TRB Standing Committees

ANB10 – Transportation Safety Management

ANB20 – Safety Data, Analysis and Evaluation

ANB25 – Highway Safety Performance

Synthesis Report on Safety-Related Papers

presented at the 95th TRB Annual Meeting

Prepared by

Alfonso Montella, Mohamed Abdel-Aty, Mohamad Banihashemi, Frank Gross, Tomas Hall, Tarek Sayed, Raghavan Srinivasan, Andrew Tarko, and Lin Wang

TRB Standing Committee ANB10 – Transportation Safety Management

The committee will be concerned with the development and coordination of integrated safety management programs to reduce death and injury on transportation systems. Areas of concern include: 1) the advancement of safety management systems, 2) research and technology to improve safety, and 3) models of safety delivery systems.

Website: http://www.anb10.org

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TRB Standing Committee ANB20 – Safety Data, Analysis and Evaluation

This committee is concerned with the study of roadway safety. This includes the collection, maintenance and use of crash records and related roadway, road user, and vehicle data; the development of theories, analytical techniques, and evaluation methodologies for improving the understanding of roadway safety; and the application of these theories, techniques and methods to identify road user, vehicle and/or roadway-based treatments that will enhance roadway safety.

Website: https://sites.google.com/site/trbanb20/

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- Ezra Hauer

TRB Standing Committee ANB25 – Highway Safety Performance

This Committee deals with the advancement, integration and institutionalization of quantitative highway safety information to support transportation decision-making at all levels. The function of this committee is to foster the continual development, validation and increased knowledge of science-based methods, procedures and measures that will increase the safety of the nation's highways and roadways.

Website: http://www.safetyperformance.org

Membership as of December 2015

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Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 95th Annual TRB meeting. With this aim, papers sponsored by the Committees ANB10 – Transportation Safety Management, ANB20 – Safety Data, Analysis and Evaluation, and ANB25 – Highway Safety Performance have been split into subthemes and the abstracts reproduced. For each subtheme, a brief comment on the methodological and application perspectives of the presented papers is reported. Further, some papers sponsored by other Interacting Committees which are within the scopes of ANB10[1], ANB20[2], and ANB25[3] have been identified and classified in order to promote better interaction between ANB10, ANB20, ANB25 and these other Committees. Indeed, highway safety is a worldwide major social challenge which requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

This year, forty-six events sponsored by ANB10, ANB20, and ANB25 are planned:

- Four Committee meetings (see Table 1);
- Seventeen Subcommittee meetings (see Table 2);
- Three workshops (see Table 3);
- Fifteen lectern sessions (see Table 4); and
- Seven poster sessions (see Table 5).

The Committee meetings will be held on Monday morning from 8:00 AM to 12:00 PM (ANB20), Monday afternoon from 1:30 PM to 5:30 PM (ANB10), Wednesday afternoon from 2:30 PM to 6:00 PM (ANB25), and Thursday morning from 8:00 AM to 12:00 PM (ANB25).

The papers address the following topics (some papers are classified in more categories):

a) Crash Data and Data Analysis;
b) Network Screening;
c) Safety Performance Functions;
d) Crash Severity Prediction;
e) Crash Modification Factors;
f) Surrogate Measures of Safety; and
g) Transportation Safety Management.

[1] The committee will be concerned with the development and coordination of integrated safety management programs to reduce death and injury on transportation systems. Areas of concern include: 1) the advancement of safety management systems, 2) research and technology to improve safety, and 3) models of safety delivery systems.
[2] This committee is concerned with the study of roadway safety. This includes the collection, maintenance and use of crash records and related roadway, road user, and vehicle data; the development of theories, analytical techniques, and evaluation methodologies for improving the understanding of roadway safety; and the application of these theories, techniques and methods to identify road user, vehicle and/or roadway-based treatments that will enhance roadway safety.
[3] This Committee deals with the advancement, integration and institutionalization of quantitative highway safety information to support transportation decision-making at all levels. The function of this committee is to foster the continual development, validation and increased knowledge of science-based methods, procedures and measures that will increase the safety of the nation's highways and roadways.

Table 1 ANB 10, ANB20, and ANB25 Committee Meetings

Time	Title	Location
Monday, 8:00AM – 12:00AM	Safety Data, Analysis and Evaluation Committee, ANB20	Marriott Marquis, Ballroom Salon 12 (M2)
Monday, 1:30PM – 5:30PM	Transportation Safety Management Committee, ANB10	Marriott Marquis, Ballroom Salon 8 (M2)
Wednesday, 2:30PM – 6:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Ballroom Salon 8 (M2)
Thursday, 8:00AM – 12:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Liberty JK (M4)

Table 2 ANB 10, ANB20, and ANB25 Subcommittee Meetings

Time	Title	Location
Monday, 8:00AM – 9:45AM	Transportation Safety Planning Subcommittee, ANB10(3)	Marriott Marquis, Ballroom Salon 14 (M2)
Monday, 1:30PM – 3:15PM	Animal-Vehicle Collisions Subcommittee, ANB20(2)	Marriott Marquis, Ballroom Salon 14 (M2)
Monday, 7:30PM – 9:30PM	Animal-Vehicle Collisions Subcommittee, ANB20(2)	Marriott Marquis, Ballroom Salon 13 (M2)
Tuesday, 8:00AM – 9:45PM	Rural Road Safety Policy, Programming, and Implementation Joint Subcommittee of ANB10, AFB30	Marriott Marquis, Eastern Market (M3)
Tuesday, 10:15AM – 12:00PM	Emergency Medical Services Safety Subcommittee, ANB10(5)	Marriott Marquis, Ballroom Salon 16 (M2)
Tuesday, 3:45PM – 5:30PM	Bicycle and Pedestrian Safety Analysis Joint Subcommittee of ANB20, ANF10, ANF20, ANB25	Marriott Marquis, Ballroom Salon 14 (M2)
Tuesday, 3:45PM – 5:30PM	School Transportation Subcommittee, ANB10(6)	Marriott Marquis, Ballroom Salon 16 (M2)
Tuesday, 7:30PM – 9:30PM	Future Directions in Safety Analysis Joint Subcommittee of ANB20, ANB25	Marriott Marquis, Ballroom Salon 14 (M2)
Tuesday, 7:30PM – 10:00PM	Intersections Joint Subcommittee of AHB65, AFB10, AHB70, and ANB20	Marriott Marquis, Ballroom Salon 9 (M2)
Wednesday, 8:00AM – 9:45PM	Traffic Speed and Safety - Cross-cutting Issues Joint Subcommittee of ANB20, AHB65, ANB10	Marriott Marquis, Ballroom Salon 7 (M2)
Wednesday, 10:15AM – 12:00PM	Toward Zero Deaths Goal Subcommittee, ANB10(9)	Marriott Marquis, Ballroom Salon 7 (M2)
Wednesday, 12:15PM – 2:15PM	User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marriott Marquis, Ballroom Salon 7 (M2)
Wednesday, 12:15PM – 2:15PM	International Research Subcommittee, ANB25(5)	Marriott Marquis, Ballroom Salon 8 (M2)
Wednesday, 2:30PM- 4:00PM	Global Road Safety Subcommittee, ANB10(8)	Marriott Marquis, Ballroom Salon 7 (M2)
Wednesday, 6:15PM – 7:15PM	Policy and Legal Aspects Subcommittee, ANB25(1)	Marriott Marquis, Ballroom Salon 12 (M2)
Wednesday, 6:15PM – 7:15PM	Conferences and Meetings Subcommittee, ANB25(4)	Marriott Marquis, Ballroom Salon 13 (M2)
Wednesday, 7:30PM – 9:30PM	Combined Highway Safety Performance Research Subcommittees Meeting, ANB25(2)-ANB25(6)-ANB25(7)	Marriott Marquis, Ballroom Salon 12 (M2)

Table 3 ANB 10, ANB20, and ANB25 Workshops

Time	Title	Location
Sunday, 9:00AM - 12:00PM	(136) Global Applications of the Safe System Approach: Aiming for Zero Road Deaths	Convention Center, 103B
Sunday, 9:00AM - 12:30PM	(146) Doctoral Student Research in Transportation Safety	Convention Center, 103A
Sunday, 1:30AM - 4:30PM	(182) Introduction to SHRP 2 Roadway Information Database	Convention Center, 103A

Table 4 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(211) Rural Road Safety Research and Practical Applications	Convention Center, 206
Monday, 8:00AM – 9:45AM	(226) Highway Safety Update: State of the Practice and HSM Version 2.0	Convention Center, 203
Monday, 10:15PM – 12:00PM	(283) Toward Zero Deaths Policies in Action at Local and Regional Levels	Convention Center, 103A
Monday, 10:15PM – 12:00PM	(283) Impaired Driving in Low and Middle Income Countries: Challenges and Opportunities for Progress	Convention Center, 103B
Monday, 1:30PM – 3:15PM	(360) Accident Investigations by National Transportation Safety Board	Convention Center, 103A
Monday, 7:30PM – 9:30PM	(474) Vision Zero: Pathways to the Safe City	Convention Center, 151B
Tuesday, 8:00AM – 9:45AM	(486) Animal-Vehicle Collisions: Understanding and Reducing Risk for Driver Safety and Sustainability	Convention Center, 140A
Tuesday, 10:15AM – 12:00PM	(565) Emphasizing Human Factors in Highway Safety: Recognizing Road User Needs to Reduce Crashes	Convention Center, 101
Tuesday, 1:30PM – 3:15PM	(625) Advances in Highway Safety Performance	Convention Center, 103A
Tuesday, 3:45PM – 5:30PM	(680) Using Naturalistic Driving Study Data for Road Safety Analysis: Connecting Crashes to Safety-Critical Events	Convention Center, 101
Wednesday, 8:00PM – 9:45PM	(768) Analysis of International Road Safety Data	Convention Center, 103A
Wednesday, 8:00PM – 9:45PM	(769) Thinking Outside the Box When All the Funding Is in Boxes: Tools to Support Multidisciplinary Road Safety Decision Making	Convention Center, 102B
Wednesday, 10:15PM – 12:00PM	(820) Are Road Safety Research Results Used in Manuals, Policies, and Practices?	Convention Center, 102 B
Wednesday, 2:30PM – 4:00PM	(846) National Highway Traffic Safety Administration Data Systems and Services: Changes Are Coming	Convention Center, Salon B
Wednesday, 4:30PM – 6:00PM	(864) National Highway Traffic Safety Administration Vehicle and Behavioral Safety Research	Convention Center, 102B

Table 5 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 2:00PM – 3:45PM	(388) Highway Safety Performance	Convention Center, Hall E
Monday, 4:15PM – 6:00PM	(439) Current Issues in Ecology and Transportation	Convention Center, Hall E
Monday, 4:15PM – 6:00PM	(446) Case Studies in Performance-Based Analysis of Geometric Design	Convention Center, Hall E
Monday, 4:15PM – 6:00PM	(448) Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data	Convention Center, Hall E
Tuesday, 10:45AM – 12:30PM	(592) Active Research on Safety of Pedestrian and Bicycle Transportation	Convention Center, Hall E
Tuesday, 10:45AM – 12:30PM	(593) Safety Analysis with Surrogate Measures	Convention Center, Hall E
Tuesday, 2:00PM – 3:45PM	(656) School Transportation Research	Convention Center, Hall E

2 Crash Data and Data Analysis

Mohamad Banihashemi, GENEX Systems

Crash data and data anaysis covers a wide variety of subject areas in highway safety. There were forty papers identified that fit in this major category. The main sub-categories into which these papers could be split are calibration of crash prediction models, use of spatial data in safety analysis, connected and automated vehicles and safety, hotspots, pedestrian and bicyclists' safety, and vision zero. Besides these categories several papers were studying the effect of different factors on safety. These factors included travel-time reliability, rumble strips, fog density, socioeconomic factors, horizontal curves, weather, and distraction. Another group of papers were studying the safety of certain facility types including freeways, freeway-to-freeway ramps, freeways with HOV lanes, and diverging diamond interchanges.

Calibration of crash prediction models is a major step in using these models in safety evaluation of highways. Shirazi, M et al. (16-1844) and R. Srinivasan et al. (16-5237) studies the effect of data size on calibration. Colonna, P et al. (16-3413) has studies the effect of region selection factors on calibration. Qin, X. et al. (16-5043) presented an analytical approach on conducting calibration and S. Dadvar et al. (16-6750) suggested using CMF calibration factors instead of usual aggregated calibration factor.

Different uses of the spatial data in highway safety were proposed by M. Banihashemi (16-1454), M. Mohammed Ali (16-3117), and D. Carter et al. (16-6746). Proposing a quasi-horizontal alignment, spatial analysis of crashes, and vertical curves identification were the subject of these researches, respectively.

Effects of connected and automated vehicles (C/AV) on safety were studies by K. Kockelman et al. (16-1468) and W. Hao et al. (16-2086). Both papers were using GES records in their analyses.

Xing, J. et al. (16-4497) studied black spots charactristics in Japan and C. Chen et al. (16-4768) proposed a method to identify hotspots on urban expressways.

Noland, R. et al. (16-0410), R. Schneider et al. (16-4148), and K. Varela (16-5733) studied pedestrian and bicyclists' safety.

Vision Zero was the topic of papers submitted by A. Fleisher et al. (16-3828), B. Welle et al. (16-4189), and M. Brozen et al. (16-6697). These authors were basically offereing high-level policies and recommendations to advance Vision Zero.

Several papers were focusing on the effects of single factors on safety. Shi, Q. et al. (16-0407) studied the effect of travel time reliability on urban expressway safety. Ahmed, M. et al. (16-0601) were proposing an expert system to evaluate the safety effect of rumble strips. McCaan, K. et al. (16-1867) evaluated the effect of fog density on safety. Cesme, B. et al. (16-3475) studied the relationship between unsaturated green time and intersection safety.

Dube, C. et al. (16-5534) studied the effect of distraction-free laws on distraction-related crashes. Peck, D. (16-6792) looked at the effect of vehicle safety inspection on fatality rates. Brown, K. et al. (16-6874) investigated the effect of proximity to home on crashes. Wang, K. et al. 916-1114) developed a model to consider the effect of socioeconomic and land cover data on crashes. Banihashemi, M. (16-2702) studied the effect of horizontal curvature on crashes on urban artrials. And X. Ma et al. (16-4283) examined the effects of weather and traffic condition on crashes.

Specific types of crashes or safety of specific types of facilities were studied is several papers. Janstrup, K. et al. (16-1822) looked at the under-reported injury crashes. Pour Rouholamin, M. et al. (16-3999) analysed wrong-way driving crashes. Jalayer, M. et al. (16-4043) proposed a methodology to identify secondary crashes. Yang, B. et al. (16-5166), L. Wang et al. (16-1884), S. Srinivasan et al. (16-6333), and J. Hummer et al. (16-5481) proposed models for predicting crashes on freeways, freeway-to-freeway ramps, freeways with HOV lanes, and diverging diamond interchanges, respectively.

So, J. et al. (16-2608) proposed a microsimulation approach to enhance safety performance functions. Al Amili, S. et al. (16-3820) compared short-term traffic volume SPFs to the regular SPFs that are based on AADT. And A. Veeraragavan presented a methodology to analyse the level of safety of rural multilane highways.

Authors	Arielle Fleisher, San Francisco Municipal Transportation Agency Megan Wier, San Francisco Department of Public Health Mari Hunter, San Francisco Municipal Transportation Agency
Sponsoring Committee	ABE30, ANB10, ADD50
Session Number	474
Session Title	Vision Zero: Pathways to the Safe City
Paper Number	16-3828
Paper Title	Vision for Transportation Safety: Framework for Identifying Best Practice Strategies to Advance Vision Zero
Abstract	In this article we present the Traffic Safety Best Practices Matrix, a tool to help United States cities identify the landscape of strategies being used domestically and internationally to advance Vision Zero, as pioneered by Sweden. Many cities across the United States have expressed an interest in Vision Zero with a growing number passing policies calling for the elimination of traffic-related fatalities over the next decade. Despite the increase in interest, little guidance exists around what Vision Zero is and what actions could be implemented to help realize zero deaths. The Matrix, which culls together the results of an extensive examination of the measures that cities and countries are pursuing to reduce traffic-related fatalities and improve safety, attempts to bridge this gap by presenting a framework that cities can use to identify strategies, benchmark their efforts relative to other jurisdictions, and reach out to cities/countries pursing Vision Zero policies for additional information. We offer an analysis of the Matrix, focusing on three categories: measures with 1) widespread adoption, 2) limited implementation, and 3) minimal utilization. We discuss how these findings can inform next steps for Vision Zero implementation, with a focus on implications for U.S. cities. The main recommendations are to develop mechanisms that institutionalize Vision Zeroacross sectors, focus education on supporting changes in organizational practices and policy reform, improve collaboration across all levels of government, explore technology that meets the unique needs of cities, and create systems that facilitate accountability and encourage public participation.

Authors	Ben Welle, World Resources Institute (WRI) Wei Li, World Resources Institute (WRI) Claudia Adriazola-delgado, WRI
Sponsoring Committee	ABE30, ANB10, ADD50
Session Number	474
Session Title	Vision Zero: Pathways to the Safe City
Paper Number	16-4189
Paper Title	What Makes Cities Safer by Design? Review of Evidence and Rresearch on Practices to Improve Traffic Safety Through Urban and Sstreet Design
Abstract	Traffic fatalities kill over 1.24 million people globally each year, and are expected to rise to the 5 th leading cause of death in the world by 2030. The way cities are laid out in terms of their land uses and street grids, as well as how streets are designed can have great impact on traffic fatalities and injuries. Yet there are few resources that holistically review both urban and street design in fostering traffic safety for all road users. For this reason, this paper provides a compendium of the evidence on different urban and street design elements that embrace practices to (a)reduce exposure by preventing the need for vehicle travel, thus preventing a crash before a trip would even begin; and (b) diminish risk by encouraging safer vehicle speeds and prioritizing pedestrian and bicyclist safety. Measures were found in the following six categories to achieve this: 1) connected and compact urban design; 2) traffic calming measures to slow traffic to safe speeds for pedestrians; 3) managing safety on urban arterials, especially at intersections and in protecting vulnerable users; 4) prioritizing pedestrian facilities; 5) providing a connected network of safer bicycling infrastructure; and 6) creating safe access to high-quality public transport. This paper provides a basic review of evidence useful for safe system approaches to traffic safety, such as Vision Zero. More advanced meta-analyses and research in cities around the globe is needed to further inform effective urban and street design.

Authors	Madeline Brozen, University of California, Los Angeles (UCLA) Daniel Shockley, Fehr & Peers
Sponsoring Committee	ABE30, ANB10, ADD50
Session Number	474
Session Title	Vision Zero: Pathways to the Safe City
Paper Number	16-6697
Paper Title	Toward Best Practice Collision Aanalysis for Vision Zero Programs
Abstract	Many cities in the United States want to drastically reduce transportation-related deaths by implementing "Vision Zero" programs and policies. Given the financially-constrained circumstances American cities, many are turning to collision data analysis to prioritize and justify safety investments and roadway design changes. However, differences in methodology – such as geographic areas used – can lead to different results. Cities with Vision Zero policies in place have thoughtfully considered this issue in their approaches through protracted research and studies; however, not all cities have the resources for such an intensive project. We attempt to provide direction for public officials who wish to implement a Vision Zero policy by distilling common themes from peer-reviewed literature on bicycle and pedestrian crash determinants; examining current Vision Zero policies adopted in the United States; a Vision Zero implementation plan assignment from a graduate urban planning course; and our own analysis using collision data from Los Angeles, California. We then synthesize the prior work and our own analysis to recommend a framework for Vision Zero policies; highlighting the importance of bicycle and pedestrian data collection, recommending roadway corridors as the geographical unit of analysis, and strongly emphasizing transparency in the development of a methodology.

Authors	Qi Shi, University of Central Florida (UCF) Mohamed Abdel-Aty, University of Central Florida (UCF)
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0407
Paper Title	Evaluation of the Impact of Travel Time Reliability on Urban Expressway Traffic Safety
Abstract	In urban areas, toll expressways have been constructed in order to provide motorists with safe, efficient, and reliable transportation service. There are numerous studies that have investigated traffic safety or the relationship between safety- and efficiency. Currently, only limited attention has been paid to the analysis of how traffic safety and reliability are related. This study aims at identifying the effects of travel time reliability on crash frequency. Focusing on an urban expressway in Central Florida that is equipped with Automatic Vehicle Identification system, multiple travel time reliability indicators were developed. To accommodate the data structure in crash frequency modeling, Bayesian hierarchical Poisson lognormal framework was adopted. It was confirmed that the reduction of travel time reliability resulting from late arrivals would lead to more crashes. Nevertheless, not all crashes were affected by travel time reliability. As lower reliability is likely to cause inconsistent traffic flow and interactions between vehicles, its impact on multi-vehicle crashes therefore is much more significant compared to single-vehicle crashes. Despite travel time reliability's effects on traffic safety, the necessity of using a direct reliability measurement in safety analysis was assessed by calibrating models with only traditional traffic flow variables and structural equation models that express the effects of reliability through latent variables. Based on the comparison, it was suggested that to better understand the effects of travel time reliability on safety, inclusion of direct reliability measurement would be more efficient. This study shows that the improvement of travel time reliability through providing estimated travel times to drivers in real-time is not only beneficial to improve service and may be achieve smooth traffic flow, but it is also likely to improve safety.

Authors	Robert Noland, Rutgers, The State University of New Jersey Nicholas Klein, Temple University James Sinclair, Alan M. Voorhees Transportation Center Charles Brown, Alan M. Voorhees Transportation Center
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0410
Paper Title	Pedestrian Fatality Data Quality: Problems and Definitions
Abstract	Accurate data on pedestrian fatalities is of upmost importance to public health officials, transportation planners, police, and policy-makers. It is used to make strategic decisions about when and where to invest scarce resources to eradicate preventable deaths and improve safety for all modes. We analyzed data from one year of pedestrian deaths in New Jersey, the US state with the highest share of pedestrian deaths, and found that the data is severely lacking. Roughly one quarter of the 157 pedestrian deaths reported in New Jersey in 2012 should not have been classified as pedestrians.. Some of these fatalities should not be classified as pedestrians using the reporting definitions required by the National Highway Traffic Safety Administration (NHTSA), including some that are outright errors. Other fatalities are consistent with NHTSA's definition of a pedestrian, but are questionable from a planning and data analysis perspective, as most planners and decision makers would not consider the victims to be pedestrians. We discuss these alternate definitions and classify each fatality accordingly. Implications for research and planning are discussed and we emphasize the need to both improve data collection and management, as well as for NHTSA to reconsider how they define and track pedestrian fatalities.

Authors	Mohamed Ahmed, University of Wyoming Mirza Sharif, University of Wyoming Khaled Ksaibati, University of Wyoming
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0601
Paper Title	Developing Expert System for Shoulder and Centerline Rumble Strips and Stripes to Accommodate All Road Users
Abstract	According to the Federal Highway Administration, 53 percent of annual fatal crashes are attributed to lane and road departures. Lane departure crashes are considered the most severe crashes and often dominated by sleep deprivation/fatigue, and distracted driving. While lane departure crashes are mostly driven by drivers' errors, the frequency and severity can be reduced by more forgiving roadside and specific countermeasures. Rumble strips/ stripes are considered a relatively low cost proven safety countermeasure to reduce or prevent lane departure crashes. Although rumble strips have been used for many years, many states are in the process to update their policies to better accommodate all road users. In this paper, an Expert System was developed as an interactive Portable Document Format guidebook for rumble strips/stripes implementation criteria. Rule-based Expert Systems are being used widely in various engineering fields such as; highway management, traffic impact and safety, highway design and planning, etc. Rumble strips standards and provisions for different road users vary among State DOTs. The main objective of this paper is to accumulate information regarding rumble strips designs from various transportation agencies to aid transportation engineers in decision making process for rumble strips application. The Expert System on rumble strips was prepared by using all available recent rumble strips policies and guidelines obtained from various transportation agencies. Additionally, the results from surveys on DOTs, bicyclists, nearby residents, and motorcyclists have also been used for the Expert System design. Moreover, a description on how to use the Expert System is provided.

Authors	Mehdi Alirezaei, University of Central Florida (UCF) Nuri Onat, University of Central Florida (UCF) Omer Tatari, University of Central Florida (UCF) Mohamed Abdel-Aty, University of Central Florida (UCF)
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0666
Paper Title	Impacts of Climate Change on Road Safety: System Dynamics Approach
Abstract	Road safety is one of the most complicated issues related to transportation, involving many interdependencies. Therefore, analyzing issues related to road safety requires a novel system based approaches in which feedback relationships, causal and side effects are taken into consideration. In this study, issues related to traffic accidents are investigated by considering major reasons of accidents (vehicle safety factor, transportation infrastructure factor, and driver's factor) and their complex relationships with climate change and certain economic parameters. System dynamic modeling approach is used to model the nexus of Climate Change-Road Safety-Economy, investigating the interaction between these important areas and tracking the way they are affecting each other over time. The proposed model can provide a platform for policy makers to investigate different scenarios in order to reduce the negative consequences of traffic accidents and the ways to improve the road safety. In this regard, a set of policies related to carbon emission reduction, reducing the travel demand, and improving vehicle safety index are tested to show the system behavior within the context of Climate Change-Road Safety-Economy nexus. Although reducing transportation related emissions alone cannot eliminate or reduce negative effects of climate change on road safety, reducing greenhouse gas emissions worldwide can significantly reduce the fatalities resulting from road accidents thanks to fewer extreme weather events, infrastructure damage, and distraction to the drivers. Reducing the travel demand and improving vehicle safety index can significantly reduce the number of fatalities and should be prioritized.

Authors	Kara Kockelman, University of Texas, Austin Tianxin Li, University of Texas, Austin
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1468
Paper Title	Valuing the Safety Benefits of Connected and Automated Vehicle Technologies
Abstract	Connected and automated vehicle(C/AV) technologies have a promising future in improving traffic safety, including mitigating crash severity and decreasing the possibility of crashes by offering warnings to drivers and/or assuming vehicle control in dangerous situations. Given the complexities of technology interactions and crash details, the overall safety impacts of multiple C/AV technologies have not yet been estimated. This research seeks to fill that gap by using the most current General Estimates System crash records to estimate the economic and comprehensive crash-related savings from each C/AV application. Safety benefits of Forward Collision Warning, Do Not Pass Warning, Lane Departure Warning, Control Lost Warning, Cooperative Intersection Collision Avoidance Systems, Adaptive Cruise Control, Electronic Stability Control, and other safety-related C/AV-type technologies are estimated here. Results suggest that eleven C/AV technologies, such as Forward Collision Warning combined with Adaptive Cruise Control, and Road Departure Crash Warning coupled with Lane Keeping Assist, can save Americans $140 billion each year (along with almost 2 million functional-life-years saved per year), based on pre-crash scenarios that depict the critical event occurring immediately prior to a crash (e.g., rear-end and run-off-road situations) and on the assumption that C/AV technologies reduce each associated crash's cost by 80%, thanks to crash avoidance and/or moderation of crash severity. Among the various combinations of safety applications, CICAS coupled with AV technology is anticipated to offer the biggest safety benefits, by saving more than $64 billion (in economic costs) and 820,000 functional person-years in 2013.

Authors	Mohamadreza Banihashemi, GENEX Systems
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1454
Paper Title	Using Quasi-Horizontal Alignment in the Absence of the Actual Alignment
Abstract	Horizontal alignment is a major roadway characteristic used in safety and operational evaluations of many facility types. The Highway Safety Manual (HSM) uses this characteristic in crash prediction models for rural two-lane highways, freeway segments, and freeway ramps/C-D roads. Traffic simulation models use this characteristic in their processes on almost all types of facilities. However, a good portion of roadway databases do not include horizontal alignment data; instead, many contain point coordinate data along the roadways. This data can be used to extract actual horizontal alignment data. Unfortunately, extracting horizontal alignment is a cumbersome and costly process, especially for a database of miles and miles of highways. This research introduces a so called "Quasi-Horizontal alignment" that can be produced easily and automatically from point coordinate data and can be used in the safety and operational evaluations of highways. SHRP 2 Roadway Information Database (RID) for rural two-lane highways in Washington State is used in this study. In the RID geodatabases, only about 5% of the highway sections have actual horizontal alignment data. This paper presents a process through which Quasi-Horizontal alignments are produced from point coordinates along highways by using spreadsheet software such as MS EXCEL. It is shown that the safety and operational evaluations of the highways with Quasi-Horizontal alignments are almost identical to the ones with the actual alignments. In the absence of actual alignment the Quasi-Horizontal alignment can easily be produced from any type of databases that contain highway coordinates such geodatabases and digital maps.

Authors	Kira Janstrup, Technical University of Denmark Sigal Kaplan, Technical University of Denmark Tove Hels, Danish National Police Jens Lauritsen, Odense University Hospital Carlo Prato, Technical University of Denmark
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1822
Paper Title	Understanding Traffic Crash Under-Reporting: Linking Police and Medical Records to Individual and Crash Characteristics
Abstract	While the literature in road safety has demonstrated that national crash databases are a valuable resource for the analysis of crash frequency and severity, it has also been shown that these databases suffer from the phenomenon of crash under-reporting. This study aligns to the body of research dedicated to estimating the under-reporting rate of crashes by employing the capture-recapture method on available medical and police records. Data consist of records of road users who reported their involvement in a road crash to the police and/or emergency rooms on the island of Funen in Denmark between 2003 and 2007. Moreover, this study estimates the probability for road users reported in police records to appear in hospital records (and vice versa) by estimating joint binary logit models. Results show that the likelihood of appearing in both datasets is positively related to helmet and seat-belt use, number of motor vehicles involved, alcohol involvement, higher speed and lane number, and females being injured. Interestingly, marital status and education level are not found to be associated with the probability of reporting to both the hospital and the police.

