road crashes in India resulted in the loss of approximately 1.72 lakh lives and caused injuries to over 4.62 lakh individuals. Given that road accidents stem from a complex interplay of various factors, a comprehensive set of measures is imperative to reduce both the number of accidents and resulting fatalities.

In the calendar year 2023, States and Union Territories (UTs) collectively reported a total of 4,80,583 road accidents. These incidents resulted in the loss of 1,72,890 lives and caused injuries to 4,62,825 individuals. Notably, there was a 4.2% increase in the number of road accidents in 2023 compared to the preceding year, 2022. Similarly,

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fatalities and injuries stemming from road accidents also witnessed a rise, with a 2.6% and 4.4% increase, respectively. On average, this translates to 1,317 accidents and 474 deaths every day or 55 accidents and 20 deaths every hour in the country.

1.2 NEED FOR ROAD SAFETY MEASURES

In today's world of ever-increasing road accidents, road safety improvement plays a crucial role in safeguarding precious lives and burden on society. With an increasing vehicular population all over world, heavier traffic leads to a higher percentage and likelihood of accidents across countries. In fact, road accidents are the seventh leading cause of death in the world.

Most road accidents are caused by human error; although, sometimes unmaintained roads and horrible weather conditions lead to accidents, as well. The major factors that lead to traffic accidents are as follows: drunk driving, tiredness, speeding, road rage, failure to look or judge another car's speed properly, losing control of the vehicle, tailgating, distraction, carelessness, and inexperience.

There must be number of interventions required to arrest this abnormal increase in number of road accidents across the world. The government, non-governmental organizations, civilians, and more need to start initiatives toward more technical comprehensive safety improvement measures. Increased awareness of speed limits, alcohol limitations, seatbelt usage, child restraints, mobile usage, and construction zones needs to be emphasized. New policies need to be put in place to create safer streets, and older (but good) policies need to be enforced harder for them to take proper effect. Vehicles need to continue to evolve to be safe modes of transportation for not only the driver, but also for pedestrians and cyclists.

To lower the number of accidents, road traffic authorities need to assess problems with existing laws, rules, and systems to determine the real cause of accidents. A new and improved road safety strategy can then be put in place, which will have set actions to help prevent crashes from happening. In case of do-nothing scenario, as per the estimates of Association for Safe International predictions, traffic injuries will jump to the fifth leading cause of death by 2030 in the world.

1.3 REASONS FOR ROAD ACCIDENTS

Road traffic accident results from a combination of factors related to the components of the system comprising roads, the environment, vehicles and road users, and the way they interact. These can be grouped under the following heads as depicted in Table 1.1.

Some of these factors have a detrimental effect on the occurrence of road accidents. For example, every 1% increase in mean speed produces a 4% increase in the fatal crash risk and a 3% increase in the serious crash risk. Driving under the influence of alcohol and any psychoactive substance or drug increases the risk of a crash that results in death or serious injuries. In the case of drink-driving, the risk of a road

TABLE 1.1
Factors resulting in accidents

Road User Factors	Law and Enforcement	Road Factors	Vehicular Factors	Others
• Over-speeding • Distracted driving • Non-compliance of motorcycle helmets, seatbelts, and child restraints • Fatigue • Carelessness	• Inadequate speed limits • Need for national safety laws • Reliable enforcement strategies	• Pavement failures • Inadequate footpaths, crossings, intersection designs • Poor geometrical elements • Insufficient friction	• Unsafe vehicles • Improper tire pressure • Braking failure • Lack of adequate maintenance • Improper use of vehicle restraint system	• Inadequate post-crash care • Weather conditions like heavy rain, fog, and snow

traffic crash starts at low levels of blood alcohol concentration (BAC) and increases significantly when the driver's BAC is ≥0.2% (0.04 g/dl).

Correct use of helmet can lead to approximately 42% reduction in the risk of fatal injuries and 69% reduction in the risk of head injuries. Wearing a seatbelt reduces the risk of death among drivers and front seat occupants by 45–50%, and the risk of death and serious injuries among rear seat occupants by 25%. The use of child restraints can lead to a 60% reduction in deaths.

There are many types of distractions that can lead to impaired driving. The distraction caused by mobile phones is a growing concern for road safety. Drivers using mobile phones are approximately four times more likely to be involved in a crash than drivers not using a mobile phone. Using a phone while driving slows reaction times (notably braking reaction time, but also reaction to traffic signals), and makes it difficult to keep in the correct lane, and to keep the required following distances.

1.4 CAUSES AND EFFECT OF ROAD ACCIDENTS

Although road defects are not the major cause of road crashes, efforts to improve road design, construction, and maintenance are often highly cost-effective—and much easier than trying to improve the skills and attitudes of drivers. Research shows that there are three contributing factors to road crashes:

- Human factors (involved in about 95% of crashes)
- Road and road environment factors (involved in about 28% of crashes)
- Vehicle factors (involved in around 8% of crashes)