Authors	Katie McCann, University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1867
Paper Title	Examination of the Safety Impacts of Varying Fog Densities: A Case Study of I-77 in Virginia
Abstract	Fog can represent a significant safety hazard for motorists. While several studies have examined how fog crashes differ from crashes in clear conditions, they have treated fog as a homogeneous condition and not considered the safety impact of varying fog densities. I-77 in Fancy Gap, Virginia was used as a case study to better understand how safety changes as a function of available visibility. This study used crash, speed, visibility, and traffic data to characterize typical fog events, determine differences in crash characteristics by the severity of fog, and determine how speed profiles change with the density of fog. The analysis found that crashes in fog are more likely to be severe and involve more than two vehicles, supporting the findings of prior studies. While drivers reduce their speed in fog, the mean speeds exceeded safe speeds under all fog conditions. Examination of crashes and speed profiles by severity of visibility reduction showed that the level of available visibility impacts safety. The analysis showed that the presence of any fog has a negative effect on safety, with differential effects being observed depending on the severity of visibility reduction. Safety worsened when visibility drops below the stopping sight distance for the roadways, and then further degraded when visibility dropped below 360 feet. The results show that safety impacts of fog are not uniform across fog densities, and that mitigation efforts should be focused on areas experiencing recurring dense fog.

Authors	Wei Hao, City University of New York (CUNY) Camille Kamga, City College of New York Dan Wan, City College of New York
Sponsoring Committee	ANB20
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-2086
Paper Title	Analysis of Collisions and Applicability of V2V Solutions for U.S. Urban Areas
Abstract	The automobile industry has always shown a great interest in the adoption of safety technologies to improve the safety of its passengers and drivers, as well as road users including pedestrians. This paper prioritizes and statistically describes pre-crash scenarios as a basis for the identification of crash avoidance functions enhanced or enabled by vehicle-to-vehicle (V2V) communication technology in urban areas. Pre-crash scenarios depict vehicle movements and dynamics as well as the critical event immediately prior to the crash. Crash statistics are obtained from national crash databases including the 2011-2014 General Estimates System database. Based on the findings, recommendations for potential application areas for connected vehicle safety are introduced. This paper delineates the priority pre-crash scenarios and maps them to V2V-based safety applications under development.

Authors	Mohammed Mohammed Ali, University at Albany,SUNY
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3117
Paper Title	Network Spatial Analysis for Motor Vehicle Accidents
Abstract	The clustering approach of the spatial distribution analysis was adopted to spatially analyze the motor vehicle crashes in the City of Albany, NY. The study has two main objectives: First, to statistically determine significant clustered/non-clustered pattern for specific accident's types at specific distances on the network, second, to locate and map the identified clusters on the network. Instead of the traditional planar spatial analyses / methods (in which analysis conducted on two dimensions area unit), the study use the network spatial analyses / methods (in which analysis conducted over one dimension linear unit). Two main statistical methods were used to achieve the two objectivities of the study, the network k-function (to measure clustered/non clustered pattern and geographic clustering scales), and the network kernel density estimation (to determine where these clusters occur on the network). The New York State Department of Transportation's (NYSDOT) crash data with x, y coordinates from Jan 2013 to March 2014 with total 6953 accidents was used for this purpose. 17 types of accidents were set for the analysis. These classes of accidents were classified based on many variables, such as driver's characteristics, weather condition, temporal variables, type of collusion, intersections' traffic control and reported causes of accidents. The finding indicate that there is low variation among crash types in terms of the spatial scale where clusters occur, while there is a high variety of the locations where these clusters occur at the segment level. The strongest crashes' clusters occur on major and collector streets with variation at segment level for each type.

Authors	Burak Cesme, AECOM Peter Furth, Northeastern University Daniel Dulaski, Northeastern University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3475
Paper Title	Relationship Between Unsaturated Green Time and Safety at Signalized Intersections
Abstract	Signalized intersections are among the leading causes of roadway fatalities. To improve safety at signalized intersections, contributing factors to crashes need to be better understood. This paper tests the hypothesis that safety is negatively related to unsaturated green time at signalized intersections. It is hypothesized that long periods of unsaturated green increase the likelihood of crashes at signalized intersections through three mechanisms: 1. Speeding is more likely to occur during unsaturated green periods; 2. During long periods of unsaturated green, pedestrians and left turning drivers may be tempted to make risky/unsafe crossings; and 3. Long unsaturated green periods lengthen the signal cycle, which in turn results in long delays for pedestrians, increasing the likelihood of pedestrian non-compliance. To explore the relationship between safety and unsaturated green time, intersection crash data, traffic volumes, and signal timing data were obtained from three locations. Wasted green time is used as an indicator of unsaturated green time because it can more easily be measured from available data. Crash rate was used as an indicator of safety. The analyses are limited to weekday morning and evening peak hours because of limitations on operational data. The analyses show that total crash rate at signalized intersections tends to increase as wasted green time increases. Two of the three data sets indicated a statistically significant positive correlation between wasted green time and crash rate when all crash types were considered. However, no significant positive correlation was observed for any of the data sets between wasted green time and injury crash rate.

Authors	Mahdi Pour Rouholamin, Auburn University Huaguo Zhou, Auburn University Beijia Zhang, Auburn University Rod Turochy, Auburn University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3999
Paper Title	Comprehensive Analysis of Wrong-Way Driving Crashes on Alabama Interstates
Abstract	Crash data on Alabama interstates were collected across a five-year time period from 2009 to 2013, and true wrong-way driving (WWD) crashes and their locations were identified using the hardcopy of crash reports and existing maps. A univariate analysis of each variable – supplemented with p-value, odds ratio (OR), and corresponding confidence intervals – was performed to examine the influence of each variable on the dichotomous dependent variable (type of crash, i.e., WWD vs. non-WWD). The univariate analysis was then completed with a Firth's penalized-likelihood logistic regression model to control the influence of all confounding variables on the probability of WWD crashes while considering the rareness of the event (WWD). The results indicate that modeling WWD crash occurrence using Firth's model is appropriate. Explanatory variables such as time of the day, driver age, driver mental and physical condition, roadway condition, and distance from driver's residency were found to characterize WWD crashes. Other than analysis of crash data, a comprehensive field review of 49 locations with a history of WWD crashes was conducted to identify possible general issues in terms of signage, pavement marking, and geometric design element. The angle of signs, the lack of some signs, and the disproportional size of some signs were found to be general issues in terms of signage. Regarding pavement marking, faded stop lines and lane-use arrows, and lack of wrong-way arrows and lane-line extensions were identified to be common among the locations.

Authors	Mohammad Jalayer, Auburn University Fatemeh Baratian Ghorghi, Auburn University Huaguo Zhou, Auburn University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4043
Paper Title	Identifying and Characterizing Secondary Crashes on Alabama State Highway System
Abstract	Secondary crashes (SCs) are crashes resulting from non-recurring congestion and other unexpected surrounding conditions affected by a primary crash. This type of crash results in further disruptions and congestions. Previous studies showed that more than 20 percent of the primary crashes lead to SCs and the average duration of SCs is longer than the average duration of any other crashes, representing the necessity of further attempts. In order to identify the SCs, it is required to advance investigate their characteristics. However, there is a lack of available information to link a primary crash and a secondary crash, especially from the standpoint of time and location. This paper aims to develop a method to identify secondary crashes and then to study the statistical characteristics of this type of crash based on different criteria including, collision type, severity level, time of day, area type, average emergency response duration, and roadway classification from available historical crash databases and without the necessity of further data collection efforts. A proportional test was conducted to examine the statistically significant difference between the characteristics of the primary and secondary crashes. The study uses the latest available dataset (2010 to 2013) from the critical analysis reporting environment (CARE) to point out the secondary crash locations in the state of Alabama. The outcome of this study can help state and local agencies to identify SCs for performance measure of their incident management program and to develop countermeasures to prevent SCs.

Authors	Robert Schneider, University of Wisconsin, Milwaukee Joseph Stefanich
Sponsoring Committee	ANB20
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-4148
Paper Title	Application of the Location-Movement Classification Method for Pedestrian and Bicycle Crash Typing
Abstract	Annual pedestrian and bicycle fatalities remained steady while motor vehicle fatalities declined during the last decade in the United States, underscoring the need for better methods of pedestrian and bicycle safety analysis. This study presents a new method of classifying pedestrian and bicycle crashes called the location-movement classification method (LMCM) and shows that the LMCM provides useful information that is not captured by a well-established National Highway Traffic Safety Administration (NHTSA) crash typology. Both typologies were applied to a sample of 296 pedestrian and 229 bicycle crashes reported in Wisconsin between 2011 and 2013. The LMCM revealed that pedestrian crashes of all injury severity levels were significantly more likely to be on the far side than the near side of intersections. Pedestrian crashes were significantly more likely to be fatal than non-severe when they involved motorists traveling straight, were along roadways between intersections, and involved pedestrians approaching from the motorist's left. Bicycle crashes were significantly more likely to be fatal than non-severe when they involved motorists traveling straight, were along roadways between intersections, and involved motorists traveling in the same direction as the bicyclist. These results support engineering, education, and enforcement strategies that can reduce fatal and severe pedestrian and bicycle crashes.

Authors	Jian Xing, Nippon Expressway Research Institute Shoichi Hirari, Nippon Expressway Research Institute
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4497
Paper Title	Characteristics of Black Spots on Interurban Motorways in Japan
Abstract	Thanks to various traffic safety measures, the total number of automobile accidents in Japan has been declining in recent years, but the number of accidents on motorways has not lowered as much. In this research, we have extracted 145 black spots on entire interurban motorways in Japan and analyzed the accident data to sort out the characteristics of all the black spots, which can be used as basic data for developing and applying more effective traffic safety measures. We also analyzed the road structural and accident data of each black spot to categorize the typical black spot patterns. As a result, altogether eight typical patterns have been identified, and their potential countermeasures are proposed for each pattern. As for S-shaped curves, the relations of accident-prone points within the curve and the shape of the curve are especially analyzed to take a closer look at how and where accidents occur within an S-shaped curve.

Authors	Bo Yang, Southeast University Chengcheng Xu, Southeast University Zhibin Li, Southeast University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-5166
Paper Title	Identifying the Characteristics of Crashes on Different Types of Freeway Segments
Abstract	This study aimed to explore crash characteristics and contributing factors to crash on different freeway segments. The used crash and traffic data were collected on the I-880 freeway for six years in California, United States. Unlike most of the previous studies on freeway segments, this study separately investigates basic freeway segments (type N), single-ramp influence segments (type M, type W, and type D) and multiple-ramp influence segments (type MM, type DD, type MW, and type WD). The analysis of crash rates on different freeway segments showed that the total crashes, injury or fatal crashes and rear end crashes are more likely to occur on MW segments, while the sideswipe and hit object crashes are more likely to occur on DD segments. The crash characteristics on different freeway segments then were analyzed by the nonlinear canonical correlation analysis (NLCCA) and proportionality tests. The results showed that WD segments are more likely to have an injury or fatal crash, while DD segments are more likely to have a property damage only (PDO) crash; MM segments are more likely to have a sideswipe crash, while WD segments have an opposite effect; WD and MW segments are more likely to have a rear end crash; MM segments are less likely to have a hit object crash as compared to other segments. The contributing factors were identified by binary logit models, and the results showed that different traffic variables, environmental variables and geometric variables significantly affected the likelihood of crashes on different freeway segments.

Authors	Christina Dube, VHB Cole Fitzpatrick, University of Massachusetts, Amherst Jennifer Gazzillo, University of Massachusetts, Amherst Michael Knodler, University of Massachusetts, Amherst
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-5534
Paper Title	Improved Identification of Distraction-Related Crashes and Impact of Distraction-Free Driving Laws
Abstract	Christina Dube, VHB Cole Fitzpatrick, University of Massachusetts, Amherst Jennifer Gazzillo Michael Knodler, University of Massachusetts, Amherst Distracted driving is a dangerous activity that continues to claim lives on the Nation’s roadways. This research used police-reported crash data to analyze distraction-related crashes before and after passage the Safe Driving law in Massachusetts. An initial task completed within this research was an evaluation of the process by which distraction crashes are identified. Using a crash report narrative key word search, an estimate of the amount of distraction crashes that are mischaracterized was established. Additionally, the key word search was used to validate the accuracy of distraction-related crashes reported via the driver contributing code field on the crash report form. Using the crash data, statistics for a period of two years before and after the implementation of the Massachusetts Safe Driving Law, a statewide ban on texting while driving, were compared. The research results provide valuable information for safety practitioners in targeting specific segments of the population that are likely to be engaged in distraction-related activities while driving. The use of GIS was also incorporated to provide a spatial representation to the various distraction-related crash percentages and equivalent property damage only (EPDO) results. The results from this research indicate that distracted driving remains a prominent and primary cause for crashes even after the passage of a texting ban; however the inability to control for several key factors, such as VMT by age and phone subscribers, limit some of the direct conclusions that can be drawn. The results do, however provide a solid baseline for subsequent analyses moving forward.

Authors	Karen Varela, California State Polytechnic University, Pomona
Sponsoring Committee	ANB20
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-5733
Paper Title	Pedestrian Safety at Intersections: Examination of Intersection Safety in City of Los Angeles, California
Abstract	Determining the characteristics that increase the risk of pedestrian-vehicle collisions at intersections is critical as they are meeting points for these modes with different hierarchy of vulnerability. The purpose of this study is to further explore the relationship between the pedestrian-vehicle collision rates at intersections in relation to the characteristics of roads and surrounding environments. One-hundred intersections were randomly chosen and visited at City of Los Angeles. The following variable were collected through direct observation: traffic control type, number of permissive right turns and left turns, number of protected left turns, number of lanes, number of dedicated left turn lanes, number of bike lanes, presence of gas stations, Average Daily Traffic (ADT) and whether on-street parking was permitted. Through an ordinary least square (OLS) regression, it was found that the relationship between pedestrian-vehicle collisions rates and the presence of gas-stations is statistically significant. Results also showed that ADT and permissive left turns are statistically significant.

Authors	Daniel Carter, UNC Highway Safety Research Center Raghavan Srinivasan, University of North Carolina, Chapel Hill
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6746
Paper Title	The Hills Are Alive: Identifying Vertical Curves Using Strategic Highway Research Program Roadway Data
Abstract	The second Strategic Highway Research Program (SHRP2) conducted a massive data compilation consisting of detailed roadway data, driver behavior, and vehicle kinematics. A research study recently funded by the SHRP2 Implementation Assistance Program is using SHRP2 data to provide valuable information about how drivers behave under various combinations of vertical and horizontal alignment. In this study, it was necessary to identify the presence and location of vertical curves. The objective of this paper is to present and compare two methods for identifying vertical curves using the SHRP2 RID grade data. Each method is assessed against a hypothetical road with artificially created vertical curves and a section of an actual road in Washington State which contains a ground truth vertical curve inventory. The best performing method used a linear correlation element to detect when a set of road segments formed a vertical curve. This method accurately identified the presence of vertical curves without identifying curves where none existed, although it generally underplayed the length of the curves. This is a promising result, since the objective for the overall safety study was to identify vertical curve locations. This paper demonstrates that there are good options for interpreting the data to identify vertical curves. The development of the linear correlation method represented an advancement over the simplistic difference of average grades. Comparisons to a hypothetical road and a real world road with ground truth proved useful to identify the best performing method and determine the optimal parameters for the method to produce the most accurate results.

Authors	Dana Peck, Carnegie Mellon University
Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6792
Paper Title	Effect of Vehicle Safety Inspections on Urban and Rural Fatality Rates
Abstract	There are many government officials questioning the effectiveness of the vehicle safety inspection program, in locations where it is currently implemented. Presently, there are no studies either supportive or unsupportive of the program, leaving many states modifying and even discontinuing their program due to the lack of evidence. Until there is evidence showing inspections are ineffective, no steps should be taken to discontinue safety inspection programs. This leads to two weaknesses in the transportation sector today; there is still a non-zero fatal crash rate and robust data is difficult to obtain. Currently, NHTSA provides publically available data for all fatal crashes as well as national sampled crash data. Data collection of these two databases varies in both process and content, leading to low quality, combined datasets. Consistency, availability, and oversight of data collection are necessary for using data to identify benefits and dangers on any topic. Also with the push for "big data" and the implementation of more automated vehicles, robust data is at an even higher demand. This paper applies ordinary least square regressions and two-sample tests of proportions to provide any further insight on the effectiveness of the vehicle safety inspection program. Fatalities and fatal crashes per vehicle miles traveled are calculated separately for both urban and rural areas to compare states with current safety inspection programs to states without. Numerous models are implemented to account for any state variation in a program. Then safety crash causes are evaluated to determine if crashes attributed to safety causes are lower in safety states than non-safety states. Furthermore, crashes attributed to non-safety causes are also compared assuming there should be no noticeable difference. While not every regression result was found to be significant in support of safety inspection programs, no regressions were significant and unsupportive of the program. About 95% of the models showed a decrease in fatal crash rates. The evaluation of safety-attributed crashes was more complicated and the results were not as expected. Results showed that safety crashes were statistically higher in safety states and non-safety crashes were statistically lower in safety states. It must be kept in mind that by filtering to look at crash cause, some data is lost as there are no crash attributes recorded, or they were unknown. This led to the conclusion that data collection and entry must be more uniformly entered across the nation to do similar analyses since these results contradict the regression results that safety states have lower fatality rates overall. Even though only a handful of regression models showed significance in an effective program in reducing fatality rates, almost all of the models still showed this effect of decreased fatality rates with a safety inspection program. Perhaps with more robust data, stronger results could be obtained.

Authors	Kweku Brown, Clemson University Wayne Sarasua, Clemson University Jennifer Ogle, Clemson University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6874
Paper Title	Too Close to Home? An Investigation into Crash Proximity Relative to Driver Residences in South Carolina
Abstract	A poll by a major insurance company in 2001 found that over 50% of crashes polled occur with within 5 miles from the residences of those involved in the crash. This paper investigates the proximity of traffic crashes from driver residences and how the limited capabilities of geographic information system (GIS) software and tools at the time. The lack of academic literature with regard to crash proximity to homes and other land uses is the primary motivation for this paper. Previous studies identified in the literature were based on Euclidean distance rather that network distance. This research takes advantage of the advanced network and spatial analysis capabilities to analyze crash location proximity to drivers' residences. Driver data from nearly 700,000 crashes in South Carolina from 2007 to 2012 are used in the analysis. The analysis varies significantly from survey results reported by Progressive which indicate that over 50% of crashes occur within 5 miles of the driver's residence. While the data in this study report accurate crash and residence location, the Progressive survey relies on self-reported data which tends to be over-estimated. The crash proximity distributions do not vary based on severity, gender, year, or fault. Crash proximity distances are lower compared to NHTS trip distances at 5 miles or less from home and gradually increases to more than trip length percentage after 5 miles. At the 20 and 30 miles from residence categories, women's risk ratios are 16% and 28% greater than men's.

Authors	Kai Wang, University of Connecticut John Ivan, University of Connecticut Amy Burnicki, University of Connecticut Sha Mamun, University of Connecticut
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-1114
Paper Title	Predicting Local Road Crashes Using Socioeconomic and Land Cover Data
Abstract	Estimating and applying safety performance functions (SPFs), or models for predicting expected crash counts, for roads under local jurisdiction is often challenging due to the lack of vehicle count data to be used for exposure, which is a critical variable in such functions. This paper describes estimation of SPFs for local road intersections and segments in Connecticut using socio-economic and network topological data instead of traffic counts as exposure. SPFs are developed at the traffic analysis zone (TAZ) level, where the TAZs are categorized into six homogeneous clusters based on land cover intensities and population density. SPFs were estimated for each cluster to predict the number of intersection and segment crashes occurring in each TAZ. One aggregate SPF using the entire dataset was also estimated to compare with the individual cluster SPFs. The number of intersections and the total local roadway length were also used as exposure in the intersection and segment SPFs, respectively. Total population, retail and non-retail employment and average household income are found to be significant variables. Ten percent of the observed data points were reserved for out of sample testing and in all cases, these out of sample predictions were as good as the in sample predictions.

Authors	Juneyoung Park, University of Central Florida (UCF) Mohamed Abdel-Aty, University of Central Florida (UCF)
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-1673
Paper Title	Using Generalized Nonlinear Models to Develop Crash Modification Factors for Multiple Cross-Sectional Features of Urban Arterials
Abstract	This research evaluates the safety effectiveness of multiple roadway cross-section elements on urban arterials for different crash types and severity levels. In order to consider the nonlinearity of predictors and obtain more reliable estimates, the generalized nonlinear models (GNMs) were developed using 5-years of crash records and roadway characteristics data for urban roadways in Florida. The cross-sectional method was used to develop crash modification factors (CMFs) for various safety treatments. The results from this paper indicated that increasing lane, bike lane, median, and shoulder widths were safety effective to reduce crash frequency. In particular, the CMFs for changes in median and shoulder widths consistently decreased as their widths increased. On the other hand, the safety effects of increasing lane and bike lane widths showed nonlinear variations. It was found that crash rates decrease as the lane width increases until 12 ft width and it increases as the lane width exceeds 12 ft. The crash rates start to decrease again after 13ft. It was also found that crash rates decreases as the bike lane width increases until 6 ft width and it increases as the bike lane width exceeds 6 ft. This paper demonstrated that the GNMs clearly captured the nonlinear relationship between crashes and multiple roadway cross-sectional features, which cannot be reflected by the estimated CMFs from the generalized linear models (GLMs). Moreover, the GNMs showed better model fitness than GLMs in general. Therefore, in order to estimate more accurate CMFs, the proposed methodology of utilizing the GNMs in the cross-sectional method is recommended over using conventional GLMs when there are nonlinear relationships between the crash rate and roadway characteristics.

Authors	Mohammadali Shirazi, Texas A&M University Dominique Lord, Texas A&M Transportation Institute Srinivas Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-1844
Paper Title	Sample-Size Guidelines for Recalibrating Crash Prediction Models: Recommendations for the Highway Safety Manual
Abstract	The Highway Safety Manual (HSM) prediction models are fitted and validated based on the crash data collected from a selected number of states in the United States. Therefore, for a jurisdiction to be able to fully benefit from applying these models, it is necessary to calibrate them to local conditions. The first edition of HSM recommends calibrating the models using a one-size-fits-all sample-size of 30 to 50 locations with total of at least 100 crashes per year. However, the HSM recommendation is not fully supported by documented studies. The objectives of this paper are consequently to: 1) examine the required sample size based on the characteristics of the data that will be used for the recalibration process; and, 2) propose revised guidelines. The objectives were accomplished using simulation runs for different scenarios that characterized the sample mean and variance of the data. The simulation results indicate that as the ratio of the standard deviation to the mean (i.e., coefficient of variation) of the crash data increases, a larger sample-size is warranted to fulfil certain levels of accuracies. Taking this observation into account, sample-size guidelines were prepared based on the coefficient of variation of crash data that are needed for the recalibration process. The guidelines were then successfully applied to the two observed datasets. The proposed guidelines can be used for all facility types and both for segment and intersection prediction models.

Authors	Ling Wang, University of Central Florida (UCF) Mohamed Abdel-Aty, University of Central Florida (UCF)
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-1884
Paper Title	Microscopic Safety Evaluation and Prediction for Freeway-to-Freeway Interchange Ramps
Abstract	Freeway-to-freeway interchange ramps are critical components of the freeway network. The safety of interchange ramps is a concern because of their complicated horizontal and vertical alignment. In order to better understand the crash mechanisms of interchange ramps, this work builds multilevel Poisson-lognormal models to estimate 3-hour interval crash frequencies and multilevel logistic regression models to predict real-time crash risks for single-vehicle (SV) and multi-vehicle (MV) crashes. In addition, this study explores the feasibility of using crash reports to identify the pavement conditions. The crash frequency models reveal that the logarithm of 3-hour traffic volume and average turning angle are positive significant parameters in estimating SV crash frequency; and high traffic volume, sag or downgrade vertical curve increase MV crash frequency. Meanwhile, the crash risk estimation models reveal that the average turning angle has a positive impact on SV crash risk. As for MV crash risk, it increases if the lane occupancy increases or the interchange ramp vertical alignment is downgrade. Furthermore, the crash risk estimation models also indicate that roadway surface condition is one of the most important parameters: wet roadway surfaces increase SV crash ratio by 8.87 and MV crash ratio by 2.82. This study also proves that implementing crash reports is an effective method of providing a study event's weather information. After adding the weather information from crash reports, 36.8% more studied events are matched with the roadway surface condition, and the accuracy also increases by 7.4%.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-2608
Paper Title	Enhancing Safety Performance Function-Based Safety Assessment Using Microsimulation Approach
Abstract	This study developed an enhanced crash prediction model incorporating simulated rear-end conflicts. Despite advances in crash predictive models such as Safety Performance Functions in Highway Safety Manual, accurate prediction of crash frequencies is still challenging due to limited crash data and microscopic intersection operational characteristics (e.g., traffic signal controls, lane configurations, and driver aggressiveness) not being considered. On the other hand, the simulated conflict-based surrogate safety assessment approach, which utilizes microscopic traffic simulation model and the Surrogate Safety Assessment Model, serves as a pragmatic supplement to the Safety Performance Function-based safety assessment. This study used simulated traffic conflicts to enhance the Safety Performance Function-based model structure, to exploit the advantages of both methods. To this end, we tested various forms of the simulated conflicts-incorporated crash prediction models, and calibrated the model parameters based on AADT and crash data. The enhanced functions performed better in both the calibration and validation datasets in predicting crash frequencies, and this study finally proposes a rear-end conflict-incorporated crash prediction model, which performed best among the proposed models. The findings are promising because the proposed model can complement existing Safety Performance Function-based methods which are limited in their ability to accurately assess many combinations of intersection geometrics and traffic control, particularly at signalized locations. Future researchers should consider developing similar, simulation-enhanced safety models for a wider variety of intersection and highway facilities, using a broader inventory of roadway and crash data.

Authors	Mohamadreza Banihashemi, GENEX Systems
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-2702
Paper Title	Effect of Horizontal Curves on Urban Arterials Crashes
Abstract	The Highway Safety Manual (HSM) crash prediction models estimate the expected number of crashes for different facility types. Models in Part C Chapter 12 of the first edition of the HSM include crash prediction models for divided and undivided urban arterials. Each of the HSM crash prediction models for highway segments is comprised of a “Safety Performance Function,” a function of AADT and segment length, plus, a series of “Crash Modification Factors” (CMFs). The SPF estimates the expected number of crashes for the site if the site features are of base condition. The effects of the other features of the site, if their values are different from base condition, are carried out through use of CMFs. The existing models for urban arterials do not have any CMF for horizontal curvature. The goal of this research is to investigate if the horizontal alignment has any significant effect on crashes on any of these types of facilities and if so, to develop a CMF for this feature. Washington State cross sectional data from the Highway Safety Information System (HSIS) lab was used in this research. Data from 2007 to 2009 was used to conduct the investigation. The 2010 data was used to validate the results. As the results showed, the horizontal curvature has significant safety effect on two-lane undivided urban arterials and using a CMF for horizontal curvature in the crash prediction model of this type of facility improves the prediction of crashes significantly, for both tangent and curve segments.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-3413
Paper Title	Variability of Calibration Factors of HSM Safety Performance Functions with Traffic, Region, and Terrain: Case of Italian Rural Two-Lane Undivided Road Network
Abstract	Accident prediction is a crucial step for each part of the road safety management process. The HSM first edition provided safety performance functions (SPF) in order to predict accident frequencies on different types of road infrastructures. However, crash frequencies of similar roadway segments or intersections can vary widely from one jurisdiction to another. Hence, a calibration process to local conditions is necessary before the application of HSM SPFs. HSM (2010) provides guidelines for the calibration process. However, the recent NCHRP 20-07(332) (2014) emphazises the need of considering the variability of the local calibration factor with other specified variables (severity, traffic, segment lengths, regions, terrain). Also, in that report, the matter of the assessment of calibration results is addressed. However, there is still uncertainty on which and how many variables should be considered for the calibration with regards to their influence on the overall jurisdiction factor. In this paper, the influence of traffic volume ranges, terrain types and regions on the results of the calibration study is analyzed. The NCHRP 20-07 (332) recommendations about the calibration process and the assessments of its results were applied. For the purpose of the study, a sample of roads belonging to the Italian two-lane undivided highways network was employed, considering a five-years study period. Calibration factors at the statewide scale and for different sub-groups of the sample based on traffic volumes, terrain types and regions (macro-regions and administrative regions) were computed. The influence of those variables was assessed through the analysis of the obtained results.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-3820
Paper Title	Dynamic Hotspot Identification for Expressways Using Real-Time Traffic Data
Abstract	In general, researchers use aggregated data to analyze traffic crashes. Admittedly data aggregation is essential due to the rare nature of traffic crashes and to account for regression-to-the-mean bias. However, a high level of aggregation may lead to failure of capturing the temporal variation in traffic volume, crashes, and their relationship. The potential crash occurrence is significantly affected by the short term traffic flow patterns and turbulence. However, previous researchers have used mostly Annual Average Daily Traffic (AADT) to develop Safety Performance Functions (SPFs), which does not account for the variation in the traffic flow by time periods. Therefore, the objectives of this study are to (1) develop new SPFs based on several short-term periods; (2) evaluate the developed SPFs ; (3) develop a SPF based on AADT and compare the results with the suggested approach; (4) use the Potential Safety Improvement (PSI) to identify the hotspots by time periods; and (5) compare the hotspots results with the results which are based on AADT. The study found that using short-term SPFs perform better than using a single SPF based on AADT. The study proposed a dynamic hotspot identification method. It is expected that the method enables practitioners and policy makers to better understand the crash risk changes by time-of-day, and to provide effective dynamic countermeasures using various ITS technologies.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-4283
Paper Title	Examining Effects of Weather and Traffic Condition on Single- and Multivehicle Crashes Using Random Effects Bivariate Poisson Lognormal Model
Abstract	Crash prediction models remain one of the primary approaches for studying traffic safety. However, the effects of weather and traffic conditions on single-vehicle and multi-vehicle crashes are far from being fully investigated. Benefited from advanced monitoring system, detailed weather and traffic data from a mountainous highway I-70 in Colorado are incorporated in this study, forming a multivariate panel dataset. This paper presents a novel approach to analyze and identify different hazardous factors for SV and MV crashes by developing a bivariate Poisson lognormal model with correlated segment specific random effects. The proposed model can characterize both the multivariate and panel nature of the data, and readily address three types of serial correlations within the multivariate panel data used in this study: (1) correlation between SV and MV, (2) temporal correlations across time within each segment for SV and MV respectively, and (3) possible connection between temporal correlations for SV and MV crashes. It is shown that the proposed model outperforms the two competing ones by addressing all possible unobserved heterogeneity, dealing with excessive zeros in the observed data, and bearing the smallest DIC value. In addition, the results suggest that weather and traffic related explanatory variables, especially surface conditions, play a significant role in determining SV and MV crashes. Finally, differences between hazardous factors for SV and MV crashes are also discussed.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-5043
Paper Title	Developing Analytical Procedures for Calibrating the HSM Predictive Methods
Abstract	Performance-based safety goals and objectives are more attainable with the use of the Highway Safety Manual (HSM). However, the safety performance functions (SPFs) in the HSM may not be accurate when used with local jurisdictions. Each SPF and crash modification factor (CMF) assumes a set of base site conditions which might not be realistic or representative of local highways. The calibration procedures provided in Part C Appendix-A of the HSM should therefore be modified to accommodate local data availability as well as roadway, traffic, and crash characteristics. Furthermore, a set of base conditions applicable to local highways should be determined. Results show that the HSM models underestimate the total average number of crashes on highway segments for all rural highway facility types in South Dakota. To better quantify highway safety performance, this study analyzed the underlying factors contributing to the underestimation and proposed procedures to improve crash prediction accuracy. The HSM calibration was performed with crash data from rural two-lane two-way highways, rural multilane divided and undivided highways during a five-year time period (2008-2012). The procedures include establishing new base conditions, developing jurisdiction-specific SPFs, and converting CMFs to new base conditions. The comparison results show that the customized models outperform the HSM models in predicting sites with crashes.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-5237
Paper Title	Estimation of Calibration Functions for Predicting Crashes on Rural Two Lane Roads in Arizona
Abstract	This paper describes a study that used data from two-lane rural roads in Arizona to illustrate two issues. One issue is the importance of selecting an appropriate sample size for calibrating the Highway Safety Manual (HSM) predictive models based on the desired accuracy of the calibration factor, instead of relying on the guidance from the HSM (the HSM recommends 30-50 sites with at least 100 crashes per year, but there is no statistical basis for this guidance). Second, this study illustrates the usefulness of estimating calibration functions when individual calibration factors do not provide a proper fit of the local data. Based on the outcome of the exploration of these two issues, this study recommends a simple calibration function for predicting total crashes on rural two-lane roads in Arizona. This paper also provides a brief overview of a procedure in Microsoft Excel that can be used by practitioners (after appropriate training) to estimate simple calibration functions.

Authors	Sivaramakrishnan Srinivasan, University of Florida Phillip Haas, University of Florida Priyanka Alluri, Florida International University (FIU) Albert Gan, Florida International University (FIU) James Bonneson, Kittelson & Associates, Inc. (KAI)
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-6333
Paper Title	Crash Prediction Method for Freeway Segments with High Occupancy Vehicle (HOV) Lanes
Abstract	This study developed methods for estimating the expected crash frequency on urban freeway segments with HOV lanes. The safety impacts of the type of separation between the managed lanes and general purpose lanes were examined. Separate models were estimated for fatal and injury (FI) crashes and all crashes using five years' of data from California, Washington, and Florida. All these facilities have one HOV in each direction (included in the count of total number of lanes). Models are presented for six-, eight-, ten-, and twelve- lane facilities. The effect of separation type on crash rates is found to be statistically significant only in the models for ten-lane facilities. All the estimated models have been implemented in a spreadsheet program which will enable analysts to apply these equations for crash prediction. Overall, this study provides procedures that will help FDOT consider safety in decisions about planning and designing freeways with HOV or HOT lanes.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-6750
Paper Title	LOCAL CALIBRATION OF CRASH MODIFICATION FACTORS TO IMPROVE PREDICTABILITY OF HIGHWAY SAFETY MANUAL – CASE OF MARYLAND RURAL TWO-LANE, TWO-WAY ROADS
Abstract	The predictive methods of the Highway Safety Manual predict crash frequency by applying uncalibrated safety performance function (SPF) and a set of uncalibrated crash modification factors (CMFs) to each location individually: Then the predicted crashes are required to be adjusted by local calibration factor (LCF) at the aggregated level (i.e., at least 30 sampled sites per SPF). Although this calibration procedure assures total predicted crashes be localized, still prediction of crashes for individual locations may suffer from aggregated localization process. An approach to locally calibrate CMFs to minimize individual location prediction errors while maintaining equality of total observed and total predicted crashes which could eliminate the need for LCF development was proposed to improve crash predictability of the HSM. The proposed approach was tested by applying on the data for Maryland State rural two-lane, two-way roads (R2U) and three years of crash data (2008-2010). The results of comparing prediction errors showed that the proposed method could produce smaller prediction errors than the HSM calibration method for individual locations while keeping the total number of predicted crashes equal to the total number of observed crashes and the differences were statistically significant and supporting the preference of proposed method over the HSM method. Application of proposed method can lead to more accurate identification of hot-spots and site-specific strategies in terms of funding allocation.

Authors	Amirthalingam Veeraragavan Abhishek Basu, Indian Institute of Technology Madras
Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-6768
Paper Title	ANALYSIS ON THE LEVEL OF SAFETY OF MULTI-LANE RURAL HIGHWAY UNDER HETEROGENEOUS TRAFFIC CONDITION
Abstract	Praveen Vayalamkuzhi, Indian Institute of Technology, Madras (IIT) This paper presents an analysis of the level of safety on a multi-lane rural highway operating in plain and rolling terrain and under heterogeneous traffic conditions by developing safety performance functions (SPFs). The study involves collection of data and information about the various elements contributing to crash occurrence like roadway characteristics, traffic conditions and environmental characteristics. Due to the random variation and rareness of crashes, Poisson regression and Negative binomial of count data modeling approach were used. Zero-Inflated models were also developed to verify the significance of the dependent variable (crash) with excess zeros. The study enabled better understanding of the influence of geometric design characteristics on road crashes under heterogeneous traffic conditions and provided insight on the significant effect of operating speed on curves and tangent sections along the highway.. The methodology may be used for the evaluation of safety performance of rural highways and for the development of the geometric design guidelines for multi-lane rural highways under heterogeneous traffic conditions.

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Sponsoring Committee	ANB25
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-4768
Paper Title	Hotspot Identification for Urban Expressway Using Quantitative Risk Assessment Method
Abstract	Hotspot identification (HSID) is the first and key step of expressway safety management process. Besides the direct personal injury and property damage, Crashes may also result in lane closing or capacity reduction, which will lead to non-recurrent congestion. This study presents a new HSID method using quantitative risk assessment (QRA) method. The occurrence of crashes is treated as a risk, the probability and consequences of crashes are both considered. The probability of crash occurrence is calculated based on the Empirical Bayesian method with the predicted crash frequency using Bayesian negative binomial model. The consequences of crash take account for both the direct losses and indirect losses of crashes, which are quantitatively unified by equivalent monetary index. The indirect losses of crashes are defined by the extra delay losses caused by the crash and calculated using analytical methods named deterministic queuing diagram. A case study on the urban expressways of Shanghai is presented. The results show that the new QRA method for HSID enables the identification of a set of high-risk sites that reflect the potential total safety costs to society. Corresponding countermeasures can be suggested and help improving both the safety and efficiency on the urban expressway system.

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Sponsoring Committee	ANB25
Session Number	625
Session Title	Advances in Highway Safety Performance
Paper Number	16-5481
Paper Title	Safety Evaluation of Seven of the Earliest Diverging Diamond Interchanges Installed in the US
Abstract	Diverging diamond interchanges (DDIs) are increasingly popular because they provide improved traffic operations and cost savings. DDIs should be safer based on theory, but previous empirical safety studies have been limited. The objective of this work was, therefore, to conduct a broader safety evaluation of DDIs and recommend a crash modification factor (CMF) for the conversion of a conventional diamond to a DDI. The team analyzed seven of the earliest DDIs in the US. Four were in MO and there were also sites in KY, NY, and TN. The team collected over 28 site-years of crash and other data before conversion and over 19 site-years of data after conversion. The primary analysis was before and after with comparison sites to account for trends and potential simultaneous event biases. The results showed that crashes were reduced at most of the sites, and the team recommended a CMF of 0.67, meaning that installation of a DDI to replace a diamond should reduce all crashes by 33 percent. The reduction in injury crashes was even larger, with the team recommending a CMF of 0.59. Other analyses indicated that DDI installation should mean a substantial reduction of angle and turning crashes with some reduction in rear end crashes as well, although rear end crashes will still be the dominant crash types after DDI installation. Clearly DDIs offer potential safety benefits and agencies should consider them strongly as replacements for conventional diamonds.

3 Network Screening

Raghavan Srinivasan, University of North Carolina, Chapel Hill

Network screening is the identification of crash hotspots, also referred to as hazardous road locations, high-risk locations, accident-prone locations, black spots, sites with promise, or priority investigation locations. Network screening is the first step of the highway safety management process and it is vital that a sound procedure is used; otherwise, resources will be wasted on locations that are incorrectly identified as unsafe while those that are unsafe will remain untreated.

From a methodological perspective, the following methods were used:

- Grid-cell based tobit model (Xie et al., 16-0205);
- Data from Light detection and ranging (LiDAR) for extracting roadway data (Bassett et al., 16-1472);
- Multinomial logit fractional split model (Lee et al., 16-3848);
- Bayesian Poisson Lognormal Simultaneous Equation Spatial Error Model (BPLSESEM) (Lee and Abdel-Aty, 16-4000);
- Bayesian spatio-temporal interaction approach compared with the Poisson-lognormal (PLN) model and FB ranking using a Bayesian spatial and temporal (B-ST) model, (Dong et al., 16-4515);
- Bayesian Latent Class (BLC) compared with empirical Bayesian negative binomial (EB-NB) model (Afghari et al., 16-4613).

From an applications perspective, the papers addressed several issues, such as:

- Pedestrian safety at the grid/zonal level (Xie et al., 16-0205);
- Network level (Bassett et al., 16-1472 and Afghari et al., 16-4613);
- Traffic analysis zonal level examining crashes by transportation mode (Lee et al., 16-3848);
- Bicycle crashes at the zonal level (Lee and Abdel-Aty, 16-4000);
- Area level (Dong et al., 16-4515).

Authors	Kun Xie, New York University Kaan Ozbay, New York University Hong Yang, Old Dominion University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-0205
Paper Title	Analysis of Pedestrian Safety Using Big Data
Abstract	This study aims to explore the potential of using big data technologies in advancing the pedestrian safety analysis including the investigation of contributing factors and the hotspot identification. Manhattan, which is the most densely populated urban area of New York City, is used as a case study. A massive amount of data from a variety of sources were collected, integrated and processed, including taxi trip, subway turnstile, traffic volume, road network, land use, demo-economic data. A parallel computation program was designed to process the massive amount of taxi data in Hadoop-based platform. We attempt to investigate the overall safety patterns of pedestrian rather than selected samples, so the whole study area was uniformly split into grid cells as the basic geographical units of analysis. The cost of each crash, weighted by injury severity, was assigned to the cells based on the relative distance to the crash site using a kernel density function. A tobit model was developed to relate grid cell-specific contributing factors to crash costs which are left-censored at zero. Effects of contributing factors on pedestrian safety were fully explored using the grid cell-based tobit model. The potential for safety improvement (PSI) which could be obtained by using the actual crash cost minus the cost of "similar" sites estimated by the tobit model was used as used as a measure to identify and rank pedestrian crash hotspots. The hotspot identification method proposed takes into account two important factors that are generally ignored, i.e., injury severity and effects of exposure indicators. In addition, a pedestrian hotspot map of the whole study area was obtained with higher resolution than conventional methods based on census tracts or traffic analysis zones. The hotspots ranking obtained in this study can support government agencies in making better decisions on allocation of resources for countermeasure development.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1472
Paper Title	Use of Roadway Attributes in Hot Spot Identification and Analysis
Abstract	This research focuses on an improved method for incorporating roadway attribute data in the selection and analysis of hot spots using the Utah Crash Prediction Model (UCPM) and the Utah Crash Severity Model (UCSM) in conjunction with the framework for highway safety mitigation in Utah with its six primary steps: network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and effectiveness evaluation. The improved method for incorporating roadway attribute data was part of the network screening, diagnosis, and countermeasure selection. Methods were developed to locate and evaluate the usefulness of available data. A systemization methodology was created to convert raw data into roadway attributes, such as grade and vertical sag/crest curve location. For the roadway attributes to be useful in selection and analysis, a methodology to combine and associate the attributes to crashes on problem segments and problem spots was developed. A previous methodology developed for "Hot Spot Identification and Analysis" was enhanced to include steps for the inclusion and defining of the roadway attributes. Applying the methods and processes to a segment of I-80 in Utah identified as a hot spot showed that the absence of continuous rumble strips and the shoulder design could be an area to improve along the segment to reduce the number and/or severity of crashes. Using the tools, methodology, and processes to connect crashes to the roadway attributes at the hot spot location can help provide information about potential causes of crashes and areas of focus to improve the safety of the roadways.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3848
Paper Title	A Macroscopic Analysis of Crash Proportion by Mode: A Fractional Split Multinomial Logit Modeling Approach
Abstract	In traffic safety literature, crash frequency variables are analyzed using univariate count models or multivariate count models. In this study, we propose an alternative approach to modeling multiple crash frequency dependent variables. Instead of modeling the frequency of crashes we propose to analyze the proportion of crashes by transportation mode. A flexible multinomial logit fractional split model is employed for analyzing the proportions of crashes by transportation mode at the macro-level. In this model, the proportion allocated to an alternative is probabilistically determined based on the alternative propensity as well propensity of all other alternatives. Thus, exogenous variables directly affect all alternatives. The approach is well suited to accommodate for large number of alternatives without a sizable increase in computational burden. The model was estimated using crash data at Traffic Analysis Zone level from Florida. The modeling results clearly illustrate the applicability of the proposed framework for crash proportion analysis. Further, the Excess Predicted Proportion (EPP) – a screening performance measure analogous to Highway Safety Manual (HSM) Excess Predicted Average Crash Frequency is proposed for hot zone identification. Using EPP, a statewide screening exercise by the various modes considered in our analysis was undertaken. The screening results revealed that the spatial pattern of hot zones is substantially different across the various modes considered.

Authors	Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-4000
Paper Title	Exploring Zonal Level Bicycle Traffic Crashes and Hot Zone Identification
Abstract	In recent bicycle crash analyses been emphasized and conducted at the macroscopic level, however, there are still unanswered research questions: (1) what are the contributing factors for the number of bicycle crashes per crash location zone and factors for the number of crash-involved bicyclists per residence zone? (2) do the two targets have common unobserved factors and spatial autocorrelations? (3) is there a way to analyze the hot zones for the two targets simultaneously? Therefore, the main objectives of this study are to identify the contributing factors both for 'Bicycle crashes per crash location ZIP' and 'Crash-involved bicyclists per residence ZIP'. Bayesian Poisson Lognormal Simultaneous Equation Spatial Error Model (BPLSESEM) was employed and revealed significant factors for the two target variables. Subsequently, a novel hot zone identification method was suggested to combine both hot zones from where vulnerable bicyclists originated with hot zones where many bicycle crashes occur. For the former zones, targeted safety education and awareness campaigns can be provided as countermeasures whereas area-wide engineering treatments and enforcement may be effective safety treatments for the latter ones. Therefore, it is expected that practitioners can provide appropriate safety treatments for bicycle crashes using the method and results from this study.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4515
Paper Title	Macroscopic Hotspots Identification: a Bayesian Spatio-temporal Interaction Approach
Abstract	This study proposes a Bayesian spatio-temporal interaction approach for hotspot identification by applying the full Bayesian (FB) technique in the context of macroscopic safety analysis. Compared with the emerging Bayesian spatial and temporal approach, the Bayesian spatio-temporal interaction model contributes to a detailed understanding of differential trends through analyzing and mapping probabilities of area-specific crash trends differing from the mean trend highlights specific locations where crash occurrence is deteriorating or improving over time. With traffic analysis zones (TAZs) crash data collected in Florida, an empirical analysis was conducted to evaluate the following three approaches for hotspot identification: FB ranking using a Poisson-lognormal (PLN) model, FB ranking using a Bayesian spatial and temporal (B-ST) model and FB ranking using a Bayesian spatio-temporal interaction (B-ST-I) model. The results show that (a) the models accounting for space-time effects perform better in safety ranking than does the PLN model, and (b) the FB approach using B-ST-I model significantly outperforms the B-ST approach in correctly identifying hotspots by explicitly accounting for the space-time variation in addition to the stable spatial/temporal patterns of crash occurrence. In practice, B-ST-I approach plays key roles in addressing two issues: (a) how the identified hotspot have evolved over time and (b) the identification of areas that, whilst not yet hotspots, show a tendency to become hotspots. Finally, it can provide guidance to policy decision makers to efficiently improve the zonal-level safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4613
Paper Title	A Bayesian Latent Class Safety Performance Function for Identifying Motor Vehicle Crash Blackspots
Abstract	The current state of the practice in Blackspot Identification (BSI) utilizes safety performance functions based on total crash counts to identify transport system sites with potentially high crash risk. This paper postulates that total crash count variation over a transport network is a result of multiple distinct crash generating processes including geometric characteristics of the road, spatial features of the surrounding environment, and driver behaviour factors. However, these multiple sources are ignored in current modelling methodologies in both trying to explain or predict crash frequencies across sites. Instead, current practice employs models that imply that a single underlying crash generating process exists. The model mis-specification may lead to correlating crashes with the incorrect sources of contributing factors (e.g. concluding a crash is predominately caused by a geometric feature when it is a behavioural issue), which may ultimately lead to inefficient use of public funds and misidentification of true blackspots. This study aims to propose a latent class model consistent with a multiple crash process theory, and to investigate the influence this model has on correctly identifying crash blackspots. We first present the theoretical and corresponding methodological approach in which a Bayesian Latent Class (BLC) model is estimated assuming that crashes arise from two distinct risk generating processes including engineering and unobserved spatial factors. The Bayesian model is used to incorporate prior information about the contribution of each underlying process to the total crash count. The methodology is applied to the state-controlled roads in Queensland, Australia and the results are compared to an Empirical Bayesian Negative Binomial (EB-NB) model. A comparison of goodness of fit measures illustrates significantly improved performance of the proposed model compared to the NB model. The detection of blackspots was also improved when compared to the EB-NB model. In addition, modelling crashes as the result of two fundamentally separate underlying processes reveals more detailed information about unobserved crash causes.

4 Safety Performance Functions

Mohamed Abdel-Aty and Ling Wang, University of Central Florida (UCF)

Nineteen papers were found to have developed or used safety performance functions (SPFs). These papers could be categorized by their research objectives, the study unit, methodologies used, and applications based on their conclusions. Regarding the objectives of the identified studies, the majority aimed at motor vehicle crashes while other papers focused on specific issues, such as pedestrian safety and bicycle safety. Numerous statistical methods have been found in these papers to construct the safety performance functions. The basic models are Poisson, Negative binomial or Poisson log-normal. These papers covered both macro- and micro-level safety analyses. Macro-level studies investigated safety issues at an area basis. Micro-level studies were conducted on specific locations such as roadway segments and intersections. Applications of these safety performance functions include identification of crash contributing factors for safety improvement, quantifying the safety effectiveness of particular variables, identification of crash hotspots, and proving better safety performance functions.

As mentioned, the majority of the papers had objectives of general or motor vehicle safety improvement. However, there are several papers addressing pedestrian or bicycle or both (16-2469, 16-3777, 16-4354, 16-6909). These papers covered both macro- and micro-level safety analyses. Macro-level studies investigated the safety issues at traffic analysis zone (16-2469, 16-3777, 16-6909). Micro-level studies were conducted on urban or rural areas for roadway segments (16-2131, 16-2454, 16-2508, 16-3531, 16-3540, 16-3729, 16-4040, 16-5048, 16-5892, 16-6533), freeways (16-2514), intersections (16-4354, 16-6483), and some special locations such as weaving segments (16-1103), or ramps (16-1640). Meanwhile, there was also a paper which focused on crashes that occurred at the zonal boundaries (16-4133).

In safety performance functions, Poisson models, Negative Binomial (also known as Poisson-gamma) models and Poisson-lognormal models often served as the starting point to model the crash mechanisms on the studied objects. However, extensions such as random effects model (16-3729), random parameters model (16-1640), Heterogeneous Geometric Slopes Model (HGSM) (16-2454), Fixed Geometric Slopes Model (FGSM) (16-2454), generalized estimating equation (GEE) model (16-2131), zero-inflated negative binomial model (16-2469, 16-3729, 16-4354), hurdle negative binomial model (16-2469), Conditional Autoregressive (CAR) model (16-2508, 16-3777), Finite Mixture of Negative Binominal regression model (FMNB) (16-2514), Kernel Regression (KR) (16-3531), Structural Equation Modelling (SEM) (16-4040), heterogeneous dispersion negative binomial regression (HNB) (16-5892), copula based bivariate negative binomial model (16-6909), and models considering spatial and temporal correlations (16-2469, 16-2508, 16-6483, 16-6533) could all be found. Meanwhile, Bayesian inference was used in model estimations in some papers (16-2508, 16-3540, 16-3777, 16-4133).

From an application point of view, although almost all of the papers shared the same goal to reduce crash occurrence and improve traffic safety, they still had their own priorities. A large body of papers developed safety performance functions to understand crash contributing factors (16-1103, 16-1640, 16-2131, 16-2514, 16-3777, 16-5892). Some papers built models to quantify the safety effects of particular variables (16-2508, 16-4040, 16-4133, 16-5048). Some papers endeavored to identify and rank crash hotspots for improvement by safety performance functions (16-4354, 16-6909). Others might contribute to developing better safety performance models (16-2454, 16-2469, 16-3531, 16-3540, 16-3729, 16-6483, 16-6533).

Authors	Ling Wang, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qi Shi, University of Central Florida Juneyoung Park, University of Central Florida
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1103
Paper Title	Predicting Expressway Weaving Segments Crashes using Bayesian Multilevel Logistic Regression
Abstract	Weaving segmentsarepotential recurrent bottleneckswhich affect the efficiency and safety of expressways during peak hours.Meanwhile, they are one of the most complicated segments, since on- and off-ramp traffic merges, divergesand weavesin thelimited space. One effective way to improve the safety of weaving segmentsisstudyingcrash likelihood with the objective of, identifyinghazardous conditionsand reducingthe risk of crashesby Intelligent Transportation Systems (ITS) traffic control. This study presents a Bayesian multilevel logistic regression model for crashes atexpressway weaving segments. The results show thatthe mainline speedat the beginningof the weaving segments,the speed differencebetween the beginning and the end of weaving segment, logarithm of volume have significant impactsonthe crash riskofthe following 5-10 minutes forweaving segments. The configuration is also an important factor. Weaving segment,inwhich there is no need for on-or off-ramp traffic to change lane, is with high crash risk because ithas more traffic interactions and higher speed differencesbetween weaving and non-weaving traffic.Meanwhile, maximumlength, which measures the distance at which weaving turbulence no longer has impact, isfound to bepositivelyrelated tothe crash riskat the 95% confidence interval. In addition to traffic and geometric factors, wet pavement surface condition significantly increasesthe crash ratio by 77%. The proposed model along with ITS, e.g., ramp metering, Dynamic Message Sign (DMS), can be used to enhance the safety of weaving segmentsin real-time.

Authors	Taehun Lee, Seoul Institute Yoon-Young Choi, Seoul National University Seung-Young Kho, Seoul National University Dong-Kyu Kim, Seoul National University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1640
Paper Title	Multilevel Frequency Model for Ramp Crashes that Reflects Heterogeneity among Ramp Types
Abstract	Freeway ramps connect either two freeways or a freeway and a national highway. They are generally more vulnerable to crashes than the mainline. Freeway ramps on a trumpet interchange are classified into on- and off-ramps by their function, and direct, semi-direct, and loop ramps by their configuration. There is, therefore, heterogeneity among the ramp types due to the similarity of function and configuration. A generalized liner model (GLM), which is widely used to predict crash frequency, is limited in that it assumes each of crashes is independent of any other, despite the heterogeneity. This study aims to develop a multilevel frequency model for ramp crashes that reflects heterogeneity among ramp types. Based on data from 1,155 ramp crashes for a four-year period from 2007 to 2010, we examine the factors influencing ramp crashes and specify a hierarchical model structure. To investigate the statistical significance and appropriateness of our model, estimation results of the model are compared with those of two different models, such as an unconditional model and a random intercept model. The fixed effects of the proposed model indicate that off-ramps are more vulnerable to crashes than on-ramps and that crash frequency increases as ramp length shortens. The random effects of the model show that the intra-class correlation is 0.185, meaning that the proposed multilevel model is suitable for predicting ramp crashes. The results of this paper provide enhanced understanding about ramp crashes and contribute to the safe design and maintenance of freeway ramps.

Authors	Jocilene Otilia da Costa, University of Minho Elisabete Fraga Freitas, University of Minho Paulo António Alves Pereira, University of Minho
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-2131
Paper Title	Collision Prediction Models with Longitudinal Data: A Note on Modeling Collision Frequency in Road Segments in Portugal
Abstract	In spite of the strategic importance of the national Portuguese road network, there are no recent studies concerned with either the identification of contributory factors to road collisions or collision prediction models (CPMs) for this type of roadway. This study presents an initial contribution to this problem by focusing on the national roads NR-14, NR-101 and NR-206, which are located in Portugal's northern region. This study analyzed the collisions frequencies, average annual daily traffic (AADT) and geometric characteristics of 88 two-lane road segments through the analysis the impact of different database structures in time and space. The selected segments were 200-m-long and did not cross through urbanized areas. Data regarding the annual traffic collision frequency and the AADT were available from 1999 to 2010. The GEE procedure was applied to ten distinctive databases formed by grouping the original data in time and space. The results show that the different observations within each road segment present mostly an exchangeable correlation structure type. This paper also analyses the impact of the sample size on the model's capability of identifying the contributing factors to collision frequencies, therefore must work with segments homogeneous greatest possible. The major contributing factors identified for the two-lane highways studied were the traffic volume (AADT), lane width, horizontal sinuosity, vertical sinuosity, density of access points, and density of pedestrian crossings. Acceptable CPM was identified for the highways considered, which estimated the total number of collisions for 400-m-long segments for a cumulative period of six years.

Authors	Minho Park, Korea Institute of Civil Engineering and Building Technology Venky Shankar, Pennsylvania State University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-2454
Paper Title	Heterogeneous Negative Binomial Model of Interstate Crash Frequencies Performance-based Insights into the Effects of Interstate Geometrics Design Standard
Abstract	The safety research in terms of modeling has contributed to reduce the accident frequency by analyzing the relationship between traffic accidents and geometric variables. However, there was a lack of considering the various specifications of geometrics which are not homogeneously constructed in reality and this could be misleading the derived results. That is, in the case of geometry, although recommended values based on guidelines are present, in conventional accident modeling, as the geometry data were used in the form of an integrated ones, there are disadvantages that derived model could not describe the reality correctly on which a mixture of geometries installed. Therefore, in this study, to develop the existing contemporary safety modeling using negative binomial method, two models were derived named as HGSM (Heterogeneous Geometric Slopes Model) and FGSM (Fixed Geometric Slopes Model) and by comparison, some paramount information which was difficult to reveal out in classic negative binomial could be found that will be helpful for the future road policy with respect to safety and economic.

Authors	Qing Cai, University of Central Florida Jaeyoung Lee, University of Central Florida Naveen Eluru, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-2469
Paper Title	Macro-level Pedestrian and Bicycle Crash Analysis: Incorporating Spatial Spillover Effects in Dual State Count Models
Abstract	This study attempts to explore the viability of dual-state models (i.e., zero-inflated and hurdle models) for traffic analysis zones (TAZs) based macro-level pedestrian and bicycle crash analysis. Additionally, spatial spillover effects are explored in the models by employing exogenous variables from neighboring zones. Both conventional single-state model (i.e., negative binomial) and dual-state models such as zero-inflated negative binomial and hurdle negative binomial models with and without spatial effects are developed. The model comparison for pedestrian and bicycle crashes revealed that the models that considered observed spatial effects perform better than the models that did not consider the observed spatial effects. Across the models with spatial spillover effects, the dual-state models especially zero-inflated negative binomial model offered better performance compared to single-state models. Moreover, the model results clearly highlighted the importance of various traffic, roadway, and sociodemographic characteristics of the TAZ as well as neighboring TAZs on pedestrian and bicycle crash frequency.

Authors	Xuesong Wang, Tongji University Jinghui Yuan, Tongji University Grant G. Schultz, Brigham Young University Wenjing Meng, Suzhou Singapore International School
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-2508
Paper Title	Investigating Safety Impacts of Roadway Network Features of Suburban Arterials in Shanghai, China
Abstract	With the rapid changes in land use development along suburban arterials in Shanghai, there is also a corresponding increase in traffic demand along these arterials.With a preference toward increased accessibility and efficiency, these arterials have been installed with an increased number of signalized intersections and accesses to serve local traffic needs.The absence of a defined functional hierarchy along the road network, together withthe non-uniform installation of signals and accesses tends to deteriorate arterial safety.Previous studies on arterial safety have generally been based on a single type of road entity (either intersection or roadway segment).These studies only analyzed partial safety impacts of signal spacing and access density, as these factors would significantly influence the safety performance of both intersections and roadway segments.Macro level safety modeling was usually applied to investigate the relationship between the zonal crash frequencies and demographics, road network features and traffic characteristics. In this study, a new modeling strategy was proposed to analyze the safety impactsof roadwaynetwork features (i.e.,road network patterns, signal spacing and access density) of arterials by applying amacro level safety modeling technique.Bayesian Conditional Autoregressive models were developed for arterials covering 173 Traffic Analysis Zones in the suburban area in Shanghai. The results identified that the road network pattern with collector roads parallel to the arterials was shownto be associated with fewer crashes than those without parallel collectors. Higher signal density and access densityalso tendedto increase crash frequencieson arterials.

Authors	Xuesong Wang, Tongji University Yan Li, Tongji University Ting Wang, Tongji University XiaoKun Wang, Rensselaer Polytechnic Institution Rongjie Yu, Tongji University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-2514
Paper Title	Factors Affecting Freeway Safety: Analysis of Single- and Multivehicle Crashes in Shanghai, China
Abstract	The freeway mileage and traffic volume in Shanghai have been increasing fast in recent years. However, the traffic safety situation on freeways is also getting increasingly concerning. No comprehensive safety evaluation studies have been conducted so far due to the lack of reliable traffic and crash data. In order to identify the different contributing factors for single-vehicle (SV) and multi-vehicle (MV) crashes, information about the geometric design features and traffic operational characteristics on a 45km-long freeway segment in Shanghai has been collected. The Finite Mixture of Negative Binominal regression models (FMNB) were applied to analyze SV and MV crashes separately.The two-component FMNB model produced the best goodness-of-fit. The modeling results suggested that segment length had significant influence, indicating that analyzing the whole segment as one homogenous sampleis inappropriate. Moreover, only segment length and the indicator variable for three-lane segments showed consistent effects on both SV and MV crashes, while all other significant variables' effectswere different. Therefore, it is necessaryto investigate SV and MV crashes separately.

Authors	LalitaThakali, University of Waterloo Liping Fu, University of Waterloo Tao Chen, University of Waterloo
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3531
Paper Title	Model-Based Versus Data-Driven Approach for Road Safety Analysis: Do More Data Help?
Abstract	Crash data for road safety analysis and modeling are growing steadily in size and completeness due to latest advancement in information technologies. This increased availability of large datasets has generated resurgent interest in applying data-driven nonparametric approach as an alternative to the traditional parametric models for crash risk prediction. This paper investigates the question of how the relative performance of these two alternative approaches changes as crash data grows. We focus on comparing two popular techniques from the two approaches: negative binomial models (NB) for the parametric approach and kernel regression (KR) for the nonparametric counterpart. Using two large crash datasets, we investigates the performance of these two methods as a function of the amount of training data. Through a rigorous bootstrapping validation process, we find that the two approaches exhibit strikingly different patterns, especially, in terms of sensitivity to data size. We find that the kernel regression method outperforms the model based approach – NB in terms of predictive performance and that performance advantage increases noticeably as data available for calibration grows. With the arrival of the Big Data era and the added benefits of enabling automated road safety analysis and improved responsiveness to latest safety issues, nonparametric techniques (especially those of modern machine approaches) could be included as one of the important tools for road safety studies.

Authors	Maria-Ioanna M. Imprialou, Loughborough University Mike Maher, Loughborough University Mohammed Quddus, Loughborough University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3540
Paper Title	Exploring Crash Risk Factors Using Bayes Theorem and Optimization Routine
Abstract	Regression models used to analyse crash counts are associated with some kinds of data aggregation (either spatial, or temporal or both) that may result in inconsistent or incorrect outcomes. This paper introduces a new non-regression approach for analysing risk factors affecting crash counts without aggregating crashes. The method is an application of the Bayes' Theorem that enables to compare the distribution of the prevailing traffic conditions on a road network (i.e. a priori) with the distribution of traffic conditions just before crashes (i.e. a posteriori). By making use of Bayes' Theorem, the probability densities of continuous explanatory variables are estimated using kernel density estimation and a posterior log likelihood is maximised by an optimisation routine (Maximum Likelihood Estimation). The method then estimates the parameters that define the crash risk that is associated with each of the examined crash contributory factors. Both simulated and real-world data were employed to demonstrate and validate the developed theory in which, for example, two explanatory traffic variables speed and volume were employed. Posterior kernel densities of speed and volume at the location and time of crashes have found to be different that prior kernel densities of the same variables. The findings are logical as higher traffic volumes increase the risk of all crashes independently of collision type, severity and time of occurrence. Higher speeds were found to decrease the risk of multiple-vehicle crashes at peak-times and not to affect significantly multiple- vehicle crash occurrences during off-peak times. However, the risk of single vehicle crashes always increases while speed increases.

Authors	Feng Chen, Tongji University Suren Chen, Colorado State University Xiaoxiang Ma, Colorado State University
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3729
Paper Title	Crash Frequency Prediction using Refined Temporal scale Data and Zero-inflated Negative Binomial Models with Random Effects
Abstract	Zero-inflated Negative Binomial models with site-specific random effects are developed with the panel data to analyze hourly crash frequency on highway segments with one-mile length in average. In addition to the refined scales in temporal domain, the new crash frequency prediction models can also consider unbalanced panel-data structure and random nature of the observations. The real-time traffic, weather and road surface condition data, primarily from the Road Weather Information System (RWIS), are incorporated along with the road characteristics. The RWIS data is available on most major highways around the United States as well as some other countries. Therefore, this study introduces promising engineering technology to develop refined-scale crash frequency models, which can be conveniently applied to many other major highways. The proposed models are demonstrated by studying one portion of Interstate I-25 in Colorado, from which some interesting insights for crash frequency prediction are made available, adding to the understanding of crash risks on major highways.

Authors	Xuesong Wang, Tongji University Junguang Yang, Tongji University Chris Lee, University of Windsor Shikai You, Tongji University Zhuoran Ji, Tongji University
Sponsoring Committee	ANB20
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-3777
Paper Title	Macro-level Safety Analysis of Pedestrian Crashes in Shanghai, China
Abstract	Pedestrian safety has become one of the most important issues in the field of traffic safety nowadays. With the rapid urbanization and motorization, pedestrian crashes in China surged in recent years. This study aims at investigating the association between pedestrian crash frequency and various predictor variables including roadway, traffic, and land use features. The relationship was modeled using the data from 263 Traffic Analysis Zones (TAZs) within the urban area of Shanghai – the largest city in China. Since spatial correlation existed among the zonal-level crashes, Bayesian Conditional Autoregressive (CAR) models with six different spatial proximity structures were developed to characterize the spatial correlations among TAZs. Model results indicated that the 0-1 adjacency matrix outperformed the other spatial proximity structures. Two land use weight matrixes also provided good model fit and prediction accuracy. More pedestrian crashes were associated with higher road density and shorter intersection spacing since they increase vehicle-pedestrian interactions. Car trip generation used as the surrogate pedestrian exposure variable had positive effect on pedestrian crashes. Pedestrian crash frequency were higher in TAZs with medium land use intensity than TAZs with low and high land use intensity. Thus, higher priority should be given to TAZs with median land use intensity to improve the pedestrian safety.

Authors	Suliman Gargoum, University of Alberta Karim El-Basyouny, University of Alberta
Sponsoring Committee	ANB20
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-4040
Paper Title	Path Analysis of the Relationship between Speed and Safety
Abstract	Road safety is influenced by many factors; these factors include characteristics of the road, climate, traffic and, most importantly, vehicle speeds. Previous research shows that increases in speed are typically associated with an increased collision risk. Moreover, previous studies have also found relationships between road and traffic characteristics and collisions. In addition, these features have also been found to affect speeds. Therefore, one could suspect that some of the effects those factors have on safety could be imposed indirectly through their effects on speed. In fact, this is only one way in which the relationship between speed and safety could be confounded. This paper attempts to model the relationship between average speed and collision frequency, while taking into account the mediated effects of other factors that confound the relationship. The data used in this study originated from 361 two-lane urban roads in the city of Edmonton, Canada. The average speeds were obtained from 35 million speed survey observations collected over a five-year period. The speed data are linked to the crash frequency at each location during the same time-frame along with the other factors (road, traffic and climate). Path analysis is used to model the different relationships. The results show that, among others, average speed, volume, segment-length, medians and horizontal curves all significantly affect collisions. On the other hand, shoulder lanes, speed limits and vehicle-lengths are some variables that significantly influence speeds. The results also show that the effects of some variables on safety are indeed mediated through speeds.

Authors	Chowdhury Siddiqui, Mid-Region Council of Governments Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4133
Paper Title	Analyzing Geographical Boundary Dependency in Macroscopic Safety Modeling Using Motor Vehicle Crash Data
Abstract	Traditional macroscopic safety models have been fitting aggregated zonal crashes entirely against zonal characteristics within which crashes had occurred. The underlying assumption there is that crashes within a zone are only influenced by the characteristics of that zone. This study investigated this assumption in the light of zonal influence on motor vehicle crashes (total and severe crashes) that occurred at or near the zonal boundaries. Models were specified by a hierarchical structure with sub-models that provided separate estimates of covariate sets for crashes which occurred at or near boundaries, and which occurred within a zone (interior crashes) away from zonal boundaries. The proposed model structure was compared using spatial and non-spatial statistical models fitted for a wide array of independent variable sets. Two layers of zonal influences were investigated- i) influence of immediate neighbors, and ii) additional influence of neighbors of immediate neighbors. Additionally, roadway network hierarchy was considered in model sub-level specification since motor vehicles have a wider radius of exposure than the non-motorized modes. Comparison among the candidate models yielded interesting results. It was found that the complex nested model structure did not necessarily provide the best model fit. Models with sub-models based on roadway network hierarchy were found to have the best goodness-of-fit measures for both total and severe crashes. In general, the results indicated that demographic and socioeconomic variables constituted better model fit than that of trip and land use related variables for the modeling area.

Authors	Yiyi Wang, Montana State University Shivam Sharda, Montana State University Haizhong Wang, Oregon State University
Sponsoring Committee	ANB20
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-4354
Paper Title	A Systemic Safety Analysis of Pedestrian Crashes: Lessons Learned
Abstract	The objectives of this study are twofold. First, this study synthesized relevant research and limitations of systemic (pedestrian) safety analysis. Second, the study explored one of the limitations identified relative to ranking roadway facilities based on primary risk factors. An intersection-pedestrian-crash data set from Austin, Texas was used. Comparisons among candidate ranking methods suggest that results were very sensitive to the weights used, and the grouping-based ranking method combining arbitrary weights produced relatively stable results. However, the finding is inconclusive, and more research would be needed to investigate alternative methods, especially the ones suitable for making decisions under multiple criteria (risk factors).

Authors	Jiří Ambros, CDV – Transport Research Centre Veronika Valentová, CDV – Transport Research Centre Jiří Sedoník, CDV – Transport Research Centre
Sponsoring Committee	ANB20
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-5048
Paper Title	Linking Rural Road Environment, Speed and Safety Factors with a 'Two-Stage' Model: a Feasibility Study
Abstract	Speed on two-lane rural roads is a critical safety issue. In this regards various research perspectives have been adopted, including speed models (relating speed to design consistency factors) and safety models (which estimate safety using exposure data and design consistency variables). Unfortunately both approaches have often been carried out separately, and influences on speed choice have been limited only to geometrical variables. In contrast safety models are often expanded with wide array of exposure and risk factors. The study aims to investigate the issue of speed and safety from a different perspective, using so called 'two-stage' model which estimates speed (using more explanatory variables) and further applies it in a simple safety performance function. This approach can be superior to the traditional approach as it preserves model parsimony while capturing the most important safety effects. The specific objective of the study is to prove feasibility of a 'two-stage' model in linking environment, speed and safety factors on a sample of Czech rural roads. To this end, data collection was carried out on approx. 100 km (60 mi) of two-lane rural roads in the Czech Republic, using speed data from instrumented vehicle, manually collected road environment data, as well as crash and exposure data retrieved from national databases. Both models are developed, described and compared to the literature. It is concluded that approach is feasible, in spite of several current limitations. Planned further improvements and future practical applications are also listed.

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Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-5892
Paper Title	Heterogeneous Dispersion Parameter Negative Binomial Models Using Roadside Geometry
Abstract	Safety performance functions (SPFs) are statistical models used to estimate crash frequencies for a specific site type with specific base conditions. Negative binomial (NB) models estimate an ancillary term that provides a correction for the dispersion heterogeneity in the data, but assume that the dispersion in the dataset is consistent across all segments. The heterogeneous dispersion NB allows segment specific parametrization of the ancillary parameter. This paper details a summary of these models, estimated for total crashes, and 31 different crash frequency classifications. Key findings of this research were that the roadside presence of a culvert, ditch, guardrail, tree or tree group led to segments having lower over-dispersion for total accidents. Roadway segments with guardrails, side slopes, or ditch extending between 90 and 100% of the length, exhibit more over-dispersion. The over-dispersion for fatalities on segments with a culvert or roadside ditch was found to be lesser than otherwise, but higher for segments with a roadside fence. Severe injury crashes were found to be dispersed higher for segments with guardrail lengths between 90 and 100%. Accounting for the effect of these roadside characteristics enables the identification of roadway segments with high or low propensities of specific crash types. By providing insight into roadside features that influence different types of crashes, while taking roadway geometry and traffic exposure into account, this work could provide the means for proactive approaches to roadway safety management.

Authors	Yue Zhao, Kittelson & Associates, Inc. Tian Zong, University of Nevada, Reno
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6483
Paper Title	Spatially Adjusted Crash Prediction Models for Signalized Intersections Along Corridors
Abstract	The presence of spatial correlations is violating the elemental assumption of independently and identically distributed errors of most statistical procedures. Ignoring such effects may cause underestimation of model variability, result in biased parameter estimates and incorrect inferences, and decrease model's prediction performance. The most popular interpretation for having the spatial correlations in traffic crash data is the omitted covariables which vary in space and/or misspecified model forms. This research explores the effect of spatial correlations in crash prediction modeling. Efforts were first made to collect crash, traffic, and road inventory data at intersection level and corridor level. Significant spatial correlations were found not only within the crash dataset, but also in the model residuals and fitted values. The spatial eigenvectors were introduced to supplement the spatial effects. Spatially adjusted crash prediction models were built within Poisson mixture models. Different neighboring proximity structures were tested for the assembled data set to establish the spatial configuration that resulted in the optimal performance of the prediction models. The comparisons of model goodness-of-fit statistics indicated that the spatial correlations contribute significantly to model heterogeneity. The proposed spatially adjusted crash prediction models will support the understanding of underlying spatial processes affecting the presence or absence of crashes.

Authors	Bumjoon Bae, University of Tennessee, Knoxville Changju Lee, Virginia Transportation Research Council Tae-Young Pak, University of Georgia Asad Khattak, University of Tennessee, Knoxville
Sponsoring Committee	ANB20
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6533
Paper Title	Modifiable Temporal Unit Problem in Crash-Frequency Modeling
Abstract	Aggregation of a spatiotemporal data can involve information loss or distort attributes of individual observation, which would influence modeling results and lead to an erroneous inference, named the ecological fallacy. Therefore to decide spatial and temporal resolution is a fundamental consideration in a spatiotemporal analysis. The modifiable temporal unit problem (MTUP) occurs when using the data which is temporally aggregated. While the consideration of the spatial dimension has been increasingly studied, the counterpart, a temporal unit, is rarely considered particularly in a traffic safety modeling field. The purpose of this research is identifying the MTUP effect in crash-frequency modeling using data with various temporal scale. A sensitivity analysis framework is adopted with four negative binomial regression models and four random effect negative binomial models having yearly, quarterly, monthly and weekly temporal units. As the temporal unit changed, the result of the model estimation also changed in terms of the mean and significance of the parameter estimates. Increasing temporal correlation due to using the small temporal unit can be handled with the random effect models.

Authors	Tammam Nashad, University of Central Florida Shamsunnahar Yasmin, McGill University Naveen Eluru, University of Central Florida Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-6909
Paper Title	Joint Modeling of Pedestrian and Bicylist Crashes: Copula-Based Approach
Abstract	The study contributes to safety literature on active mode transportation safety by employing a copula based model for count frequency analysis at a macro-level. Most studies in the transportation safety area identify a single count variable (such as vehicular, pedestrian or bicycle crash counts) for a spatial unit and study the impact of exogenous variables. While the traditional count models perform adequately in the presence of a single count variable, it is necessary to modify these approaches to examine multiple dependent variables for each study unit. To that extent, the current research effort contributes to literature by developing a multivariate model by adopting a copula based bivariate negative binomial model for pedestrian and bicyclist crash frequency analysis. The proposed approach also accommodates for potential heterogeneity (across zones) in the dependency structure. The formulated models are estimated using pedestrian and bicycle crash count data at the Statewide Traffic Analysis Zone (STAZ) level for the state of Florida for the years 2010 through 2012. The STAZ level variables considered in our analysis include exposure measures, socio-economic characteristics, road network characteristics and land use attributes. A policy analysis is also conducted along with a representation of hotspot identification to illustrate the applicability of the proposed model for planning purposes. The development of such spatial profiles will allow planners to identify high risk zones for screening and treatment purposes.

5 Crash Severity Prediction

Alfonso Montella, University of Naples Federico II

Identifying factors that affect crash injury severity and understanding how these factors affect injury severity is critical in planning and implementing highway safety improvement programs.

The subcommittee identified twenty-four papers dealing with crash severity prediction. These papers are scattered across various sessions, with most papers presented at the poster session 448 Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data (Monday, 4:15PM – 6:00PM).

From a methodological perspective, several approaches were used. Most studies used discrete outcome models treating injury severity as either a nominal or ordered variable.

Nominal models used in the papers presented at the Annual Meeting were:

- Binomial logit model (Naqvi, 16-4612);
- Multinomial logit model (Osman et al., 16-5364; Ariannezhad and Wu, 16-6880);
- Nested logit model (Osman et al., 16-5364; Wu et al., 16-5394, 16-5764);
- Mixed logit model (Islam et al., 16-1496; Couto et al., 16-2295; Wu et al., 16-5764);
- Hierarchical mixed logit model (Huang et al., 16-5162);
- Hierarchical Bayesian multinomial logit with random intercept model (Chen et al., 16-4556); and
- Cluster-based binomial probit regression (Jung et al., 16-2715).

The following ordered regression modeling approaches were used:

- Ordered logit model (Osman et al., 16-5364);
- Generalized ordered logit model (Kwayu et al., 16-4315; Osman et al., 16-5364);
- Modified rank-ordered logit model (Bogue and Paleti, 16-5382);
- Ordered probit model (Dias and Dissanayake, 16-0018; Xie et al., 16-0206; Wang et al., 16-6376);
- Bivariate ordered probit model (Li et al., 16-6464); and
- Hierarchical ordered probit model (Kim et al., 16-1639).

Other papers used different approaches, such as association rules (Xu et al., 16-3830), Bayesian networks (Cai, 16-4787), Generalized Heterogeneous Data Model (Lavieri et al., 16-6858), and Multiple Indicators Multiple Causes model (Song et al., 16-2577), Zero-inflated

negative binomial regression was used to predict the hospital length of stay (Puro et al., 16-4456).

From an application point of view, the papers addressed:

- Environmental factors (Dias and Dissanayake, 16-0018; Xie et al., 16-0206; Kim et al., 16-1639; Song et al., 16-2577; Kwayu et al., 16-4315 ; Puro et al., 16-4456; Chen et al., 16-4556 ; Cai, 16-4787; Osman et al., 16-5364; Wu et al., 16-5394, 16-5764; Wang et al., 16-6376; Lavieri et al., 16-6858; Ariannezhad and Wu, 16-6880);
- Highway characteristics (Dias and Dissanayake, 16-0018; Xie et al., 16-0206; Islam et al., 16-1496; Kim et al., 16-1639; Kwayu et al., 16-4315 ; Puro et al., 16-4456; Chen et al., 16-4556; Osman et al., 16-5364; Cai, 16-4787; Wu et al., 16-5394, 16-5764; Lavieri et al., 16-6858; Ariannezhad and Wu, 16-6880);
- Road users' characteristics (Dias and Dissanayake, 16-0018; Xie et al., 16-0206; Islam et al., 16-1496; Kim et al., 16-1639; Song et al., 16-2577; Kwayu et al., 16-4315 ; Puro et al., 16-4456; Chen et al., 16-4556; Cai, 16-4787; Wu et al., 16-5394, 16-5764; Li et al., 16-6464; Lavieri et al., 16-6858; Ariannezhad and Wu, 16-6880);
- Roadside features (Cai, 16-4787);
- Traffic characteristics (Osman et al., 16-5364); and
- Vehicle characteristics (Xie et al., 16-0206; Islam et al., 16-1496; Kim et al., 16-1639; Cai, 16-4787; Huang et al., 16-5162; Li et al., 16-6464 ; Lavieri et al., 16-6858).

The papers investigated also specific road users and vehicle types, such as:

- Cyclists (Van den Berghe et al., 16-1878; Ariannezhad and Wu, 16-6880);
- Motorcyclits (Van den Berghe et al., 16-1878);
- Pedestrians (Kim et al., 16-1639; Van den Berghe et al., 16-1878; Song et al., 16-2577; Kwayu et al., 16-4315 ; Naqvi, 16-4612; Cho et al., 16-5018; Ariannezhad and Wu, 16-6880);
- Trucks (Chen et al., 16-4556; Osman et al., 16-5364).

Furthermore, Van den Berghe et al. (16-1878) used hospital data and mobility of different road users groups to calucate relative risks using the Maximum Abbreviated Injury Scale (MAIS) to classify severe injuries (MAIS3+).

Authors	Ishani Dias, Kansas State University Sunanda Dissanayake, Kansas State University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-0018
Paper Title	Comparison of Factors Affecting Work Zone Crash Severity Between Nighttime and Daytime
Abstract	Identification of factors associated with crashes in highway work zones is essential in order to establish safe, efficient traffic flow through improved work zones. According to FHWA, 87,606 crashes (1.6% of total vehicle crashes) occurred in work zones in 2010; 436 of those crashes were fatal, killing 576 people. Analysis of data published by the Kansas Department of Transportation (KDOT) showed an increase in crashes in Kansas work zones from the years 2009 to 2012. According to KDOT fact sheets, 1,781 crashes occurred in work zones in 2012. The primary objectives of this study were to identify factors that contribute to higher injury severity of crashes in work zones and to compare the characteristics nighttime and daytime work zone crashes using Kansas crash data from 2010 to 2013. Ordered probit model was used to model crash severity for nighttime crashes and daytime crashes. Driver-related, environmental-related, and road-related variables were considered in the models. Model results showed that various driver aspects and crash locations were associated with crashes resulting in severe injuries. For example, young drivers (15 to 25 years old) were found to be involved in severe injury nighttime work zone crashes, and middle-aged drivers (25 to 65 years old) were found to be involved in severe injury daytime work zone crashes. In total, more factors were related to higher crash severities at night as compared to during the day.

Authors	Kun Xie, New York University (NYU) Kaan Ozbay, New York University (NYU) Hong Yang, Old Dominion University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-0206
Paper Title	Joint Analysis of Secondary Collisions and Injury Severity Levels Using Structural Equation Models
Abstract	This study aims to investigate the contributing factors to secondary collisions and the effects of secondary collisions on injury severity levels. Manhattan, which is the most densely populated urban area of New York City, is used as a case study. In Manhattan, about 7.5% of crash events get involved with secondary collisions and as high as 9.3% of those secondary collisions lead to incapacitating and fatal injuries. Structural equation models (SEMs) are proposed to jointly model the presence of secondary collisions and injury severity levels. This study contributes to the literature by fully exploring the determinants of secondary collisions such as speeding, alcohol, fatigue, brake defective, limited view and rain. To assess the temporal effects, we use time as a moderator in the proposed SEM framework and results indicate that it is more likely to sustain secondary collisions and severe injuries at night. The parameter estimates of the proposed SEM are further compared with those of the standard probit models which estimate the presence of secondary collisions and injury severity independently. It is found that the standard probit models significantly overestimate the effects of secondary collisions on injury severity propensity since the endogeneity of the presence of secondary collisions is ignored in the estimation. Understanding the causes and impacts of secondary collisions can help the transportation agencies and automobile manufacturers develop effective injury prevention countermeasures.

Authors	Samantha Islam, University of South Alabama Akhter Hossain, Alabama Department of Transportation Timothy Barnett, Alabama Department of Transportation
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1496
Paper Title	Comprehensive Injury Severity Analysis of Sport Utility Vehicle and Pickup Truck Rollover Crashes on Roadways in Alabama
Abstract	The research described in this paper explored the factors contributing to the injury severity resulting from the rollover accidents of light trucks, sport utility vehicles (SUVs) and pickups in particular, in Alabama incorporating the effects of randomness across the observations. Given the occurrence of a rollover crash, random parameter logit models of injury severity (with possible outcomes of fatal, major, minor, and possible or no injury) were estimated. The estimated models identified a variety of statistically significant factors influencing the injury severities resulting from SUV and pickup rollover crashes. According to these models, some variables were found to be significant only in one model (SUV or pickup) but not in the other one. For example, variables such as roadway downgrade, female drivers and presence of daylight were found significant only in the SUV model. On the other hand, variables such as driver fatigue, seat belt usage and freeway were found significant only in the pickup model. In addition, some variables (such as, not wearing seat belt, two-lane roadway, horizontal curve, old driver, etc.) were found significant in both models. Also, estimation findings showed that two parameters (horizontal curve, and at intersections) in the SUV model and two parameters (horizontal curve and dry roadway surface) in the pickup model could be modeled as random parameters indicating their varying influences on the injury severity. Based on the results obtained, this paper discusses the effects of different variables on pedestrian and bicyclist injury severities and their possible explanations.

Authors	Myeonghyeon Kim, Seoul National University Seung-Young Kho Dong-Kyu Kim, Seoul National University
Sponsoring Committee	ANF10, Pedestrians
Session Number	795
Session Title	Pedestrian Safety
Paper Number	16-1639
Paper Title	Hierarchical Ordered Model for Injury Severity of Pedestrian Crashes
Abstract	The high percentage of fatalities in pedestrian-involved crashes is one of critical social problems. The purpose of this study is to investigate factors influencing injury severity in pedestrian crashes by examining the demographic and socioeconomic characteristics of the regions where crashes occurred. To understand the correlation between the unobserved characteristics of pedestrian crashes in a defined region, we apply a hierarchical ordered model, in which we set crash characteristics as lower-level variables and municipality characteristics as upper-level. Pedestrian crash data were collected and analyzed for a three-year period from 2011 to 2013. The estimation results show the statistically significant factors that increase injury severity of pedestrian crashes. At the crash level, the factors associated with increased severity of pedestrian injury include intoxicated drivers, road-crossing pedestrians, elderly pedestrians, heavy vehicles, wide roads, darkness, and fog. At the municipality level, municipalities with low population density, lower level of financial independence, fewer doctors, and a high percentage of elderly residents experience more severe pedestrian crashes. Municipalities ranked as having the top 10% pedestrian fatality rate (fatalities per 100,000 residents) have rates 7.4 times higher than municipalities with the lowest 10% rate of fatalities. Their demographic and socioeconomic characteristics also have significant differences. The proposed model accounts for a 7% unexplained variation in injury severity outcomes between the municipalities where crashes occurred. Based on our study results, we suggest policy directions to enhance pedestrian safety.

Authors	Wouter Van den Berghe, Belgian Road Safety Institute Heike Martensen, Belgian Road Safety Institute Nina Nuyttens, Belgian Road Safety Institute
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1878
Paper Title	Measuring Relative Risk of Serious Crash Through Linking Mobility and Hospital Data: Novel Approach Adopted in Belgium
Abstract	In order to calculate the risk of being seriously injured or killed in a road accident, it is necessary to have access to detailed exposure data, data on fatalities and data on serious injuries provided by hospitals. In Belgium a first successful attempt has been made for developing more accurate and useful risk measures, in particular for severe crashes. A “severe crash” is a crash in which at least one of the road users involved either died, or was “seriously” injured. Serious injured people are defined here as having injuries with a MAIS score of 3+. The approach in Belgium is based on comparing hospital data and mobility data from a major national survey (Beldam) containing mobility data and hospital data. The mobility data referred to the year 2009 and included detailed trip information of over 15000 people. The hospital data concerned the years 2007-2011 (all traffic victims in Belgium that stayed at least one night in a Belgian hospital were included in the data). The results of the project illustrate the considerable underestimation of traffic victims if only police data is taken into account. It also yielded measures of the relative risk of suffering from a severe road crash by age category and transportation mode compared to the average car driver.

Authors	Antonio Couto, University of Porto Sara Ferreira, University of Porto Marco Amorim
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-2295
Paper Title	Factors Affecting Traffic Injury Severity: Mixed Logit Model
Abstract	Traffic crashes result in loss of life, but also impact the quality of life and productivity of the crash survivors. In order to get detailed information on injury type and severity of the crash victims, hospital data has been proposed to be used alongside with police crash records. Based on hospital data, a new injury severity classification, recently adopted by the European Commission (EC), named maximum abbreviated injury scales (MAIS) was developed. In this study MAIS score was derived from the international classification of diseases (ICD). This study provides a deep analysis of the factors affecting injury severity classified by the MAIS scale. The data were obtained by a linkage process between police and hospital data sets of Porto Metropolitan Area, Portugal, covering a 6-year period (2006-2011). A mixed logit model is used to understand the factors contributing to the severity of the traffic victims and to explore the impact of them on the injury severity. Additionally, a comparison between MAIS and length of hospital are provided. As shown in this study, the relationship between the official criterion used in Portugal and other several countries reported according to length of hospital stay and the MAIS+3 level is quite different. Therefore, bias on the risk factors assessing is expected if other injury severity classification than MAIS is used as observed in the present study.

Authors	Tai-Jin Song, North Carolina State University Jaehyun So, Technische Universitaet Muenchen Jisun Lee, The Korea Transport Institute Billy Williams, North Carolina State University Younshik Chung, Korea Transport Institute
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-2577
Paper Title	Exploring Vehicle-Pedestrian Crash Severity Factors Based on In-Car Black Box Recording Data
Abstract	This study investigates the main factors affecting the crash severity of vehicle-pedestrian crashes on urban arterial roads using the video recording data collected by an in-car black box device. While many previous studies used interview data collected by police officers/witnesses, such data can lead to subjective and erroneous understandings regarding the crash situations. In contrast, the in-car black box recording data is a more reliable data source by virtue of direct crash observation. The black box video-recording data are advantageous for the safety studies because they provide not only video image information but also speed information that is measured in real-time including the time before-and-after a crash occurs. By analyzing the black box data, this study defines new reasonable independent explanatory variables affecting vehicle-pedestrian crash severity, which could not have been identified by the conventional crash report-based method. A Multiple Indicators Multiple Causes (MIMIC) model is used to investigate the relationship between the explanatory variables and crash severity. The results show that the crash characteristics most strongly associated with increased crash severity are pedestrian's failure in watching for approaching vehicles, pedestrian's jaywalking, pedestrian being classified as elderly (more than 65 years old), vehicle's excessive speed (more than 60 km/h), driver's failure to immediately stop, limited driver vision, and nighttime period. Finally, this study emphasizes the potential of individualized black box video recording data for the purpose of analyzing the crash severity by extracting additional explanatory variables and also for the purpose of exploring the factors affecting crash severity. The utility of this new crash analysis data source (black box video recordings) is expected to be beneficial when a new transportation policy is established for the purpose of reducing pedestrian crash severity.

Authors	Soyoung Jung, Hanyang University Xiao Qin, University of Wisconsin, Milwaukee Cheol Oh, Hanyang University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-2715
Paper Title	System-wide Impacts of Emergency Medical Service (EMS) Resources on Freeway Crash Severity
Abstract	Timely patient transport to permanent medical facilities is an important issue in reducing fatalities on rural freeways. The objective of this study is to quantitatively examine the system-wide effects of pre-hospital emergency medical service (EMS) resources on crash outcomes throughout the entire Korean freeway system. To achieve this objective, latent class cluster and binomial probit regression models were combined to identify pre-hospital EMS resources for different types of crashes. In the cluster-based binomial probit regression, surrogate measures for pre-hospital EMS resources were obtained by combining medical service portals, freeway heliport maps, and freeway network log data in the crash dataset. As a result, eight latent class clusters of crashes were determined based on features associated with EMS resources, province, roadway, and traffic conditions at the scene of the crash. On-scene and recovery times were commonly significant in increasing the probability of fatal crashes in both entire group and in each group of crashes, whereas the nearest ramp proximity and the number of nearby EMS facilities significantly affected fatal crashes for a certain group of crashes. The findings provide meaningful insights that can enhance EMS training programs for initial medical aid and post-crash traffic management on all provincial freeways. Supplemental nearby EMS facilities and access points to them are needed in Korea's south freeway sections in particular. This research is the first data-driven study to assess system-wide EMS resources for the entire Korean freeway system using multiple data sources, which would contribute to informed decision-making for future EMS provision.

Authors	Chengcheng Xu, Southeast University Jie Bao, Southeast University Pan Liu, Southeast University Wei Wang
Sponsoring Committee	ABE90, Transportation in the Developing Countries
Session Number	832
Session Title	Traffic Safety and Evaluation in China
Paper Number	16-3830
Paper Title	Association Rule Analysis of Contributing Factors to Extraordinarily Severe Road Traffic Crashes in China
Abstract	This study aimed to investigate the contributing factors to serious casualty traffic crashes and their interdependency in China. The serious casualty crashes are defined as crashes that lead to greater than 10 deaths. The serious casualty crash data between 2009 and 2013 were collected from the Annual Report for Road Traffic Accidents released by the Ministry of Public Security of China (MPSC). The descriptive statistics was used to illustrate the characteristics of serious casualty crashes in terms of road user, vehicle conditions, geometric characteristics, and environmental conditions. The association rule mining technique was further applied to identify sets of contributory factors that often occur together in serious casualty crashes. The results showed that the occurrences of serious casualty crashes are a result of the complex interactions among road user behavior, vehicle factors, road geometric characteristics and environmental factors. We discussed the reasons for the occurrence of serious casualty crashes in different circumstances, and note the potential implications for policymakers. The results of this study can provide useful insights for understanding why serious casualty crashes occurred and developing effective policy initiatives and engineering countermeasures for the transportation agency to reduce the fatalities and injuries caused by the serious casualty crashes.

Authors	Keneth Kwayu, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	ANF10, Pedestrians
Session Number	795
Session Title	Pedestrian Safety
Paper Number	16-4315
Paper Title	Investigating the Correlation Between Factors Contributing to Pedestrian-Involved Crashes and Their Impact on Crash Severity
Abstract	There are several factors that influence the potential for crash occurrence. These factors can be summarized as road environment, vehicle defects, driver and pedestrian behavior. Often, the influence of these factors on the likelihood of a potential crash or post-crash injury severity have been addressed independently without considering their synergy effect. This study aims at exploring co-variation of driver and pedestrian actions prior to a crash and link their interactive effect on injury severity level. Vehicle condition prior to crash was not included in the scope of this study and the focus was only on crashes involving one vehicle and one pedestrian. This scenario covered 90 percent of all pedestrian crashes that were available. Tetrachoric correlation was used to measure the association between involved parties conditions and their corresponding hazardous actions prior to crash. A generalized ordered logit model was used to test the significance of interactive driver-pedestrian pre-crash hazardous action scenarios to crash severity levels. The results showed that interaction of speeding by driver with a pedestrian who was not at fault and interaction between failures to yield by a pedestrian with driver not at fault had a significant effect on fatal and incapacitating injury. The first scenario was significantly correlated with the icy and snowy road environment while the second scenario had a significant association with pedestrian who had been drinking before the crash.

Authors	Sagar Puro, Clemson University Sijun Shen, Clemson University David Neyens, Clemson University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4456
Paper Title	Factors Affecting Hospital Length of Stay for Drivers Who Sustained Traumatic Brain Injuries from Crashes in South Carolina
Abstract	Traumatic brain injuries (TBIs) are a major cause of disability and mortality and many TBIs are caused by motor vehicle crashes. Hospital length of stay (LOS) is often regarded as a representation of consumption of hospital resources and drivers injury severity. The purpose of this study is to investigate the effects of crash factors and drivers characteristics on the hospital LOS for drivers sustaining a TBI in traffic crashes. The South Carolina Crash Outcome Data Evaluation System (SC CODES) from 2005 to 2007 were used to build a zero-inflated negative binomial regression to predict the hospital LOS for drivers experiencing a TBI as a result of a crash. Not wearing a seatbelt, ejection from the vehicle, and roadway with high speed limit were factors associated with higher likelihood of being admitted to the hospital and/or having longer hospital LOS for drivers sustaining TBIs in crashes. Intoxicated drivers were more likely to be admitted to the hospital but tend to have a shorter LOS when they sustained a TBI in a crash. Hospital LOS may be a surrogate measurement of injury severity and also a representation of health care resource consumption. By understanding the effects of crash factors on the hospital LOS for drivers sustaining a TBI in crashes helps policy makers, roadway designers, and health care providers to develop specific educational efforts and other specific interventions to reduce health care resource consumption and improve transportation safety.

Authors	Cong Chen, University of New Mexico Guohui Zhang, University of New Mexico Tian Zong, University of Nevada, Reno Susan Bogus, University of New Mexico Yin Yang
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4556
Paper Title	Investigating Truck Driver Injury Severity Using a Hierarchical Bayesian Random Intercept Model with Cross-level Interactions
Abstract	Traffic crashes occurring on rural roadways induce more severe injuries and fatalities than those in urban areas, especially when there are trucks involved. Truck drivers are found to suffer higher potential of crash injuries compared with other occupational labors. In this study, a hierarchical Bayesian random intercept model decomposing cross-level interaction effects is developed to examine the posterior probabilities of truck driver injuries in rural truck-involved crashes. The interaction effects contributing to truck driver injury outcomes are investigated based on two-year rural truck-involved crashes in New Mexico from 2010 to 2011. The analysis results indicate that the cross-level interaction effects play an important role in predicting truck driver injury severities, and the proposed model produces comparable performance with the traditional random intercept model even after penalization by high model complexity. It is revealed that factors including road grade, number of vehicles involved in a crash, maximum vehicle damage in a crash, vehicle actions, driver age, seatbelt use, and driver under alcohol or drug influence, as well as a portion of their cross-level interaction effects with other variables are significantly associated with truck driver incapacitating injuries and fatalities. These findings are helpful to understand the respective or joint impacts of these attributes on truck driver injury patterns in rural truck-involved crashes.

Authors	Hasan Naqvi, National Highways Authority of India
Sponsoring Committee	ANF10, Pedestrians
Session Number	795
Session Title	Pedestrian Safety
Paper Number	16-4612
Paper Title	Risk Factors for Fatal Pedestrian Crashes on National Highways in India
Abstract	In India, 486,476 crashes are reported and 137,572 fatalities during 2013. Major share of crashes (28.8% of total crashes) are on National Highways. Considering high importance of NHs in overall road network with respect to its connectivity to state capitals and business centres, and cater to high share of traffic (40%), there is an urgent need to investigate factors contributing to crashes on NHs. In this study, an attempt is made to establish relationship between fatal crashes and probable contributory factors for three NHs; based on available crash data. The study results revealed that fatal crash per kilometer is four times higher on six-lane as compared to two-lane paved shoulder NH. The model results revealed that likelihood of fatal pedestrian crash is higher on four-lane and six-lane than two-lane paved shoulder NH and chances of fatal pedestrian crash is lower with “two or more vehicles” than with “single vehicle”. Therefore, pedestrian facilities on divided highways must be incorporated in design when two-lane paved shoulder highways are upgraded to four-lane and six-lane highways.

Authors	Xiaonan Cai, Shanghai Jiao Tong University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4787
Paper Title	Analysis of Factors Affecting Serious Roadway Incidents in China Based on Bayesian Network
Abstract	A serious roadway incident is defined as a motor-vehicle crash resulting in more than ten deaths. In this study, Bayesian networks were applied to analyze and prioritize the factors that influence serious roadway incidents in China. The Bayesian network structure was developed based on expert knowledge using Dempster-Shafer evidence theory, and the structure was modified based on a test for conditional independence. This paper collected 484 serious roadway incidents for the period 2000-2012 to calculate the posterior probability of each factor using the expectation-maximization learning algorithm. Results showed that the most influential factor contributing to serious roadway incidents was driver behavior, followed by vehicle condition, road condition and external environment. And compared to the other behaviors, speeding and mistaken adjustment had greater influence on serious roadway incidents. The findings in this study provide useful and valuable information for engineers to take corrective and preventative measures to reduce the probability for serious roadway incidents.

Authors	Junhan Cho, Samsung Traffic Safety Research Institute Kitae Jang, Korea Advanced Institute Science and Technology Suji Kim, Korea Advanced Institute Science and Technology Lee Hyunmin
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-5018
Paper Title	Effects of Pedestrian Volume on Per-Pedestrian Crash Rate and Severe Injury Probability
Abstract	This study evaluates the effects of safety in numbers phenomenon not only on the risk of crash occurrences but also on the probability of severe or fatal injuries in case of crashes. Pedestrian volume and crash data obtained from six districts in Seoul Metropolitan city and entire Jeju Island were jointly analyzed to examine crash rate and fatal or severe injury probability as a function of pedestrian volume. The analyses show that both crash rate and fatal or severe injury probability decline as pedestrian volume increases. In other words, the increase in the number of pedestrian crashes is not proportionate but less than the increase in pedestrian volume; and the probability of severe or fatal injuries in case of crashes diminishes with the pedestrian volume. This finding implies that the policy and planning measures promoting walk trips may have a favorable effect on pedestrian safety by reducing individual risk of crashes as well as injuries.

Authors	Shuaiqi Huang, Pennsylvania State University Puttipan Seraneeprakarn, Pennsylvania State University Venkataraman Shankar, Pennsylvania State University
Sponsoring Committee	ABJ80, Statistical Method
Session Number	638
Session Title	Statistical Methods in Transportation
Paper Number	16-5162
Paper Title	Heterogeneity in Hybrid-Involved Crash Severities: Exploratory Analysis Using Hierarchical Mixed Logit Model with Hierarchical Hybrid Vehicle Attributes
Abstract	Contemporarily, hybrid vehicles have been increasingly accepted by consumers because of environmental, economic and nonrenewable (e.g. fossil fuels) resource concerns. In addition to the differences in fuel source, hybrid vehicles are different from the fuel-engine vehicles in terms of ride characteristics, ride noise, weight, etc. These differences can be sources of potential shifts in severity distributions involving hybrid vehicle crashes. However, how the attributes of a hybrid vehicle affect our inferences on crash severity propensities is a largely unaddressed issue in the literature. This paper attempts to contribute some insight into the impact of hybrid vehicle attributes on crash severity propensities by using a hierarchical mixed logit model to predict the crash severity in crashes involving hybrid vehicles. The hierarchical model allows for the identification of factors that can influence of the mean of the random parameters in the mixed logit. Using statewide data from reported crashes in Washington State involving hybrid vehicles, this paper develops the model for the severity of crashes involving hybrid vehicles, by considering factors such as roadway conditions, environment factors, occupant attributes and vehicle characteristics. The hierarchical influences consist of hybrid vehicle attributes, due to the fact that at least one of the vehicles involved in the crash dataset is a hybrid. The research results shows that the hierarchical mixed logit is a plausible approach for gaining insight into the particular impact of hybrid vehicle attributes on crash severity parameters.

Authors	Mohamed Osman, University of Memphis Rajesh Paleti, Old Dominion University Sabyasachee Mishra, University of Memphis Mihalis Gkolias, University of Memphis
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-5364
Paper Title	Analysis of Injury Severity of Large Truck Crashes in Work Zones
Abstract	Work zones are critical part of the transportation infrastructure renewal process consisting of rehabilitation of roadways, maintenance, and utility work. Given the specific nature of a work zone (complex arrangements of traffic control devices and signs, narrow lanes, duration) a number of crashes occur with varying severities involving different vehicle sizes. In this paper we attempt to investigate the causal factors contributing to injury severity of large truck crashes in work zones. Considering the discrete nature of injury severity categories, a number of comparable econometric models are developed including multinomial logit (MNL), nested logit (NL), ordered logit (ORL), and generalized ordered logit (GORL) models. The MNL and NL models belong to the class of unordered discrete choice models and do not recognize the intrinsic ordinal nature of the injury severity data. The ORL and GORL models, on the other hand, belong to the ordered response framework that was specifically developed for handling ordinal dependent variables. Past literature did not find conclusive evidence in support of either the unordered or the ordered frameworks. So, this study compared these alternate modeling frameworks for analyzing injury severity of crashes involving large trucks in work zones. The model estimation was undertaken by compiling a database of crashes that (1) involved large trucks and (2) occurred in work zones in the past 10 years in Minnesota. The empirical findings indicate that the GORL model provided superior data fit compared to all the other models. Also, elasticity analysis was undertaken to quantify the magnitude of impact of different factors on work zone safety and the results of this analysis suggest the factors that increase the risk propensity of sustaining severe crashes in a work zone include crashes in the daytime, lower Average Annual Daily Traffic (AADT), higher speed limits, and crashes occurring on rural principal arterials.

Authors	Shelley Bogue, Old Dominion University Rajesh Paleti, Old Dominion University
Sponsoring Committee	ABJ80, Statistical Method
Session Number	638
Session Title	Statistical Methods in Transportation
Paper Number	16-5382
Paper Title	Modified Rank-Ordered Logit Model to Analyze Injury Severity of Occupants in Multivehicle Crashes
Abstract	The current study developed a simultaneous model of severity outcomes of all people involved in a crash. Specifically, a Modified Rank Ordered Logit (MROL) methodology that can determine the relative order of occupant injury severity as well as the actual injury severity was developed. The final model quantifies the effects of several key occupant, vehicle, and accident level variables on four possible levels of injury severity. The presence of crash-level unobserved factors that can moderate the influence of these key variables was also accounted by allowing random parameter heterogeneity in the parameter estimates of the final model. The results indicate the presence of strong crash level unobserved factors that influence all severity outcomes as well as random heterogeneity in the effect of key covariates including occupant's gender, speed limit, and seating position. The performance of the MROL model was compared with the traditional mixed multinomial logit (MMNL) model that is the most commonly used model in both research and practice for safety analysis. Overall, the results demonstrate superior predictive ability of the MROL model in comparison to the MMNL model. The traditional MMNL model performed satisfactory in terms of replicating the simple shares of different injury severity levels across all occupants. However, the performance of the MMNL model dropped significantly when the observed and predicted shares were compared for combinations of injury severity levels among crashes involving multiple occupants. Lastly, elasticity effects were computed to demonstrate considerably different policy implications of the MROL and MMNL models.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-5394
Paper Title	Heterogeneous Analysis of Gender on Driver Injury Severities in Single-Vehicle Rollover Crashes
Abstract	In this study, a mixed logit model is developed to identify the heterogeneous impacts of gender-interpreted contributing factors on driver injury severities in single-vehicle rollover crashes. The random parameter of the variables in the mixed logit model, the heterogeneous mean, is elaborated by driver gender-based linear regression models. The model is estimated using crash data in New Mexico from 2010 to 2012. The percentage changes of factors' predicted probabilities are calculated and a transferability test is conducted in order to better understand the model specifications and temporal stability. Female drivers are found more likely to experience severe or fatal injuries in rollover crashes than male drivers without considering the other factors captured in this study. However, the probability of male drivers being severely injured is higher than female drivers when the road surface is unpaved. Three other factors with fixed parameters are also found to significantly increase driver injury severities, including Wet,Loose Materials, and Alcohol Influenced. This study provides a better understanding of contributing factors influencing driver injury severities in rollover crashes as well as their heterogeneous impacts in terms of driver gender. Those results are also helpful to develop appropriate countermeasures and policies to reduce driver injury severities in single-vehicle rollover crashes.

Authors	Qiong Wu, University of New Mexico Guohui Zhang, University of New Mexico Xiaoyu Zhu, Metropia Inc. Xiaoyue Liu, University of Utah Hua Wang
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-5764
Paper Title	Driver Injury Severity Analysis of Single-Vehicle Crashes on Rural and Urban Roadways
Abstract	This study analyzes driver injury severities for single-vehicle crashes occurring in rural and urban areas using data collected in New Mexico from 2010 to 2011. Nested logit models and mixed logit models were developed in order to account for the correlation between severity categories (No injury, Possible injury, Visible injury ,Incapacitating injury and fatality) and individual heterogeneity among drivers. Various factors, such as crash and environment characteristics, geometric features, and driver behavior are examined in this study, and elasticity analyses were conducted to better quantify their impacts on driver injury severity. Although the mixed logit model fits the data better than the nested logit model in the analysis of rural crashes, the two models are both recommended due to their unique characteristics. In the analysis of urban crashes, only the nested logit model is presented since no random parameter is found in the mixed logit model. The results indicate that significant differences exist between factors contributing to driver injury severity in single-vehicle crashes for rural and urban areas. There are five significant variables captured only in the rural crash model and six significant variables identified only in the urban crash model. These findings can help transportation agencies develop effective policies or appropriate strategies to reduce injury severity resulting from single-vehicle crashes

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Sponsoring Committee	AND40, Visibility
Session Number	699
Session Title	Road Illumination, Signage, and Visibility
Paper Number	16-6376
Paper Title	Safety Effects of Street Illuminance at Urban Signalized Intersections in Florida
Abstract	Nighttime crashes are overrepresented in the nationwide and statewide roadway systems. Nighttime safety at signalized intersections in urban areas receives more attention because of frequent and serious vehicle-to-vehicle and vehicle-to-pedestrian/bicyclist traffic conflicts at night. Street illumination has been proven to be an effective countermeasure for increasing the visibility of intersection and reducing nighttime crashes. However, the safety effects of illuminance at urban signalized intersections were not well documented. Thus, this paper aims to investigate the impacts of illuminance on both nighttime crash occurrence and nighttime crash injury severity at urban signalized intersections. Illuminance data and crash data for a sample of 91 signalized intersections were collected from Tampa Bay, Florida. The negative binomial model and the probit model were developed to examine the safety effects of intersection illuminance in terms of crash frequency and the risk of fatality and severe injury, respectively. The models show that increasing intersection illuminance from low (< 0.2 fc) to medium (≥ 0.2 fc and <1.1 fc) can reduce nighttime crash frequency and night-to-day crash ratio by approximately 50%. If illuminance is kept at 0.9 fc or higher, the risk of fatality and severe injury significantly decreases, especially for pedestrian/bicycle involved crashes, head-on crashes, and angle crashes. Summing up the two safety effects, it is suggested that illuminance at urban signalized intersections should be kept at 0.9 fc or higher.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6464
Paper Title	Investigating the Interplay Between Attributes of At-fault and Not-at-Fault Drivers and the Associated Impacts on Crash Injury Occurrence and Severity Level
Abstract	The paper proposes a two-staged modelling approach to identify the association between one vehicle's attributes and the injury severity of victims in the partnering vehicle in two-vehicle crashes. The two-staged modelling approach involves using a bivariate binary probit model to first determine the probability of injury and the corresponding probability of no injury occurring, followed by the use of a bivariate ordered probit model to further investigate the conditional probability of the specific severity level (conditioned on the prior assumption that an injury already occurred). The empirical models are estimated by using a dataset containing all reported traffic crashes that occurred between 2006 and 2010 in the City of Toronto. In this study, the victims involved in each crash are categorized by the vehicles they were in as "not-at-fault" and "at-fault". Factors that are found to be associated with increases in the probability of more severe injuries of not-at-fault vehicles are the driving condition (drunk, fatigue and inattentive driving), driving action, driving maneuver, impact type, and whether a truck or a bus is found to be the at-fault vehicle in the crash. In the context of traffic safety analysis, this exercise reveals meaningful insights by understanding how one attribute could behave differently for the not-at-fault and at-fault vehicles.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6858
Paper Title	Introducing Latent Psychological Constructs in Injury Severity Modeling: Multivehicle and Multioccupant Approach
Abstract	This paper presents a comprehensive model of injury severity that accounts for unmeasured driver behavior attributes. Using indicators of risky and distracted/careless driving present in crash databases, the model system incorporates a latent variable component where latent constructs describing such behaviors can be modeled as a function of observed attributes of the driver. The model system also includes a measurement equation where the latent constructs of driver behavior are combined with other explanatory factors to model injury severity outcomes for all vehicular occupants in two-vehicle crashes. Building upon previous research, the paper presents a Generalized Heterogeneous Data Model (GHDM) capable of jointly modeling injury severity outcomes for all passengers in multiple vehicles by seat position. The model system is found to offer key insights on how various factors differentially affect injury outcomes for occupants in different seat positions. The results of the model have important implications for the design of safety interventions and advanced vehicular features and technologies. Engineering designs that accommodate the diminished capabilities of older drivers, include rear seat safety features, and alert drivers to frontal collisions before they occur (collision warning systems and automated braking systems) would contribute to substantial reductions in injury severity across all vehicular occupants.

Authors	Amin Ariannezhad, University of Arizona Yao-Jan Wu, University of Arizona
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-6880
Paper Title	Effects of Adverse Weather in Different Light Conditions on Crash Severity During Arizona's Monsoon Season
Abstract	Environmental factors, including adverse weather and light conditions, have been widely recognized as contributing factors to crash severity and frequency. Heavy downpours occur during the monsoon season in Arizona and surrounding areas during the summer. Considering the effects of light conditions on driver perception of adverse weather, and thus on crash risk, this study investigates the effects of weather and light conditions on crash severity by estimating four separate multinomial logit models for specific weather (heavy rainfall or clear) and light conditions (daytime or nighttime). Marked differences were found between these conditions in terms of the significant factors affecting crash severity. Drivers likely behave differently in different environmental conditions. Our findings indicated that addressing factors such as age groups, speed limits, roadway types, slow driving in heavy rain, and excessive speeding with safety strategies and educational efforts may improve traffic safety during heavy rainfall as well as in clear weather. Various other significant factors are discussed and compared based on the weather and light conditions models.

6 Crash Modification Factors

Alfonso Montella, University of Naples Federico II and Tarek Sayed, University of British Columbia

The Subcommittee identified nineteen papers dealing with crash modification factors and crash modification functions. A few papers papers employed the empirical Bayes approach (Joo et al., 16-3503; Himes et al., 16-4225; Lyon et al. 16-6137) and the Full Bayes approach (Sayed et al., 16-1510; Islam et al., 16-1576; Osama et al., 16-0753). Cross-sectional regression methods were employed in five studies (Ahmed et al., 16-0598; Noland and Rutgers, 16-4150; Niaki et al., 16-5343; Saleem and Persaud, 16-6347; Wang et al., 16-6376). Meta-analysis was used in one study (Musicant et al., 16-3659). Path analysis, a form of structural equation modelling, was used in one study (Gargoum and El-Basyouny, 16-4040). Some studies used simple approaches: before-after analyses with control groups were employed in three studies (Li and Graham, 16-1363; Sahnoon et al., 16-4081; Koorey, 16-4965) and naïve before-after analyses were employed in one study (Rothenberg et al., 16-4289).

Other evaluation techniques were also proposed. The safety impact of countermeasures was generally represented by changes in crash frequency and/or crash severity. However, some studies evaluated simulated traffic conflicts as a surrogate measure (Hussein et al., 16-3394; Li et al., 16-6120). Crash modification functions were also proposed (Osama et al., 16-0753).

The evaluated countermeasures included horizontal curvature (Saleem and Persaud, 16-6347), installation of left-turn lanes at signalized intersections (Osama et al., 16-0753), wet-reflective pavement markings (Lyon et al., 16-6137), nighttime illuminance (Niaki et al., 16-5343; Wang et al., 16-6376), red-light cameras (Sahnoon et al., 16-4081), bike lanes (Rothenberg et al., 16-4289; Koorey, 16-4965; Niaki et al., 16-5343), rest areas on freeways (Joo et al., 16-3503), 20 mph zones (Li and Graham, 16-1363), regulatory headlight signs (Ahmed et al., 16-0598), speed limit change (Islam et al., 16-1576; Musicant et al., 16-3659), speed changes (Gargoum and El-Basyouny, 16-4040), intersection conflict warning systems (Himes et al., 16-4225), transit design alternatives at signalized intersections (Li et al., 16-6120), the New York City's summer streets program (Hussein et al., 16-3394), and the Insurance Corporation of British Columbia road improvement program (Sayed et al., 16-1510).

Authors	Mohamed Ahmed, University of Wyoming Sherif Gaweesh, University of Wyoming Khaled Ksaibati, University of Wyoming MD. Hamidur Rahman, University of Wyoming
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-0598
Paper Title	Investigating the Impact of Compliance Rate on Safety Effectiveness of Regulatory Headlight Signs in Wyoming
Abstract	Although automatic Daytime Running Lights (DRLs) may have a significant impact on increasing vehicle conspicuity during different times of the day, their effect on the overall safety is still up for debate. A recent study by the National Highway Traffic Safety Administration (NHTSA) showed that DRLs offer no statistically significant reduction in the frequency or severity of the crashes analyzed. There are functional issues with using the automatic DRLs only; drivers with automatic DRLs often do not turn on their low beam headlights in adverse weather conditions and at dusk or dawn. This is especially dangerous because the taillights do not come on until the low beam headlights are turned on manually. This becomes more important at hazardous roadway sections that require both headlights and taillights. This study investigated the impact of the compliance rate, and the penetration of the DRL technology on the safety benefits of regulatory headlight signs on mountainous rural two-lane highways. The safety effectiveness of headlight signs was examined based on (DRLs) equipped and (non-DRLs) equipped vehicles. Simple odds and ratio of odds ratios were utilized to adjust for a variety of exogenous factors. Four different scenarios were considered in analyzing the crash data. A case-control method was used to compare crashes for a set of passenger vehicles equipped with DRLs and vehicles without DRLs on roadways sections with and without Headlight Signs. The low compliance rate may result in a misleading conclusions about the safety benefits of the regulatory headlight signs. A careful analysis should be carried out to quantify the actual benefits.

Authors	Ahmed Osama, University of British Columbia Tarek Sayed, University of British Columbia Emanuele Sacchi, University of British Columbia
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-0753
Paper Title	Crash Modification Functions for Installation of Left-Turn Lanes at Signalized Intersection Approaches
Abstract	This paper presents the results of a study performed to develop crash modification functions (CMFunctions) for installing left-turn lanes at signalized intersection approaches. CMFunctions were obtained from a longitudinal (before-after) safety study that accounted for treatment location characteristics (heterogeneity). This approach for developing CMFunctions can offer several advantages over the commonly used cross-sectional evaluations which have several statistical shortcomings. The developed CMFunctions incorporated a time variable to acknowledge that the safety treatment effects do not occur instantaneously but are spread over future time. This was achieved using non-linear intervention full-Bayes models. A total of 12 treatment sites were selected along with 67 comparison sites for the evaluation. The treatment included the addition of one or more left-turn lanes. Overall, the analysis showed significant safety improvements for fatal-plus-injury and total collisions, but statistically non-significant reductions for property-damage-only collisions. The significant covariates included in the CMFunctions were the time trend, total entering volumes, and category of the new left-turn lanes installation.

Authors	Haojie Li, Southeast University Daniel Graham, Imperial College London
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1363
Paper Title	Effects of 20-mph Zones on Road Casualties in London Application of Doubly Robust Methods
Abstract	This paper aims to evaluate the impacts of 20 mph zones on reducing road casualties in London by accounting for both confounding factors and the selection of proper control groups. A total of 234 treated zones and 2844 potential control zones are included in the data sample. This paper employed the doubly robust method which provides two opportunities for obtaining unbiased causal effects given the fact that we rarely know the true relations among potential outcomes, treatment assignment, and confounding factors. The doubly robust method is compared with another three methods: inverse probability weighting, regression adjustment and propensity score matching. The results show that the 20 mph zones consistently have significant impact on reducing casualties in both absolute number and percentages, especially for KSI and pedestrian-related casualties. It also suggests that the main factors affecting the decisions on 20 mph zones are the historical records of casualties and socio-economic characteristics.

Authors	Tarek Sayed, University of British Columbia Emanuele Sacchi, University of British Columbia Paul de Leur, Insurance Corporation of British Columbia (ICBC)
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1510
Paper Title	Evaluating the Safety Benefits of the Insurance Corporation of British Columbia Road Improvement Program Using Full Bayes Approach
Abstract	The objective of this study is to conduct a time-series (before to after) evaluation of the safety performance of a sample of locations that have been improved under the Insurance Corporation of British Columbia (ICBC) Road Improvement Program (RIP). The program started in 1989 where ICBC establishes partnerships with local road authorities in British Columbia and to work cooperatively to make sound investments in road safety improvements. The overall effectiveness of the RIP was assessed by: 1) determining whether the frequency and/or severity of collisions at the improvement sites has been reduced after the implementation of the improvement; and 2) quantifying the program costs versus the economic safety benefits to determine the return on ICBC's road safety investment. A total of 72 urban intersections were included in the evaluation. The intersections were divided in three different groups: intersection with new pedestrian signal installations (13 sites), intersections with geometric design improvements (30 sites), and intersections with traffic signal upgrades (29 sites). The methodology adopted for estimating the safety benefits was a before-after study with the full Bayes method, whereas the cost-benefit analysis was carried out using two indicators: net present value and benefit–cost ratio with a payback period of 5 years. Overall, the total reduction of severe (fatal-plus-injury) and non-severe (property-damage-only) collision frequency for the urban intersections was found equal to 19.6% and 7.6%, respectively. Finally, an overall benefit-cost ratio of 4.3:1 was achieved.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-1576
Paper Title	Before-After Safety Evaluation Using Full Bayesian Macroscopic Multivariate and Spatial Models
Abstract	A significant number of studies have addressed spatial correlation in traffic collision modelling. It has been generally concluded that the inclusion of spatial correlation improves model goodness-of-fit and the precision of parameter estimates. However, its application in before-after safety evaluation has rarely been documented in the traffic safety literature. To this end, the objectives of the current study were to (i) apply both the univariate and multivariate full Bayesian (FB) spatial models in before-after safety evaluation, and (ii) compare the results with those of non-spatial FB models. A posted speed limit (PSL) reduction in urban residential neighbourhoods in Edmonton, Canada was taken as a case study to perform the before-after safety evaluation. Yearly collision data and other neighbourhood characteristics data were collected for a group of treated and reference neighbourhoods to develop macroscopic models. Four different models considered in this study were (i) Poisson-lognormal, (ii) Poisson-lognormal with conditional autoregressive (CAR) distribution, (iii) multivariate Poisson-lognormal and (iv) multivariate Poisson-lognormal with CAR distribution. Within the model formulation, the yearly trend of collisions was addressed by taking random-intercept across the years. The results showed that the multivariate Poisson-lognormal with CAR distribution model for collision severities outperformed the other three models, based on the deviance information criteria (DIC). Parameter estimates showed slight differences across the different models. However, for the current dataset, the results of the before-after safety evaluation showed similar findings across different models. The estimated collision reductions were 13%, 24% and 12% for total, severe and property-damage-only (PDO) collisions, respectively.

Authors	Mohamed Hussein Bianca Popescu, University of British Columbia Tarek Sayed, University of British Columbia Lee Kim, AKRF, Inc.
Sponsoring Committee	ANF10, Pedestrians
Session Number	506
Session Title	Pedestrian Safety Analysis
Paper Number	16-3394
Paper Title	Analysis of Road User Behavior and Safety during New York City's Summer Streets Program
Abstract	Automated computer vision video analysis techniques were used to analyze video data during the operation of New York City's Summer Streets Program at a major signalized intersection. The main objectives of this study were to: 1) diagnose pedestrian and cyclist safety issues during the "shared space" operation and 2) demonstrate the feasibility of the automatic extraction of road user (e.g. pedestrian, runner, rollerblader, or cyclist) data required for microscopic behavior analysis. Road users' speeds and pedestrian gait parameters (step frequency and step length) were automatically extracted and analyzed. The results show that pedestrian walking speed was highest during the Summer Street operation (1.49 ± 0.54 m/s) as they had more street space to use and slowest during normal operations (1.30 ± 0.22 m/s). Bike speeds were low during the Summer Streets event (3.62 ± 0.97 m/s), likely because of interaction with pedestrians, but increased during normal traffic operations. Pedestrians and cyclists moving in groups tended to be slower, confirming results found in previous studies. The safety analysis was conducted using traffic conflict techniques (TCT). It was observed that the lowest rate of conflicts between pedestrians and cyclists and between cyclists was found to be during Summer Streets operations. In addition, an analysis of spatial violations show that some road users were not observing traffic rules in the transition period after Summer Streets ceased to operate.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-3503
Paper Title	Evaluating Effects of Supplemental Rest Areas on Freeway Crashes Korean Study
Abstract	Drowsy driving caused by simple and repetitive road geometries in freeway systems degrades driver's recognition, increasing the potential for severe crashes. To prevent drowsy driving on freeways, Korea Expressway Corporation has provided spaces so that road users can take a break and has installed supplemental rest areas in the freeway system. The supplemental area is an additional small-sized resting facility between regular rest areas, which is unique throughout the world. However, no empirical studies have been conducted in Korea to quantitatively evaluate whether supplemental rest areas reduce crashes caused by drowsy driving. As an initiative to evaluate the supplemental rest areas, this study aims to quantitatively validate the effects of supplemental rest areas on reducing drowsy driving-related crash occurrences by an empirical Bayes approach. The result showed that supplemental rest areas have reduced crashes caused by drowsy driving on freeways by 81%. As the first data-driven research to evaluate supplemental rest areas, the result of this study implies that supplemental rest areas provide more opportunities to avoid drowsy driving, which is encouraged for high-speed highways as a cost-effective safety improvement strategy.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-3659
Paper Title	Impact of Speed Limit Change on Driving Speed and Road Safety at Interurban Roads: Meta-analysis
Abstract	A meta-analysis was conducted to study the effect of changing the speed limit on mean driving speed and on safety in interurban roads. We analyzed information of 108 research results, documented in a database collected by Elvik et al. (2004). The linkage between accidents ratio (after/before) and the mean driving speed ratio was studied by estimating the power parameter in the Nilsons' power model. A modified power model was applied to estimate the linkage between speed limit (rather than mean driving speed) ratio and accidents ratio. When speed limit was raised, the mean driving speed ratio was on average 1.04 (SD=0.04), significantly higher than 1 but smaller than the speed limit ratio (average=1.17, SD=0.05). The power parameters in Nilson's power model and in its modified version were 3.73 (SD=2.61) and 0.99 (SD=0.46). When speed limit was reduced, the mean driving speed ratio was 0.93 (SD=0.04), significantly smaller than 1 but larger than the speed limit ratio (average=0.82, SD=0.04). The corresponding power parameters were 2.81 (SD=0.65) and 1.24 (SD=0.44). This paper summarizes research knowledge about the link between changes in speed limit, driving speed and safety. We found that the average speed changes in the same direction as the speed limit, but the magnitude of the change is smaller. As a result, the power parameters in the second version of the power model are lower compared to those in the original Nilson's model, and so the average change in safety is nearly proportional to the change in speed limit.

Authors	Suliman Gargoum Karim El-Basyouny, University of Alberta
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-4040
Paper Title	Path Analysis of Relationship Between Speed and Safety
Abstract	Road safety is influenced by many factors; these factors include characteristics of the road, climate, traffic and, most importantly, vehicle speeds. Previous research shows that increases in speed are typically associated with an increased collision risk. Moreover, previous studies have also found relationships between road and traffic characteristics and collisions. In addition, these features have also been found to affect speeds. Therefore, one could suspect that some of the effects those factors have on safety could be imposed indirectly through their effects on speed. In fact, this is only one way in which the relationship between speed and safety could be confounded. This paper attempts to model the relationship between average speed and collision frequency, while taking into account the mediated effects of other factors that confound the relationship. The data used in this study originated from 361 two-lane urban roads in the city of Edmonton, Canada. The average speeds were obtained from 35 million speed survey observations collected over a five-year period. The speed data are linked to the crash frequency at each location during the same time-frame along with the other factors (road, traffic and climate). Path analysis is used to model the different relationships. The results show that, among others, average speed, volume, segment-length, medians and horizontal curves all significantly affect collisions. On the other hand, shoulder lanes, speed limits and vehicle-lengths are some variables that significantly influence speeds. The results also show that the effects of some variables on safety are indeed mediated through speeds.

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Sponsoring Committee	ANB40, Traffic Law Enforcement
Session Number	504
Session Title	Traffic Law Enforcement Research: Countermeasure Evaluation, Data Analysis, and Officer Safety
Paper Number	16-4081
Paper Title	Impact of Red-Light Enforcement Cameras on Safety Performance at Signalized Intersections in Abu Dhabi
Abstract	Red-light-running crashes have been always a major concern to both researchers and practitioners. In Abu Dhabi, UAE, the red-light crashes contribute to around 60 % of the total severe crashes at signalized intersections. This fact called for a project in year 2013 where new red-light cameras (RLCs) were planned to cover 150 intersections in Abu Dhabi City. With the completion of the second stage of this project, a total of 36 signalized intersections have been covered either fully (all intersection approaches) or partially (only major approaches) with a total of 108 RLCs. These RLCs are now in place and fully functioning since January 2014. The primary aim of this study is to examine the impact of the installed RLCs on the traffic safety performance in the city. To waive the effects of other factors, two groups were created including a Study Group (36 signalized intersections with RLCs) and a Comparison Group (36 similar intersection without RLCs). The results indicated a reduction of around 40 to 52 % for the number of crashes and 48 to 60 % for the number of fatalities/injuries. The majority of at-fault drivers were young male drivers from Asian countries with read-and-write educational level. Moreover, crashes and fatalities/injuries were modelled using the Negative Binomial technique. Among 13 tested variables describing the traffic exposure, traffic violations, number of lanes, and coverage of intersections by RLCs, only the number of lanes was found significant in two significant models.

Authors	Robert Noland, Rutgers, The State University of New Jersey Yemi Adediji, Rutgers, The State University of New Jersey
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	448
Session Title	Numbers in Safety: Revealing What's Behind Them Through Advances in Assembling, Analyzing, and Modeling Crash Data
Paper Number	16-4150
Paper Title	Omitted Variable Bias in Crash Reduction Factors
Abstract	Transportation planners and traffic engineers are increasingly turning to crash reduction factors to evaluate changes in road geometric and design features in order to reduce crashes. Crash reduction factors are typically estimated based on segmenting a highway, to associated crashes with geometric features; this allows statistical methods to be applied to the data. Concurrently there is a stream of research that relies on spatial units of analysis to examine crashes; these typically use broad features of the road network combined with socio-economic and demographic factors that are associated with crashes. In this paper, we examine whether omission of these other factors in a link-based geometric results in omitted variable bias. Our results suggest that there is no change in coefficient signs, but that there is a reduction in the magnitude of estimates. The sign of spatial variables, however, is quite different when combined into a link-based model. We also find substantial variability in coefficient estimates, and discuss the implications of these results for the use of crash reduction factors.

Authors	Scott Himes, VHB Frank Gross, VHB Kimberly Eccles, VHB Bhagwant Persaud, Ryerson University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	625
Session Title	Advances in Highway Safety Performance
Paper Number	16-4225
Paper Title	Multi-State Safety Evaluation of Intersection Conflict Warning Systems (ICWS)
Abstract	Intersection Conflict Warning Systems (ICWS) were selected for evaluation under the Federal Highway Administration (FHWA) Evaluation of Low-Cost Safety Improvements Pooled Fund Study. This strategy is intended to reduce the frequency of crashes by alerting drivers of conflicting vehicles on adjacent approaches at unsignalized intersections. The evaluation was based on a multistate database of geometric, traffic, and crash data obtained for four-legged rural two-way stop-controlled intersections equipped with ICWS in Minnesota, Missouri, and North Carolina. To account for potential selection bias and regression-to-the-mean, an empirical Bayes (EB) before-after analysis was conducted, using safety performance functions (SPFs) for reference groups of similar four-legged rural two-way stop-controlled intersections without ICWS installation. These SPFs also control for changes in traffic volumes over time and time trends in crash counts unrelated to the strategy. The aggregate results indicate statistically significant crash reductions at the five percent level for all crash types for two-lane at two-lane intersections and four-lane at two-lane intersections. For two-lane at two-lane intersections, the CMFs for total crashes, fatal and injury crashes, and right-angle crashes are 0.73, 0.70, and 0.80, respectively. For four-lane at two-lane intersections, the CMFs for total crashes, fatal and injury crashes, and right-angle crashes are 0.83, 0.80, and 0.85, respectively. The benefit-cost ratio estimated with conservative cost and service life assumptions is 27:1 for all two-lane at two-lane intersections and 10:1 for four-lane at two-lane intersections with post-mounted warning signs. The results suggest that the strategy, even with conservative assumptions on cost, service life, and the value of a statistical life, can be highly cost effective. As this is an evolving strategy, this study reflects installation practices to date.

Authors	Heather Rothenberg, Sam Schwartz Engineering Daniel Goodman, Federal Highway Administration (FHWA) Carl Sundstrom, UNC Highway Safety Research Center
Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	538
Session Title	Bicycling Research Mega Session
Paper Number	16-4289
Paper Title	Separated Bike Lane Crash Analysis
Abstract	This paper highlights the methodology and results of a safety data analysis undertaken as part of the study process for the Federal Highway Administration's (FHWA) Separated Bike Lane Planning and Design Guide. It outlines challenges and recommends a data collection framework that will lead to a better understanding of the full volume and safety picture for separated bike lanes. This study evaluated 18 sites before and after the installation of separated bike lanes. Of the 18 sites, 14 locations had data on both total crashes and bicycle crashes. Eight of these locations saw a decrease in total crashes and five sites saw a decrease in bicycle crashes. This translates to nine of 14 sites demonstrating a decrease in crashes of some sort. Four of the 14 sites saw decreases in both bicycle and total crashes. Similar trends are seen when considering bicycle exposure at sites with at least four average annual bicycle crashes. Five of the 10 sites saw decreases in average annual bicycle crashes per average hourly bicycle volume. It appears that the introduction of separated bike lanes may result in increased challenges at intersections. All six of the sites where the analysis included consideration of intersection vs. midblock crashes saw an increase in the percentage of crashes that occurred at an intersection. This was true for bicycle crashes as well as those not involving a bicycle. However, these comparisons did not control for changes in bicycle volumes between the before and after periods. There are significant data limitations to this study. In particular, challenges associated with obtaining bicycle volume data (both before and after) make it difficult to understand the true impacts on safety of separated bike lanes. Also, the small number of bicycle crashes occurring at these locations yield analysis results with very large percentage changes (increases or decreases) since a change of one or two crashes can effectively double or triple the crash count for that site. It is critical that this data is collected so that future studies may evaluate the safety of separated bike lanes under different conditions and designs in greater detail. For this reason, a recommended minimum data collection approach is presented in this paper to, over time, improve the quantity and quality of data on separated bike lanes.

Authors	Glen Koorey, University of Canterbury
Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	538
Session Title	Bicycling Research Mega Session
Paper Number	16-4965
Paper Title	Effect of Cycle Lanes on Cycling Numbers and Safety
Abstract	Marked on-road cycle lanes are a relatively inexpensive means of providing for cycling; however, their use has been questioned in terms of both their safety and their effectiveness in attracting more people to take up cycling. While both questions have been previously researched, the findings were rather inconclusive. A recent Engineering Masters research project in Christchurch, New Zealand investigated the relative effects on cycle count and crash numbers of installing a series of cycle lanes. Twelve routes installed in Christchurch during the mid-2000s were analyzed, together with some control routes that already had cycle lanes. Cycle count data from a series of route locations and dates were used to establish cycling trends before and after installation. These were also compared against cycle crash numbers along these routes during the same periods. The results generally show no consistent "step" increase in cycling numbers immediately following installation of cycle lanes, with some increasing and decreasing. Changes on cycling growth rates were more positive, although it is clear that other wider trends such as motor traffic growth are having an effect. Taking into account the control routes and relative changes in volumes, the study also found notable reductions in cycle crashes following installation, typically with a 23% average reduction in crash rates. However, this reduction was not statistically significant at the 95% level.

Authors	Matin Nabavi Niaki, Polytechnique Montreal Ting Fu, McGill University Nicolas Saunier, Polytechnique Montreal Luis Miranda-Moreno, McGill University Luis Amador-Jimenez, Concordia University Jean-Francois Bruneau, University of Sherbrooke
Sponsoring Committee	AND40, Visibility
Session Number	699
Session Title	Road Illumination, Signage, and Visibility
Paper Number	16-5343
Paper Title	Effects of Road Lighting on Bicycle and Pedestrian Accident Frequency: Case Study in Montreal, Canada
Abstract	Although vehicle, bicycle and pedestrian flows are considerably lower during nighttime, this time accounts for higher accident rates compared to daytime. A highly influential factor is the lack of clear visibility at nighttime. Several studies have showed the negative effects of the lack of clear visibility on bicycle and pedestrian accident frequency and injury severity at nighttime. Studies that have evaluated this issue have considered only the presence of light. The presence of light is not sufficient to evaluate road users' safety: different amounts of lighting can have different effects on a driver's vision such as discomfort glare, and disability glare, or the available light may not provide adequate contrast for object detection. Only a limited number of past studies in this field actually measured the amount of nighttime illuminance. Our study relies on the collection of road illuminance data on road links during nighttime in downtown Montréal using an illuminance sensor mounted on an electric scooter. The pedestrian and bicycle accident frequency were analysed separately using the negative binomial model. Results from this study show unexpectedly that an increase in road lighting is associated with more bicycle and pedestrian accidents, which may be explained by the decision to add or increase the amount of lighting where accidents occur. The presence of a bike facility and arterial roads were associated with a decrease in bicycle accident occurrence. For pedestrians, the number of lanes per link and the pedestrian flow were associated with an increase in nighttime accident frequency, while the vehicle flow is associated with a decreasing number of accidents. The study highlights the usefulness of illuminance data collection, but also calls for more investigation of the precise relationship between safety and the amount of light provided by road lighting.

Authors	Lu Li, IBI Group Bhagwant Persaud, Ryerson University Amer Shalaby, University of Toronto
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-6120
Paper Title	Using Microsimulation to Investigate Safety Impacts of Transit Design Alternatives at Signalized Intersections
Abstract	This study investigates the use of crash prediction models and micro-simulation to develop an effective surrogate safety assessment measure at the intersection level. With the use of these tools, hypothetical scenarios can be developed and explored to evaluate the safety impacts of design alternatives in a controlled environment, in which factors not directly associated with the design alternatives can be fixed. The use of traffic conflicts generated from the micro-simulation models, once calibrated and validated, and linked with observed crash frequency, greatly alleviates the lengthy time needed to collect sufficient crash data for evaluating alternatives, due to the rare and infrequent nature of crash events. A set of generalized linear models with negative binomial error structure is developed to correlate the simulated conflicts with the observed crash frequency in Toronto, Ontario, Canada. Crash prediction models are also developed for crashes of different impact types and for transit-involved crashes. The resulting statistical significance and the goodness-of-fit of the models suggest adequate predictive ability. Based on the established correlation between simulated conflicts and observed crashes, scenarios are developed in the micro-simulation models to investigate the safety effects of individual transit line elements of by making hypothetical modifications to such elements and estimating changes in crash frequency from the resulting changes in conflicts. The findings imply that the existing transit signal priority schemes can have a negative effect on safety performance and that the existing near-sided stop positioning and streetcar transit type can be safer at their current state than if they were to be replaced by their respective counterparts.

Authors	Craig Lyon, Persaud and Lyon Inc. Bhagwant Persaud, Ryerson University Kimberly Eccles, VHB
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	499
Session Title	Safety-Related Traffic Control Device Research
Paper Number	16-6137
Paper Title	Safety Evaluation of Wet-Reflective Pavement Markings
Abstract	The application of wet-reflective pavement markings was selected for safety evaluation as part of a Federal Highway Administration (FHWA) Pooled Fund Study. This strategy involves upgrading existing markings from standard marking materials to wet-reflective markings, applied as a paint, tape or thermoplastic material, and designed to provide an improved level of retroreflectivity during wet road conditions. Geometric, traffic, and crash data were obtained at treated freeway sections in Minnesota, North Carolina, and Wisconsin; treated two-lane rural road locations in Minnesota; and treated multilane road sections in Wisconsin. To account for potential selection bias due to regression-to-the-mean, an empirical Bayes (EB) before-after analysis was conducted. For freeways, the combined results for all States indicate reductions in crashes that are statistically significant at the 5 percent level for injury and wet-road crashes, with estimated crash modification factors (CMFs) of 0.881 and 0.861, respectively. For multilane roads, statistically significant reductions were estimated for total crashes (CMF=0.825), injury crashes (CMF=0.595), run-off-road crashes (CMF=0.538), wet road crashes (CMF=0.751), and night-time crashes (CMF=0.696). For two-lane roads, the sample of crashes was too small to detect effects with statistical significance, but there are indications that the treatment may have a safety benefit for wet-road crashes. Benefit-cost ratios estimated with conservative cost and service life assumptions suggest that the treatment can be cost effective, especially so for multilane roads.

Authors	Taha Saleem, Ryerson University Bhagwant Persaud, Ryerson University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	388
Session Title	Highway Safety Performance
Paper Number	16-6347
Paper Title	Another Look at the Safety Effects of Horizontal Curvature on Rural Two-Lane Highways
Abstract	Crash Modification Factors (CMFs) are used to represent the effects on crashes of changes to highway design elements and are usually obtained from observational studies based on reported crashes. The design element of interest for this paper is horizontal curvature on rural 2-lane highways. Crash prediction models are developed for curve sections on rural 2-lane highway and the tangent up and down stream of the curve sections and their predictive capabilities are evaluated. The relationship between crashes at different traffic volumes and deflection angles are explored to get approximate estimates of CMFs for increases in the minimum radius (by factors of 1.10, 1.25, 1.50, and 2.00) considering the effects of increased tangent lengths for sharper curves. The overall results indicate that even at different design speeds and deflection angles, the CMF estimates for incremental increases in radius lie within the same range.

Authors	Zhenyu Wang, University of South Florida Fulu Wei, Jilin University Pei-Sung Lin, USF Center for Urban Transportation Research Seckin Ozkul, USF Center for Urban Transportation Research Jason Jackman Michael Bato, USF Center for Urban Transportation Research
Sponsoring Committee	AND40, Visibility
Session Number	699
Session Title	Road Illumination, Signage, and Visibility
Paper Number	16-6376
Paper Title	Safety Effects of Street Illuminance at Urban Signalized Intersections in Florida
Abstract	Nighttime crashes are overrepresented in the nationwide and statewide roadway systems. Nighttime safety at signalized intersections in urban areas receives more attention because of frequent and serious vehicle-to-vehicle and vehicle-to-pedestrian/bicyclist traffic conflicts at night. Street illumination has been proven to be an effective countermeasure for increasing the visibility of intersection and reducing nighttime crashes. However, the safety effects of illuminance at urban signalized intersections were not well documented. Thus, this paper aims to investigate the impacts of illuminance on both nighttime crash occurrence and nighttime crash injury severity at urban signalized intersections. Illuminance data and crash data for a sample of 91 signalized intersections were collected from Tampa Bay, Florida. The negative binomial model and the probit model were developed to examine the safety effects of intersection illuminance in terms of crash frequency and the risk of fatality and severe injury, respectively. The models show that increasing intersection illuminance from low (< 0.2 fc) to medium (≥ 0.2 fc and <1.1 fc) can reduce nighttime crash frequency and night-to-day crash ratio by approximately 50%. If illuminance is kept at 0.9 fc or higher, the risk of fatality and severe injury significantly decreases, especially for pedestrian/bicycle involved crashes, head-on crashes, and angle crashes. Summing up the two safety effects, it is suggested that illuminance at urban signalized intersections should be kept at 0.9 fc or higher.

7 Surrogate Measures of Safety

Tomas Hall and Andrew Tarko, Purdue University

Fifteen papers dealing with surrogate measures of safety have been identified. In these papers, surrogate measures are used either as the primary approach to safety analysis or as a supplement to the more traditional crash-based approach.

Ten papers undertake the fundamental effort of validating, improving, and/or implementing new methods for measuring surrogate measures of safety (Zheng et al., 16-1670; Zaki et al., 16-1886; Kluger et al., 16-2043; Santiago-chaparro et al., 16-2418; Wu and Jovanis, 16-2771; Chun and Fontaine, 16-2826; Gallelli et al., 16-3888; Scopatz et al., 16-4080; AlRajie and Ismail, 16-4383; Ni and Rao, 16-5263). Papers also examine proactively estimated crash risk (Kluger et al., 16-2043; Ni and Rao, 16-5263) and estimate potential crash severity based on conflicts (Ni and Rao, 16-5263).

Traffic conflicts and **speed** are the most frequently used surrogate measures for studying safety. **Traffic conflicts** are used in eight papers (Zheng et al., 16-1670; Zaki et al., 16-1886; Santiago-chaparro et al., 16-2418; Nelson et al., 16-2461; Scopatz et al., 16-4080; AlRajie and Ismail, 16-4383; Ni and Rao, 16-5263; Li et al., 16-6120). Additionally, **speed** measures are used in five papers (Kluger et al., 16-2043; Chun and Fontaine, 16-2826; Stipancic et al., 16-2848; Gallelli et al., 16-3888; Hall et al., 16-5827).

Time-to-collision (TTC) and **post-encroachment time (PET)** are the most commonly used traffic conflict indicators, used in five papers (Zheng et al., 16-1670; Santiago-chaparro et al., 16-2418; Scopatz et al., 16-4080; AlRajie and Ismail, 16-4383; Ni and Rao, 16-5263). Another criterion used in three papers is **deceleration** (Kluger et al., 16-2043; Chun and Fontaine, 16-2826; Stipancic et al., 16-2848). Finally, Noble et al., 16-1490 attempts to distinguish between the behavior of **red and yellow light runners**.

In terms of data sources and techniques, various methods are utilized. **Field observations**, which included video or GPS-based observations in many cases, are used in eleven papers (Noble et al., 16-1490; Zheng et al., 16-1670; Zaki et al., 16-1886; Santiago-chaparro et al., 16-2418; Chun and Fontaine, 16-2826; Stipancic et al., 16-2848; Gallelli et al., 16-3888; Scopatz et al., 16-4080; AlRajie and Ismail, 16-4383; Ni and Rao, 16-5263; Hall et al., 16-5827). Of these papers, three use data collected in real-time from the mobile-devices of roadway users: Chun and Fontaine, 16-2826; Stipancic et al., 16-2848; Gallelli et al., 16-3888. **Naturalistic driving**-related data are important in three papers (Noble et al., 16-1490; Kluger et al., 16-2043; Wu and Jovanis, 16-2771). **Microsimulation** tools are also used (AlRajie and Ismail, 16-4383; Li et al., 16-6120). Finally, s**elf-reported data** is used by Nelson et al., 16-2461.

The most important topics studied this year include the following: **Intersection safety** by eight papers (Noble et al., 16-1490; Zaki et al., 16-1886; Santiago-chaparro et al., 16-2418; Scopatz et al., 16-4080; AlRajie and Ismail, 16-4383; Ni and Rao, 16-5263; Hall et al., 16-5827; Li et al., 16-6120) and **Pedestrians and cyclists** by five papers (Zaki et al., 16-1886; Nelson et al., 16-2461; Scopatz et al., 16-4080; AlRajie and Ismail, 16-4383; Ni and Rao, 16-5263).

Authors	Alexandria Noble, Virginia Polytechnic Institute and State University Kristofer Kusano, Toyota Technical Center, U.S.A. John Scanlon, Virginia Polytechnic Institute and State University Zachary Doerzaph, Virginia Tech Transportation Institute Hampton Gabler, Virginia Polytechnic Institute and State University
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-1490
Paper Title	Driver Approach and Traversal Trajectories for Signalized Intersections Using Naturalistic Data
Abstract	The objective of this paper is to assess driver intersection approach and traversal trajectories in response to the traffic control device (TCD) and driver behavior based on stopping behavior. Regression analysis was used to construct average trajectories of vehicles approaching signalized and stop-controlled intersections. A total of 12,688 observations from signalized intersections from the CICAS-V project (*1*) database were used in this analysis. The selected data were subjected to Multivariate Adaptive Regression Splining to develop a model of a typical driver's velocity on their approach to the intersection based on the vehicle's proximity to the stop bar (range [m]) and other categorical factors such as vehicle type, time of day, road surface condition, and weather. The resulting models highlight the differences in driver approach speeds at as they approach intersections depending on the signal phase and intended course of action. The models predict the vehicle speed as a function of distance to the stop bar of the intersection (range). These models will be used in future tasks calculate vehicle approach speeds in real-world intersection crashes.

Authors	Lai Zheng, Harbin Institute of Technology Karim Ismail, Carleton University Xianghai Meng, Harbin Institute of Technology
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-1670
Paper Title	Investigating Heterogeneity of PET Thresholds Determined by Peak-over-Threshold Approach
Abstract	Inconsistency in conflict definition is a fundamental issue of traffic conflict technique and it also raises plenty of questions on the validity of this technique. An important aspect of inconsistency is that thresholds to distinguish traffic conflicts from normal events have barely been clearly determined. This study proposes a peak over threshold (POT) approach to determine PET thresholds between traffic conflicts and normal events. The determined thresholds are evaluated by testing the correlation between the defined conflicts and observed crashes. A further regression analysis is conducted to explain heterogeneity of POT determined thresholds. The results show that traffic conflicts defined by POT determined thresholds have a relatively strong relationship with observed crashes with the Pearson's correlation coefficient of 0.66 and the threshold heterogeneity in this study mainly stems from the variety of exposure (*i.e.*, traffic volume). This study implies that POT approach which can account for possible heterogeneity in the thresholds between traffic conflicts and normal events has a promising prospect in improving the validity of traffic conflict technique.

Authors	Mohamed Zaki, University of British Columbia Tarek Sayed, University of British Columbia Shewkar Ibrahim, City of Edmonton
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-1886
Paper Title	Comprehensive Safety Diagnosis Using Automated Video Analysis: Applications to an Urban Intersection in the City of Edmonton
Abstract	The objective of this study is to conduct a safety diagnosis based on automated traffic conflict analysis and to demonstrate automated data collection techniques for a major signalized intersection in the city of Edmonton, Alberta. Concerns were raised about the potential safety implications of increasing the speed limit from 50 km/hr to 60 km/hr along the road segments approaching the intersection, particularly related to pedestrian and cyclists safety. A detailed safety diagnosis analysis was therefore initiated to identify factors that may be contributing to safety concerns and to propose potential safety improvements. The diagnosis also included an estimation of the violation rate at the facility as well as general information on the vehicle speed and non-motorized road-users crossing behavior. It was observed that the high frequency of conflicts between vehicles and vulnerable road users (i.e., pedestrians and cyclists) and the presence of heavy vehicles can lead to more severe conflicts and possible collisions if the speed limit is raised. Based on the outcome of the performed analysis, several recommendations were proposed that would potentially improve the safety for all road-users without affecting the mobility along the intersection. Also, it was recommended not to raise the existing speed limit and to keep it at the current level. This study demonstrated the practical application of the automated traffic conflict analysis technology and its ability to assist traffic engineers with conducting a comprehensive safety assessment.

Authors	Robert Kluger, University of Virginia Brian Smith, University of Virginia Hyungjun Park, University of Virginia
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-2043
Paper Title	Identification of Safety-Critical Events in Connected Vehicle Environments
Abstract	Presented in this paper is a 5-step heuristic algorithm that can identify crashes, near-crashes, and other safety-critical events using only data elements outlined in connected vehicle standards. Naturalistic driving study data was used as a surrogate for connected vehicle data to design the algorithm. The algorithm first estimates speed at a future time using speed and acceleration at a previous time. If this is done across a very short time-span, major discrepancies between the predicted speed and the actual speed could indicate a crash occurred. Events with such discrepancies are flagged. A logistic regression model was then constructed to predict the probability of a flagged event being a crash or near-crash. The algorithm showed promising results on a limited data set.

Authors	Kelvin Santiago-chaparro, University of Wisconsin, Madison Andrea Bill, University of Wisconsin, Madison Madhav Chitturi, University of Wisconsin, Madison David Noyce, University of Wisconsin, Madison
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-2418
Paper Title	Software-Based Methodology to Obtain Time-to-Collision Measurements from Existing Radar-Based Vehicle Detection Infrastructure
Abstract	Surrogate safety measures can be used in research to evaluate the safety performance of an intersection in what is argued to be a proactive approach. The concept is not a new one and has been around for over 40 years. Approaches used range from traditional conflict studies, to microsimulation evaluations, and, more recently, through the use of field observations using automated techniques. An argument for the use of surrogate safety measures to study transportation safety is that potentially unsafe conditions can be identified without the need to wait for crashes to happen. A problem that some of the approaches to automate the computation of surrogate safety measures from field observations is that techniques often rely on custom hardware installations for specific locations and on techniques that require calibration. These two factors can act as a barrier to the implementation by practitioners. This paper shows how vehicle trajectory data can be extracted from commercially available radar-based vehicle units to compute time to collision values between vehicles turning right and those going thru. No changes were required to the detection zones monitored by the units, the unit's settings, nor unit placement. A software-based methodology that builds on top of previous work was used to log high resolution vehicle trajectory data and to analyze the data.

Authors	Trisalyn Nelson, University of Victoria Meghan Winters, Simon Fraser University Taylor Denouden, University of Victoria Karen Laberee, University of Victoria Ben Jestico, University of Victoria Darren Boss, University of Victoria
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-2461
Paper Title	Temporal Variation in Bicycle Collisions and Near Misses
Abstract	Issues of safety have been identified as a primary barrier to increased bicycling ridership. Previous studies have quantified how safety changes across space with variation in environmental conditions such as vehicle volume and infrastructure. Our goal is to quantify how safety varies through time (daily and hourly). We utilize a novel data set compiled by BikeMaps.org, a website for citizen self-reporting of cycling collisions and near misses. BikeMaps.org is a global tool, but local promotion in Victoria, Canada has generated 353 citizen reports and the study area for this paper. Contextualized by ridership and insurance-reported cycling collisions, we illustrate variation in the number of collisions and near misses by day and hour. Results indicate a higher proportion of cycling incidents on Wednesdays and during peak commuting periods (8:00 – 8:59 and 16:00 – 17:59). The morning peak has a higher proportion of both incidents and serious injury, even when compared to the underlying ridership, and the largest proportion of incidents occurred on busy streets with no bike facilities. During the afternoon commuting peak period, the incident proportion was lower and similar proportions of incidents were observed on busy streets both with and without cycling infrastructure. BikeMaps.org data allow for dynamic analysis of change through time and provide an increased sample when near misses are captured. As such, BikeMaps.org has potential use as a surveillance tool for assessing transportation policy change, locally and elsewhere. Real-time graphics of patterns through time can be viewed for any location where BikeMaps.org data have been contributed at BikeMaps.org/vis.

Authors	Kun-Feng Wu, National Chiao Tung University Paul Jovanis, Pennsylvania State University
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-2771
Paper Title	Cohort-Based Analysis Structure for Modeling Driver Behavior Using an In-Vehicle Data Recorder
Abstract	In recent years, increasing availability of in-vehicle data recorder (IVDR) technologies has resulted in more safety studies unobtrusively observing the behavior of drivers during actual driving. This research proposes and applies a flexible analysis structure that can be applied to data reflecting events of interest which include crash data, safety critical event data from naturalistic driving studies and alert warnings from on-board safety warning systems. The fundamental requirements for the data include a need for GPS and GIS to allow positioning the vehicle on a network, and the occurrence and recording of events of interest with attributes, which may include those reflecting the roadway, environment, driver and event. One distinguishing feature of the formulation is the explicit inclusion of exposure to risk. The analysis approach responds to four challenges: inclusion of exposure to risk; allowance for inclusion of driver, event, environment and roadway attributes in a structured formulation; modeling of driving exposure in differing contexts including both roadway and environment; and, allowance for comparison to baseline hazard where no events occur. A hierarchical mixed effect Poisson regression approach is used to demonstrate the analysis structure. Data from University of Michigan Transportation Institute (UMTRI)'s Curve Warning System (RDCW) Field Operation Test (FOT) are used in the empirical application of the method. The model is used to identify drivers with significantly higher numbers of alerts overall and separately on major and minor arterials. The paper concludes with a discussion of potential applications beyond field operational test settings, which include analysis of crash and other NDS-observed events.

Authors	PilJin Chun, University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-2826
Paper Title	Feasibility of Using Segment Speed Deceleration Events as Safety Surrogate Measures at a Series of Freeway Interchanges
Abstract	The Virginia Department of Transportation (VDOT) is currently constructing an Active Traffic Management (ATM) system on I-66, a major commuter route into Washington, D.C.. The ATM system incorporates a variety of techniques intended to address safety and mobility through the use of intelligent transportation systems. A major goal of the system is to improve freeway safety by mitigating conflicts where traffic transitions from high speeds into congested flow. Following system activation, VDOT wants to be able to quickly assess whether the system is improving safety. The researchers examined the relationship between the frequency of mainline speed deceleration events at interchanges and crash frequency to determine whether speed deceleration events are a reliable surrogate measure for crash frequency. Travel time data from the private company INRIX was used to determine the number of speed deceleration events, and this data was combined with crash and volume data to establish a relationship between speed deceleration event and crash frequencies. Models were developed to determine relationships between speed deceleration events, vehicle-miles traveled (VMT), and frequency of rear end and sideswipe crashes. In most cases, the relationships were linear in shape. The research showed that strong relationships could be developed between speed deceleration events and total rear end and sideswipe crashes, indicating that private sector speed data could be used to derive useful safety surrogate measures for quick safety assessments. Advantages and disadvantages of using private sector speed data for safety surrogate analysis are also discussed.

Authors	Joshua Stipancic, McGill University Luis Miranda-Moreno, McGill University Nicolas Saunier, Polytechnique Montreal
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-2848
Paper Title	The Who and Where of Road Safety: Extracting Surrogate Indicators from Smartphone-Collected GPS Data in Urban Environments
Abstract	Environment and driver behaviour are significant contributory factors in traffic collisions. Surrogate safety measures, non-crash measures that are physically and predictably related to crashes, provide opportunities for user-centric approaches to road safety and reduce dependency on crash data in environment-centric approaches. The purpose of this study is to extract surrogate safety measures from the smartphone-collected GPS data of regular drivers and to analyze those measures from an environment-centric and user-centric perspective. GPS travel data was collected using the Mon Trajet smartphone application in Quebec City, Canada over 21 days. Crash data was obtained from the Ministry of Transportation Quebec for a five year period from 2006 to 2010. The selected surrogate indicator, hard braking events (HBEs), demonstrated a spatial correlation of 0.67 with collision occurrence. Despite strong correlation, HBEs tend to overestimate risk on highway facilities and underestimate risk on local and arterial streets as the sample data collected from regular drivers likely over-represents travel on highways and under-represents travel on urban streets. The user-centric analysis showed that more HBEs occur during the AM and PM peak periods, and that braking in the PM peak period tends to be more severe, demonstrating that HBEs are not only spatially correlated with actual collision occurrence, but also make sense intuitively with respect to the behaviours related to collision occurrence. Future work will determine if other surrogate indicators that are more closely correlated with collision occurrence can be extracted, and disaggregating the analyses by facility type should improve the results.

Authors	Vincenzo Gallelli, University Mediterranea of Reggio Calabria Giuseppe Guido, University of Calabria Frank Saccomanno, University of Waterloo Alessandro Vitale, University of Calabria
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-3888
Paper Title	New Surrogate Safety Measure Derived from GPS Mobile Probes
Abstract	GPS-equipped smartphone allow the tracking and monitoring of vehicle operations in real-time, even if tracking errors caused by en-route satellite signal disruptions must be taken into account to accurately reflect traffic conditions. In this paper, the Authors intend to demonstrate how, through the use of mobile devices, it is possible to estimate instantaneous speeds which can be used to locate sites where safety is compromised due to poor road geometry. A new surrogate safety measure (Unsafe Speed Index, *USI*) is introduced to measure the difference between individual vehicle operating speed and the safe design speed at a specific location. This safety index is suitable to identify sites where safety at a given location is compromised by driving too fast for the underlying geometric restrictions. Locations with higher USI values were found to correspond closely to sites with a higher number of speed-related crashes as reported over a period of five years.

Authors	Robert Scopatz, VHB Yuying Zhou, VHB Kristie Johnson, National Highway Traffic Safety Administration
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-4080
Paper Title	Methodology for Collecting Naturalistic Observation Data of Pedestrian and Driver Interactions
Abstract	The growing use and influence of technology has the potential to endanger pedestrians more than before; however, the extent to which pedestrian safety is affected as a result of distraction among drivers and pedestrians is not well established. The ongoing NHTSA project: *Effect of Electronic Device Use on Pedestrian Safety* is intended to quantify the risk of pedestrian crashes due to the use of electronic devices by both pedestrians and drivers. High quality data on the prevalence of distraction among pedestrians and drivers is required to assess the impact of distraction on crash risk. Valid surrogate measures of traffic conflict as well as State pedestrian crash data are needed to investigate the contribution of pedestrian and driver distraction to crash frequency and severity. A robust field data collection method was used for collecting pedestrian-vehicle conflicts, distractors, and safety-related behaviors simultaneously in real time.

Authors	Haitham AlRajie, Carleton University Karim Ismail, Carleton University
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-4383
Paper Title	Investigation of Using Microscopic Traffic Simulation Tools to Predict Cyclist-Vehicle-Traffic Conflicts at Signalized Intersections
Abstract	Researchers have been questioning if traffic microsimulation tools can be used for road safety evaluations. This studyexamines the use traffic microsimulation to predict conflicts between right-turning vehicles and through cyclists at signalized intersections. Moreover, this study evaluates if calibrating these models to describe the driving behavior at signalized intersection significantly improves the conflicts prediction. It was found that VISSIM has the potential to predict traffic conflicts of interest. In particular, a moderate correlation was found between real conflicts and simulated conflicts of the default models (r=0.525). A strong correlation was found between real conflicts and calibrated models' simulated conflicts (r=0.618). However, a one-way ANOVA test indicated that travel time calibration did not significantly affect VISSIM's conflicts prediction accuracy. It was also found that VISSIM's prediction accuracy is expected to decrease as either the cyclists' volume or the product of cyclists' volume and right-turning vehicles' volume increase.

Authors	Ying Ni, Tongji University Manqi Rao, School of Transportation Engineering Tongji University
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	592
Session Title	Active Research on Safety of Pedestrian and Bicycle Transportation
Paper Number	16-5263
Paper Title	Pedestrian-Vehicle Conflict Risk Analysis in Different Right-Turn Signal Schemes at Intersections
Abstract	There is an inseparable relationship between traffic accidents and traffic conflicts. Traffic conflict technique (TCT), as an alternative method, has been increasingly applied in the evaluation of traffic safety. Much research has been conducted to study the conflicts between vehicles, but the research on pedestrian-vehicle conflicts between right-turn vehicles and crossing pedestrians in different signal control schemes, is still insufficient. This paper presents a contrastive conflict analysis of two signalized intersections with different right-turn control schemes. A conflict analysis method based on trajectories of road users is proposed. Trajectory data were collected at two intersections, one with control scheme of RTOR, and the other with PPRT. Based on the trajectories extracted from videos, conflict position, time, speed and conflict indicators of road users were calculated. Via analyzing existing research results, considering the data type and the purpose of this study, adaptive collision probability and collision severity model were developed. Combining collision probability with corresponding collision severity, a conflict risk assessment model was established. According to signal schemes and lane function, cycle length and crosswalk were split into several time and space intervals counted as space-time cells, and pedestrian-vehicle conflict risk degree of each space-time cell was calculated by risk assessment model. A temporal-spatial distribution diagram of conflict risk was drawn. The proposed conflict risk assessment model is compatible with existing pedestrian-vehicle conflict analysis results. The constrastive conflict analysis of right-turn signal control scheme provides theoretical reference for amelioration of pedestrian safety at intersections.

Authors	Thomas Hall, Purdue University Andrew Tarko, Purdue University Mario Romero, Purdue University
Sponsoring Committee	ANB75, Standing Committee on Roundabouts
Session Number	505
Session Title	Evaluation of Roundabout Safety Through Users' Experience
Paper Number	16-5827
Paper Title	Heavy-Vehicle Rollover Propensity at Roundabouts on High- and Low-Speed Roads: Case Study
Abstract	Construction of roundabouts recently commenced on high-speed roads (45 mph or greater) in Indiana, many of which carry a significant amount of truck traffic. Crash studies in the U.S. and globally show that heavy vehicle rollovers may be an issue at such roundabouts. This paper presents a case study comparing the safety-related behavior of truck drivers at roundabouts on both low and high-speed roads. The rollover model used in this study is more suitable for truck trailers than previous models used for design considerations, accounting for the intricacies of semi-trailers and other heavy vehicles by incorporating both complex trailer paths that do not conform to the road alignment and the resulting vehicle tilt. The model was utilized to determine the proximity to rollover of heavy vehicles at roundabouts by introducing Δv, the difference between the critical rollover speed determined from the model and the observed vehicle speed. Although this study did find a difference between the roundabouts on low and high-speed roads in terms of the proximity to rollover in the circulation, the difference could not be connected to the driver speeds on the approach roads. Drivers on the high-speed approach began their deceleration earlier and had similar speed profiles to drivers on the low-speed approach close to the roundabout. The low-speed, single-lane roundabout had a smaller average minimum Δv_c on the circulatory roadway, 2.6–3.4 mph lower depending on the assumed trailer loading. This single-lane roundabout limited driver path selection to a greater extent than the high-speed, two-lane roundabout. The single-lane roundabout tended to confine drivers' speed choice which might have been the main cause of the higher rollover risk in the circulation compared to the two-lane roundabout.

Authors	Lu Li, IBI Group Bhagwant Persaud, Ryerson University Amer Shalaby, University of Toronto
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	593
Session Title	Safety Analysis with Surrogate Measures
Paper Number	16-6120
Paper Title	Using Microsimulation to Investigate Safety Impacts of Transit Design Alternatives at Signalized Intersections
Abstract	This study investigates the use of crash prediction models and micro-simulation to develop an effective surrogate safety assessment measure at the intersection level. With the use of these tools, hypothetical scenarios can be developed and explored to evaluate the safety impacts of design alternatives in a controlled environment, in which factors not directly associated with the design alternatives can be fixed. The use of traffic conflicts generated from the micro-simulation models, once calibrated and validated, and linked with observed crash frequency, greatly alleviates the lengthy time needed to collect sufficient crash data for evaluating alternatives, due to the rare and infrequent nature of crash events. A set of generalized linear models with negative binomial error structure is developed to correlate the simulated conflicts with the observed crash frequency in Toronto, Ontario, Canada. Crash prediction models are also developed for crashes of different impact types and for transit-involved crashes. The resulting statistical significance and the goodness-of-fit of the models suggest adequate predictive ability. Based on the established correlation between simulated conflicts and observed crashes, scenarios are developed in the micro-simulation models to investigate the safety effects of individual transit line elements of by making hypothetical modifications to such elements and estimating changes in crash frequency from the resulting changes in conflicts. The findings imply that the existing transit signal priority schemes can have a negative effect on safety performance and that the existing near-sided stop positioning and streetcar transit type can be safer at their current state than if they were to be replaced by their respective counterparts.

8 Transportation Safety Management

Frank Gross, VHB

Thirty-one papers describing different aspects of transportation safety management will be presented at the 2016 TRB Annual Meeting, which are briefly discussed below.

Several papers discuss the development, implementation, and evaluation of **data-driven safety plans and programs**. Siddique et al. (16-1410) describe Oregon's 'jurisdictionally blind' safety program, known as the All Roads Transportation Safety (ARTS) Program to improve safety on all public roads. Sayed et al. (16-1510) employed a full Bayes approach to evaluate the safety effectiveness of the Insurance Corporation of British Columbia (ICBC) Road Improvement Program (RIP). Two papers explain the need to consider correlations, interdependencies, and conflicting objectives while developing an optimal safety improvement program (Haas and Bekhor, 16-1988; Mishra, 16-5972). Mishra added that analyzing performance measures in combination helps to strengthen decisions related to allocation of safety resources. Two papers describe network-screening efforts; Rothenfluh and Menendez (16-2640) describe the application of a Network Safety Management (NSM) tool in Zurich, Switzerland, while Fawcett et al. (16-4299) employ a Bayesian hierarchical model to identify hot spots in Halle, Germany.

Three papers address **data collection and management issues** related to effective safety management and data-driven decision-making. Noland et al. (16-0410) investigates the quality of police-reported pedestrian fatal crashes. Moonam et al. (16-5384) develop an application to automate the mapping of traffic crashes to an all roads network. Leich et al. (16-5861) describe the measurement accuracy of automated video surveillance technology.

Two papers describe opportunities to employ advanced tools in **countermeasure selection**. Ahmed et al. (16-0601) developed an interactive guidebook to help transportation agencies make decisions related to rumble strips/stripes. Campbell et al. (16-3078) describe and provide examples of opportunities to apply the Human Factors Guidelines for Road Systems (HFG) to the road safety audit (RSA) process.

Several papers explored the **safety effects of factors such as operations, environment, economics, and development**. Shi and Abdel-Aty (16-0407) employed a Bayesian hierarchical Poisson lognormal framework to investigate the safety effects of travel time reliability, and concluded that agencies may improve safety by providing estimated travel times to drivers in real-time. Alirezaei et al. (16-0666) employed a system dynamics approach to investigate the impacts of climate change on road safety. Wang (16-2580) used random effects negative binomial models to explore the relationship between safety and level of service (LOS) at the intersection approach level. Ariannezhad et al. (16-4022) conducted a macro-level safety analysis to understand the effects of different modal shares and trip purposes on traffic safety. Brown et al. (16-5034) conducted a spatial analysis to identify clusters of at-risk drivers based on socio-economic and demographic characteristics. Quiroga and Tsapakis (16-6335) explored relationships between crashes and oil and gas energy developments.

Three papers discussed specific **driver behavior issues** through the use of surveys. Sivakumar and Krishnamurthy (16-1853) developed a binary logit model to explore willingness to pay to reduce risk.

Deka and Brown (16-2687) surveyed planning professionals, police officers, and pedestrians to explore perceptions of seriousness, prevalence, and solutions to distracted driving and walking. One of the key findings from the surveys is that all three groups consider distracted driving and walking to be serious problems that are becoming increasingly more common over time. Silverans and Van den Berghe (16-3633) present the results of a series of three historical roadside surveys (speeding, drink driving, and seat-belt wearing) to demonstrate the necessity of objective and representative measurements of the evolution of at-risk behavior in the entire driving population.

Two papers discussed the broader area of **traffic safety culture**. Hubbard (16-3904) explores safety attitudes and practices for young adults in the aviation and roadway sectors, examines differences in safety training that may contribute to a positive safety culture, and identifies practices in aviation that may be beneficial in the roadway sector. Johnson and Womack (16-5784) administered a survey, and the results indicite an increase in concern for many traffic safety problems, but mixed support for countermeasures. The results also show a “do as I say, not as I do” mentality, with respondents engaging in driving behaviors that they also cite as unacceptable.

Connected and automated vehicle (C/AV) technologies have a promising future in improving traffic safety, including mitigating crash severity and decreasing the possibility of crashes by offering warnings to drivers and/or assuming vehicle control in dangerous situations. A paper by Kockelman and Li (16-1468) explores the safety benefits of Forward Collision Warning, Do Not Pass Warning, Lane Departure Warning, Control Lost Warning, Cooperative Intersection Collision Avoidance Systems, Adaptive Cruise Control, Electronic Stability Control, and other safety-related C/AV-type technologies.

Four papers focus on **school transportation safety** (Larsen et al., 16-1894; Yu, 16-2162; Von Hagen and Sweeney, 16-3546; Ermagun and Levinson, 16-6745). These papers deal with issues related to: performance measures, how the built environment influences behavior and safety, perceptions of safety issues (e.g., strangers, cell phones, and traffic), and public transit in school trips.

Four papers focus on **Emergency Medical Service (EMS)** (Jung et al., 16-2715; Dimitriou et al., 16-3997; Hu et al., 16-4220; Sarker et al., 16-5748). These papers deal with issues related to: system-wide impacts of EMS resources; impact of response times, distance to trauma centers, and level of trauma center; and traffic incident management to reduce risk of secondary crashes.

Authors	Qi Shi, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0407
Paper Title	Evaluation of the Impact of Travel Time Reliability on Urban Expressway Traffic Safety
Abstract	In urban areas, toll expressways have been constructed in order to provide motorists with safe, efficient, and reliable transportation service. There are numerous studies that have investigated traffic safety or the relationship between safety- and efficiency. Currently, only limited attention has been paid to the analysis of how traffic safety and reliability are related. This study aims at identifying the effects of travel time reliability on crash frequency. Focusing on an urban expressway in Central Florida that is equipped with Automatic Vehicle Identification system, multiple travel time reliability indicators were developed. To accommodate the data structure in crash frequency modeling, Bayesian hierarchical Poisson lognormal framework was adopted. It was confirmed that the reduction of travel time reliability resulting from late arrivals would lead to more crashes. Nevertheless, not all crashes were affected by travel time reliability. As lower reliability is likely to cause inconsistent traffic flow and interactions between vehicles, its impact on multi-vehicle crashes therefore is much more significant compared to single-vehicle crashes. Despite travel time reliability's effects on traffic safety, the necessity of using a direct reliability measurement in safety analysis was assessed by calibrating models with only traditional traffic flow variables and structural equation models that express the effects of reliability through latent variables. Based on the comparison, it was suggested that to better understand the effects of travel time reliability on safety, inclusion of direct reliability measurement would be more efficient. This study shows that the improvement of travel time reliability through providing estimated travel times to drivers in real-time is not only beneficial to improve service and may be achieve smooth traffic flow, but it is also likely to improve safety.

Authors	Robert Noland, Rutgers, The State University of New Jersey Nicholas Klein, Temple University James Sinclair, Alan M. Voorhees Transportation Center Charles Brown, Alan M. Voorhees Transportation Center
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0410
Paper Title	Pedestrian Fatality Data Quality: Problems and Definitions
Abstract	Accurate data on pedestrian fatalities is of upmost importance to public health officials, transportation planners, police, and policy-makers. It is used to make strategic decisions about when and where to invest scarce resources to eradicate preventable deaths and improve safety for all modes. We analyzed data from one year of pedestrian deaths in New Jersey, the US state with the highest share of pedestrian deaths, and found that the data is severely lacking. Roughly one quarter of the 157 pedestrian deaths reported in New Jersey in 2012 should not have been classified as pedestrians.. Some of these fatalities should not be classified as pedestrians using the reporting definitions required by the National Highway Traffic Safety Administration (NHTSA), including some that are outright errors. Other fatalities are consistent with NHTSA's definition of a pedestrian, but are questionable from a planning and data analysis perspective, as most planners and decision makers would not consider the victims to be pedestrians. We discuss these alternate definitions and classify each fatality accordingly. Implications for research and planning are discussed and we emphasize the need to both improve data collection and management, as well as for NHTSA to reconsider how they define and track pedestrian fatalities.

Authors	Mohamed Ahmed, University of Wyoming Mirza Sharif, University of Wyoming Khaled Ksaibati, University of Wyoming
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0601
Paper Title	Developing Expert System for Shoulder and Centerline Rumble Strips and Stripes to Accommodate All Road Users
Abstract	According to the Federal Highway Administration, 53 percent of annual fatal crashes are attributed to lane and road departures. Lane departure crashes are considered the most severe crashes and often dominated by sleep deprivation/fatigue, and distracted driving. While lane departure crashes are mostly driven by drivers' errors, the frequency and severity can be reduced by more forgiving roadside and specific countermeasures. Rumble strips/ stripes are considered a relatively low cost proven safety countermeasure to reduce or prevent lane departure crashes. Although rumble strips have been used for many years, many states are in the process to update their policies to better accommodate all road users. In this paper, an Expert System was developed as an interactive Portable Document Format guidebook for rumble strips/stripes implementation criteria. Rule-based Expert Systems are being used widely in various engineering fields such as; highway management, traffic impact and safety, highway design and planning, etc. Rumble strips standards and provisions for different road users vary among State DOTs. The main objective of this paper is to accumulate information regarding rumble strips designs from various transportation agencies to aid transportation engineers in decision making process for rumble strips application. The Expert System on rumble strips was prepared by using all available recent rumble strips policies and guidelines obtained from various transportation agencies. Additionally, the results from surveys on DOTs, bicyclists, nearby residents, and motorcyclists have also been used for the Expert System design. Moreover, a description on how to use the Expert System is provided.

Authors	Mehdi Alirezaei, University of Central Florida (UCF) Nuri Onat, University of Central Florida (UCF) Omer Tatari, University of Central Florida (UCF) Mohamed Abdel-Aty, University of Central Florida (UCF)
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-0666
Paper Title	Impacts of Climate Change on Road Safety: System Dynamics Approach
Abstract	Road safety is one of the most complicated issues related to transportation, involving many interdependencies. Therefore, analyzing issues related to road safety requires a novel system based approaches in which feedback relationships, causal and side effects are taken into consideration. In this study, issues related to traffic accidents are investigated by considering major reasons of accidents (vehicle safety factor, transportation infrastructure factor, and driver's factor) and their complex relationships with climate change and certain economic parameters. System dynamic modeling approach is used to model the nexus of Climate Change-Road Safety-Economy, investigating the interaction between these important areas and tracking the way they are affecting each other over time. The proposed model can provide a platform for policy makers to investigate different scenarios in order to reduce the negative consequences of traffic accidents and the ways to improve the road safety. In this regard, a set of policies related to carbon emission reduction, reducing the travel demand, and improving vehicle safety index are tested to show the system behavior within the context of Climate Change-Road Safety-Economy nexus. Although reducing transportation related emissions alone cannot eliminate or reduce negative effects of climate change on road safety, reducing greenhouse gas emissions worldwide can significantly reduce the fatalities resulting from road accidents thanks to fewer extreme weather events, infrastructure damage, and distraction to the drivers. Reducing the travel demand and improving vehicle safety index can significantly reduce the number of fatalities and should be prioritized.

Authors	Zahidul Siddique, Oregon Department of Transportation Doug Bish, Oregon Department of Transportation Kevin Haas, Oregon Department of Transportation
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1410
Paper Title	Oregon's All-Roads Transportation Safety Program: Data-Driven Program to Improve Safety on All Public Roads
Abstract	Historically the Oregon Department of Transportation (ODOT) has spent Highway Safety Improvement Program (HSIP) funding only on state highways. However, half of the fatalities and serious injuries occur on non-state highways (i.e. city streets and county roads). In order to address this concern and to comply with the MAP-21 requirement that HSIP funding be spent on all public roads, ODOT has developed a 'jurisdictionally blind' safety program, known as the All Roads Transportation Safety (ARTS) Program for addressing safety on all public roads in the state of Oregon. The objective of the ARTS program is the same as that of the HSIP – to reduce fatalities and serious injuries on all public roads by using a data-driven approach. The ARTS Program has two components – hotspot and systemic. Safety projects were selected using a combination of a selection and an application based approach. For hotspot approach, lists of potential safety projects were prepared using crash history and then the projects were prioritized based on benefit cost ratios. The systemic component, which has three focus areas – roadway departure, intersection, and pedestrian/bicycle, is an application based process, in which ODOT and local agencies competed for available safety funding. Systemic projects were selected based on benefit-cost ratio or cost-effectiveness index. Through collaboration with various stakeholders, ODOT was able to select safety projects on both state and non-state highways using a data-driven approach. It is expected that these projects will significantly improve safety on all Oregon roads by reducing fatal and serious injury crashes.

Authors	Kara Kockelman, University of Texas, Austin Tianxin Li, University of Texas, Austin
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1468
Paper Title	Valuing the Safety Benefits of Connected and Automated Vehicle Technologies
Abstract	Connected and automated vehicle(C/AV) technologies have a promising future in improving traffic safety, including mitigating crash severity and decreasing the possibility of crashes by offering warnings to drivers and/or assuming vehicle control in dangerous situations. Given the complexities of technology interactions and crash details, the overall safety impacts of multiple C/AV technologies have not yet been estimated. This research seeks to fill that gap by using the most current General Estimates System crash records to estimate the economic and comprehensive crash-related savings from each C/AV application. Safety benefits of Forward Collision Warning, Do Not Pass Warning, Lane Departure Warning, Control Lost Warning, Cooperative Intersection Collision Avoidance Systems, Adaptive Cruise Control, Electronic Stability Control, and other safety-related C/AV-type technologies are estimated here. Results suggest that eleven C/AV technologies, such as Forward Collision Warning combined with Adaptive Cruise Control, and Road Departure Crash Warning coupled with Lane Keeping Assist, can save Americans $140 billion each year (along with almost 2 million functional-life-years saved per year), based on pre-crash scenarios that depict the critical event occurring immediately prior to a crash (e.g., rear-end and run-off-road situations) and on the assumption that C/AV technologies reduce each associated crash's cost by 80%, thanks to crash avoidance and/or moderation of crash severity. Among the various combinations of safety applications, CICAS coupled with AV technology is anticipated to offer the biggest safety benefits, by saving more than $64 billion (in economic costs) and 820,000 functional person-years in 2013.

Authors	Tarek Sayed, University of British Columbia Emanuele Sacchi, University of British Columbia Paul de Leur, Insurance Corporation of British Columbia (ICBC)
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1510
Paper Title	Evaluating the Safety Benefits of the Insurance Corporation of British Columbia Road Improvement Program Using Full Bayes Approach
Abstract	The objective of this study is to conduct a time-series (before to after) evaluation of the safety performance of a sample of locations that have been improved under the Insurance Corporation of British Columbia (ICBC) Road Improvement Program (RIP). The program started in 1989 where ICBC establishes partnerships with local road authorities in British Columbia and to work cooperatively to make sound investments in road safety improvements. The overall effectiveness of the RIP was assessed by: 1) determining whether the frequency and/or severity of collisions at the improvement sites has been reduced after the implementation of the improvement; and 2) quantifying the program costs versus the economic safety benefits to determine the return on ICBC's road safety investment. A total of 72 urban intersections were included in the evaluation. The intersections were divided in three different groups: intersection with new pedestrian signal installations (13 sites), intersections with geometric design improvements (30 sites), and intersections with traffic signal upgrades (29 sites). The methodology adopted for estimating the safety benefits was a before-after study with the full Bayes method, whereas the cost-benefit analysis was carried out using two indicators: net present value and benefit–cost ratio with a payback period of 5 years. Overall, the total reduction of severe (fatal-plus-injury) and non-severe (property-damage-only) collision frequency for the urban intersections was found equal to 19.6% and 7.6%, respectively. Finally, an overall benefit-cost ratio of 4.3:1 was achieved.

Authors	B. Sivakumar, National Institute of Technology - Calicut K. Krishnamurthy, National Institute of Technology - Calicut
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1853
Paper Title	Estimation of Willingness-to-Pay Values for Road Traffic CRASH Risk Reduction in India
Abstract	As road crashes occupy the major share of a country's economy, implementation of road safety schemes is extremely inevitable. In the absence of an estimate of traffic crash costs it will be difficult to identify the sums of money that should be invested each year on road safety countermeasures. For evaluating the acceptance of any road safety improvement scheme, public attitude towards safety and their willingness to pay (WTP) to reduce their involvement as a victim has to be taken into account. This study is an attempt to overcome the lack of reliable estimates of road crash costs in India, through a Stated Preference (SP) survey to know how users value safety and how much they are willing to pay for a safer road facility. This is the first attempt of this kind to eavaluate road crash cost. Socio-economic details, travel related details and accident related details were collected as part of the survey. The attributes considered were travel time, travel cost and accidents per year with two levels. Fractional factorial design was used to reduce the number of choice combinations for the respondents. Finally the respondents were provided with 6 alternatives to compare each with the current alternative and to select the most suitable one. It was observed that most of the respondents prefer the improved alternatives with reduced accident risk than the existing alternative they presently use. Binary Logit model was used in the study for finding the WTP values.

Authors	Kristian Larsen Ronald Buliung Guy Faulkner
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1894
Paper Title	How Do You Measure Matters? Assessing How the Built Environment Influences Children's School Travel Behavior
Abstract	School travel is one way to encourage walking and cycling on a daily basis. Much of the recent literature reports inconsistent results pertaining to how the built environment may relate to active school travel. To date, there is no consistent approach towards conceptualizing the 'environment' for its measurement and this may be partially to blame for the inconsistent results. The purpose of this paper is twofold, first to examine how characteristics of the built environment may relate to mode of school travel, but also to test how measurement of the environment may influence the results. Both the shortest path and the respondent reported route map were examined. The results indicate that model parameter estimates did vary when using these two route measurement methods. Differences in the conceptualization and measurement of the school travel environment could carry forward into misguided planning or policy interventions targeting environmental features that may actually have no influence on school travel decisions.

Authors	Inbal Haas, Technion - Israel Institute of Technology Shlomo Bekhor, Technion - Israel Institute of Technology
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-1988
Paper Title	Considering Interdependencies in the Optimal Selection of Road Safety Measures
Abstract	This paper concentrates on the optimal allocation of resources of road safety measures. All over the world, attempts are constantly being made to increase road safety by reducing the number of injuries and fatalities in road crashes. For this purpose, national safety plans are developed. These plans usually include a set of different measures, each one contributes separately to the increase of road safety, and their overall cost should not exceed a predefined budget constraint. Similar to most budget allocation problems, it is generally assumed that each safety measure delivers a certain benefit, and the set of selected measures should be based upon these individual benefits. However, such a view ignores the fact that in many cases the measures themselves are interdependent. Hence, their mutual implementation may change the overall benefit they deliver, and may affect their inclusion in the optimal set of selected measures. This problem, which has received extensive coverage with respect to transportation projects selection in general, has not received the same attention with respect to safety measures. However, the special character of safety measures calls for such an attention. This work attempts to fill this gap by presenting a methodology for optimal selection of safety measures that considers interdependence relations. This methodology is then demonstrated using a set of 60 potential safety measures, in which both the safety benefits and travel time benefits are considered.

Authors	Chia-Yuan Yu
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-2162
Paper Title	How Differences in Built Environments Affect Travel Safety Around Schools
Abstract	School locations and development patterns of the surrounding neighborhoods affect traffic safety because they generate regular, concentrated, and congested traffic flows. However, researchers have not paid sufficient attention to the impacts of community design and the built environment on the traffic safety around school areas. This study explored the influences of school siting and surrounding built environments on rates of motorist and pedestrian crashes around 120 public schools (including 77 elementary schools, 24 middle schools, and 19 high schools) in the Austin Independent School District (AISD), Texas, by using log–linear regressions. The results showed that school areas with higher population densities and higher traffic volume experienced more motorist and pedestrian crashes. A higher sidewalk coverage and a higher percentage of local roads reduced pedestrian crashes around schools, while higher percentages of highways and commercial uses and higher transit stop densities increased motorist and pedestrian crashes. Moreover, commercial uses along local roads were associated with more crashes. The results of this study informed that planners should work with stakeholders from different levels of government and from different agencies (i.e., school districts, transportation organizations, etc.) to develop strategies to address traffic safety issues around school areas in changing the infrastructure and environmental designs around existing schools and in better siting schools in the future. This study suggested three inter–related ways that planners can do so, collaborating with a wide range of stakeholders: planning a low–speed environment, locating commercial uses away, and providing pedestrian–friendly environments around schools.

Authors	Xuesong Wang, Tongji University Jia Li, Tongji University Rongjie Yu, Tongji University
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-2580
Paper Title	Relationship Between Level of Service and Traffic Safety at Signalized Intersections
Abstract	Level of Service (LOS) is the measure recommended by the Highway Capacity Manual to evaluate roadway facilities' operational condition. It is generally agreed that for signalized intersections, LOS is related to traffic safety. However; this relationship is not well established because operational condition and safety are rarely considered concurrently. In this study, LOS and crash data were acquired over a 3-year period from 164 four-legged signalized intersections in the Central Florida area. The LOS-safety relationship at the intersection approach level was investigated for different crash types using Bayesian inference. LOS was calculated for morning peak, midday, and afternoon peak. Because crashes occurring on different approaches within one intersection are likely to be affected by some unobserved variables' influence, Random Effects Negative Binomial models were used. Results showed signalized intersection approaches operating at level LOS C (LOS A is highest, F is lowest) were associated with fewer total and rear-end crashes compared to LOS D, E, and F, and approaches operating at LOS A and B were associated with fewer total and rear-end crashes than LOS C. Left turn crashes were not associated with LOS. Time varying effects of LOS on crash occurrence were examined using Random Parameter Negative Binomial models. The results showed the effects of a specific LOS on total or rear-end crashes varied across different time periods, but the variation trends were not consistent for different LOS. This study shows an understanding of LOS-safety relationship at the intersection approach level requires examining different crash types and time periods.

Authors	Marco Rothenfluh, ETHZ - Swiss Federal Institute of Technology Monica Menendez, ETHZ - Swiss Federal Institute of Technology
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-2640
Paper Title	Application of Network Safety Management Tool in Urban Areas: Case Study in Zurich, Switzerland
Abstract	Due to the economic and social cost of traffic accidents, it is essential for road administrators to properly evaluate where infrastructure investments are necessary to improve the system. Network Safety Management (NSM) is an analysis tool typically used on freeways and other interurban roads to identify the locations with the highest potential for infrastructure improvements from a safety perspective. In this paper we investigate how this tool can also be used to identify such locations within an urban environment. The area of study is the city of Zurich, and the accident data for the period 2009 to 2013. The aim of this paper is to investigate the application of NSM in urban environments, illustrate it with a real case study, evaluate the results obtained, and test their robustness for different input parameters. For this, georeferenced data are required in order to have an explicit distinction between the three road network elements used: traffic oriented roads, nodes, and residential zones. On the basis of different accident cost rates a prioritization of the individual network elements is made. The results show that mostly network elements with numerous conflict points have the highest safety potential. Further test reveal that traffic volume is the most influential parameter within the model. Additionally, more differentiated cost rates are presented, and a comparison with the road safety tool Black Spot Management (BSM) is done to verify the detected accident clusters. The findings are used to make pragmatic recommendations on the use of NSM in an urban context.

Authors	Devajyoti Deka, Rutgers, The State University of New Jersey Charles Brown, Alan M. Voorhees Transportation Center
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-2687
Paper Title	What Do Planning Professionals, Police Officers, and Common People Think About Distracted Driving and Walking?
Abstract	This paper discusses issues related to distracted driving and walking by presenting results from a survey of planning professionals, police officers, and pedestrians in New Jersey. The pedestrian intercept survey was completed by 788 individuals, whereas the online surveys for planning professional and police officer were completed by 209 and 156 individuals, respectively. The surveys primarily focused on the perceptions of seriousness, prevalence, and solutions to distracted driving and walking. One of the key findings from the surveys is that all three groups consider distracted driving and walking to be serious problems that are becoming increasingly more common over time. Among different types of driving distractions, texting and talking on hand-held phones are considered to be two of the most common and yet least safe driver distractions. All three groups perceive mandatory education for new drivers, stricter enforcement of existing laws, and more severe penalty for drivers involved in crashes as the most important solutions to distracted driving. Educating students in schools was considered to be the most important solution to distracted walking. While strong support was found for police checking phones of drivers involved in crashes, little support was found for police intervention to curb distracted walking. The findings of the study are being discussed through outreach with select agencies to identify and adopt strategies to address distracted driving and walking in New Jersey.

Authors	Soyoung Jung, Hanyang University Xiao Qin, University of Wisconsin, Milwaukee Cheol Oh, Hanyang University
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-2715
Paper Title	System-wide Impacts of Emergency Medical Service (EMS) Resources on Freeway Crash Severity
Abstract	Timely patient transport to permanent medical facilities is an important issue in reducing fatalities on rural freeways. The objective of this study is to quantitatively examine the system-wide effects of pre-hospital emergency medical service (EMS) resources on crash outcomes throughout the entire Korean freeway system. To achieve this objective, latent class cluster and binomial probit regression models were combined to identify pre-hospital EMS resources for different types of crashes. In the cluster-based binomial probit regression, surrogate measures for pre-hospital EMS resources were obtained by combining medical service portals, freeway heliport maps, and freeway network log data in the crash dataset. As a result, eight latent class clusters of crashes were determined based on features associated with EMS resources, province, roadway, and traffic conditions at the scene of the crash. On-scene and recovery times were commonly significant in increasing the probability of fatal crashes in both entire group and in each group of crashes, whereas the nearest ramp proximity and the number of nearby EMS facilities significantly affected fatal crashes for a certain group of crashes. The findings provide meaningful insights that can enhance EMS training programs for initial medical aid and post-crash traffic management on all provincial freeways. Supplemental nearby EMS facilities and access points to them are needed in Korea's south freeway sections in particular. This research is the first data-driven study to assess system-wide EMS resources for the entire Korean freeway system using multiple data sources, which would contribute to informed decision-making for future EMS provision.

Authors	John Campbell, Battelle Memorial Institute Kohinoor Kar, Arizona Department of Transportation Rebecca Szymkowski, Wisconsin Department of Transportation Samuel Tignor, Virginia Polytechnic Institute and State University Jaime Tuddao, Nevada Department of Transportation
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-3078
Paper Title	APPLYING THE HUMAN FACTORS GUIDELINES FOR ROAD SYSTEMS (HFG) TO THE ROAD SAFETY AUDIT (RSA) PROCESS
Abstract	This paper describes the activities and results associated with a pilot study to assess the value and efficacy of the Human Factors Guidelines for Road Systems, Report 600, Second Edition (HFG) for conducting road safety audits (RSAs). Published by TRB, the HFG provides focused discussions of design issues and design solutions in the context of a detailed presentation of road user needs, capabilities, and limitations. The HFG summarizes human factors principles and concepts that could be used primarily by roadway designers, traffic engineers, and safety professionals to improve roadway design and traffic safety. Five states in the United States (U.S.) participated in the pilots and, across these states, a total of 190 end-users were given in-person, instructor-led training on the objectives, contents, and application of the HFG. Of the five U.S. states participating in the pilot study, three states—Arizona, Nevada, and Wisconsin—used the HFG to support the conduct of multiple RSAs. Results from twelve RSAs using the HFG across the three states are provided. The results highlight the facility type, critical safety issues being studied, and specific chapters and guidelines in the HFG that provided valuable insights, design solutions, and countermeasures. Though the pilot study was preliminary and qualitative, the contents and materials presented in the HFG provided consistent value and aid to a diverse group of engineers and safety professionals. A consistent feature in the feedback provided by the states was that the HFG provided end-users with practical, implementable solutions to real-world problems. This report highlights the key human factor guidelines these three states used in their RSA studies.

Authors	Leigh Ann Von Hagen Shannon Sweeney
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-3546
Paper Title	Stranger Danger, Cell Phones, Traffic, and Active Travel to Schools: Perceptions of Parents and Children
Abstract	This paper summarizes one-on-one interviews with parents and their middle school children to identify similarities and differences in parents' and children's perceptions of the environment surrounding travel to and from school, how and why these perceptions form, and how they influence travel mode choice to and from school. A total of forty-eight interviews were conducted with parent-child pairs in three New Jersey communities. In particular, the interviews examined active transportation modes such as walking and bicycling to and from school. Talking directly to parents and students allowed for a deeper level of description of perspectives and concerns. Analysis of qualitative data showed differences in adult versus child perceptions and the emergence of several themes related to the environment and children's capacity for independence. Themes included differences in comfort with solo travel at different times of day, parental concern with abductions and sexual offenders, common use of cell phones and GPS technology to address safety fears, and disparity in travel mode based on gender. Implications for practice include supporting opportunities for children to walk in groups, such as the designation of "meet up" locations where students can gather without parental accompaniment, and encouraging "Walk to School" and "Walk from School" days to help parents and students become comfortable with solo walking trips. In addition, schools and communities can provide skills-based education on personal safety skills, and can identify safe areas where students can go if problems arise, to help children attain the benefits of active travel.

Authors	Peter Silverans, Belgian Road Safety Institute Wouter Van den Berghe, Belgian Road Safety Institute
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-3633
Paper Title	MONITORING EVOLUTIONS IN DRIVER BEHAVIOR THROUGH HISTORICAL SERIES OF ROADSIDE SURVEYS
Abstract	The results of three historical series of roadside surveys (speeding, drink driving and seat-belt wearing) are presented to demonstrate the necessity of objective and representative measurements of the evolution of at risk behavior in the entire driving population. For speeding the observations are based on 4 to 6 million continuous automated radar measurements on randomly selected locations across the country. Drink driving is monitored through breath testing more than 10.000 randomly selected drivers selected from moving traffic by the police according to a specifc random sampling scheme. Seat-belt wearing is measured by observing between 20 and 25 thousand drivers according to a random sampling observation scheme. It is shown that for all three topcis a historical series of more than a decade allows to monitor the overall prevalence of risky behavior, to track evolutions over time and to identify particular at risk factors associated with specific locations, times or target groups. Similar methods for surveys conducted only once or twice so far are described to illustrate the usefulness of observed data in the area of distraction, child restraint system use and speeding by motorcycle and van drivers. Based on the results of both the historical series and the more innovative new roadside surveys it is argued that historically comparable, large representative samples of observations are indispensable for an evidence based road policy.

Authors	Sarah Hubbard, Purdue University
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-3904
Paper Title	Safety Culture: Examination of Safety Attitudes Across Transportation Modes
Abstract	Transportation safety is a top priority for all agencies, although traffic fatalities remain a leading cause of death in many age groups. One traditional approaches to roadway safety is a multi-faceted strategy that addresses the 4 E's: education, enforcement, engineering and emergency response. In recent years, a number of states have also undertaken collaborative initiatives such as Toward Zero Death programs in an effort to increase roadway safety. While roadway fatalities have decreased, there is still significant opportunity for improvement. There have been many research studies to identify factors that correlate with roadway crashes (e.g., geometric factors) and document the impact of mitigation measures such as roadway improvements, policy changes (e.g., speed limits) and safety programs (e.g., campaigns to reduce distracted driving). While crashes may be considered an inevitable consequence of mobility, fatality rates vary dramatically among transportation modes, and the impressive safety record in aviation suggests that fatalities should not be considered inevitable. This research explores safety attitudes and practices for young adults in the aviation and roadway sectors, examines difference in safety training for roadways and aviation that may contribute to a positive safety culture, and identifies practices in aviation that may be beneficial in the roadway sector. In addition to providing a benchmark for the current safety culture and comparing attitudes and practices in the roadway and aviation environment, this research lays a foundation to develop best practices that will contribute to a positive safety culture, which will improve safety and reduce the costs associated with crashes in the roadway environment.

Authors	Loukas Dimitriou, University of Cyprus Constantinos Antoniou, National Technical University of Athens (NTUA) Dimitrios Efthymiou, National Technical University of Athens (NTUA)
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-3997
Paper Title	Understanding the Impact of Accessibility and Weather on Emergency Unit Reaction Times
Abstract	The provision of medical care in cases of road crashes is among the most defining elements in trauma handling. A characteristic evidence is the identification that people involved traumatic accidents that are handled within the first hour after the event (a period frequently termed as the "Golden Hour") exhibit significantly decreased morbidity and mortality, exposing the importance of reaction times in cases like severe road crashes. Moreover, in emergency services management, especially for large-scale urban conglomerations, the improvement/reduction in reaction times stands for one of the top priorities, which is subject to a number of complexities, uncertainties, burdens and constraints. In this research, reaction times in cases of road accident emergencies in urban networks are investigated, particularly correlating important features that affect them, such as location accessibility, type of emergency/accident and environmental conditions (in this case weather). The methodological framework comes from the field of spatial econometric modeling, and in particular in spatial error models-SEM, which are able to take into consideration spatial relationships, that in turn may capture location-specific relationships, weather effects or other significant elements and provide detailed results on reaction times for alternative cases of emergency. The application is performed over a suitable metropolis case, namely, the urban area of Riyadh, KSA, while the results offer valuable insight that can be exploited for a meta-analysis aiming at improving the system's performance.

Authors	Amin Ariannezhad, University of Arizona Yao-Jan Wu, University of Arizona Yi-Chang Chiu, University of Arizona Aichong Sun
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-4022
Paper Title	Incorporating Mode Choices into Safety Analysis in Traffic Analysis Zones
Abstract	Macro-level safety analysis has been recently focused on by researchers since it incorporates safety measures into transportation planning. The primary purpose of this study was to investigate the association between aggregated crashes and different trip modes and purposes in traffic analysis zones (TAZs). For this investigation, four negative binomial models were developed for total, severe, bicycle, and pedestrian crashes using crash and trip data for TAZs in Tucson, Arizona. Roadway characteristics of the TAZs were also used as explanatory variables. The results from these models indicated that home-based work and school trips had a significant impact on aggregated crash data. Home-based work production trips by private vehicle were found to be positively associated with total, severe, and bicycle crashes. Home-based work production trips by walking, using park-and-ride systems, and walking to local buses were also found to increase total crashes. Home-based school attraction trips by walking and home-based school production trips by walking to local buses were found to be positively associated with an increase of severe and pedestrian crashes. Also, home-based school production trips by bike and home-based University attraction trips by private vehicle were found to increase bicycle crashes. For safety planners and decision makers, the results of this study provide a better understanding of the effects of different modal shares and trip purposes on traffic safety. This understanding could then help them to proactively develop safety measures at the transportation planning level.

Authors	Wei Hu Qiao Dong, University of Tennessee, Knoxville Baoshan Huang, University of Tennessee, Knoxville
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-4220
Paper Title	Relationship Between Distance to Trauma Centers and Driver Mortality in Fatal Crashes Using FARS Data
Abstract	The foundation of emergency medical services (EMS) and trauma systems relies on the assumption that better outcomes are associated with a reduction in time to trauma care. However, little evidence could be found in former literatures to directly support the assumption. In this study, the data of Fatality Analysis Reporting System (FARS) from 2010 to 2012 were adopted to quantify the relationship between the distance to trauma centers and the mortality of drivers in fatal crashes. Utilizing the closest facility solver in the Geographic Information System (GIS), the distance from crash scene to trauma center was calculated, and a correlation was identified between increased distance to trauma center and increased mortality through logistic regression for all drivers in fatal crashes. The effects of trauma center on non-drivers in fatal crashes and the different degree of effects for different level of trauma center were also examined using logistic regression.

Authors	Lee Fawcett, Newcastle University Joe Matthews, Newcastle University Karsten Kremer Neil Thorpe
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-4299
Paper Title	Road Safety Hotspot Prediction: Study of Halle, Germany
Abstract	In this paper, we outline a new approach for collision hotspot identification based on a recent collaboration between researchers at Newcastle University, UK, and industrial partners at PTV Group in Germany. The primary aim of this work is the development of a tool for assessing the likelihood of accidents within a pool of potential road safety hotspots, in the future, to enable a proactive – rather than reactive – approach to safety scheme implementation. For example, during the rollout of mobile road safety cameras in the UK during the early 2000s, a particular location was deemed worthy of treatment if the number of collisions exceeded a pre-determined threshold during some prior observation period. The effectiveness of the cameras was often then assessed by a before-and-after study in which attempts were made to separate any change in collision counts into regression to the mean (RTM), trend and genuine treatment effect. In this paper, we focus mainly on an approach, which has the potential to inform practitioners of the location of future road safety hotspots, allowing the implementation of some safety countermeasure before a high collision threshold is exceeded. A fully Bayesian hierarchical model is constructed to estimate site- and time-specific RTM and trend effects, which are smoothed according to site-specific accident prediction models (APMs) constructed using an optimal set of reference sites. The Bayesian posterior predictive distribution is exploited to estimate, with error bounds, the future safety of sites within our pool of potential hotspots.

Authors	Kweku Brown, Clemson University Wayne Sarasua, Clemson University Jennifer Ogle, Clemson University
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-5034
Paper Title	Safety Planning: Analysis of the Socioeconomic and Demographic Characteristics of At-Risk Driver Residential Areas in South Carolina
Abstract	This research was initially conducted to assist in safety planning at the state level. In particular, the goal of the research was to assess the potential of down selecting geographic areas in the state using spatial and statistical tools to optimize expenditure of scarce safety funds on safety program implementations to improve driver safety in South Carolina. Addressing safety issues at high crash incidence locations through crash countermeasures or better geometric design helps to make our roadways safer; however, the most influential and ever-present factor in most crashes, the human factor, is not directly addressed. This paper investigates the socio-economic and demographic characteristics of residential locations (found using 9-digit zip codes) of drivers who were reported as having contributed to either fatal and/or injury crashes (at-risk drivers) in South Carolina. The analysis unit is at the census block group level of geography. The results of the spatial analysis and statistical analysis conducted in this research demonstrate significance in relationships between high and low density clusters of at-risk drivers and the socio-economic and demographic characteristics of the residential areas where these at-risk drivers live. For example, the median household income variable showed a negative correlation to the at-risk driver clusters meaning that areas with high median household income were more likely to have fewer at-risk drivers than other areas. The spatial and statistical analysis methods used in this research are readily transferable and use widely available census data and are dependent only on the availability of information to associate crash involved drivers to at least a nine-digit zip code boundary.

Authors	Md Hasan Moonam, University of Wisconsin, Milwaukee Xiao Qin, University of Wisconsin, Milwaukee Steven Parker, University of Wisconsin Qianwen Lu, University of Wisconsin, Madison
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-5384
Paper Title	Mapping Automation of Traffic Crashes to All-Roads Network
Abstract	Higher accuracy in crash location is indispensable to prioritize hazardous locations for implementing corrective measures to counter safety problems. Crash mapping automation is paramount to avoid manual coding of crash data, which can be costly and time consuming. Given the imperfect information, the limitation of any automation algorithms prompts the development of an effective indicator to identify crashes mapped with potential errors for manual correction. This paper introduces the enhancement of an automatic crash mapping application, Crash-Mapping Automation Tool (C-MAT), which now converts location information for traffic crashes on all roads from a police reported crash record to a geo-referenced point feature. On average, C-MAT geocodes over ninety percent crashes in the state of Wisconsin. A confidence level algorithm (CLA) has been designed and implemented along with the mapping application to measure the location accuracy for each mapped crash. CLA with its comprehensive flagging system can improve overall mapping accuracy, empower error tracing, and assist in data quality assessment. Training for crash data collectors based on the assessment results will help to improve crash data quality in the future and thus, C-MAT creates a solid base for effective and efficient safety analysis to prevent traffic crashes on all roads

Authors	Afrid Sarker, University of Memphis Rajesh Paleti, Old Dominion University Sabyasachee Mishra, University of Memphis Mihalis Gkolias, University of Memphis
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-5748
Paper Title	Prediction of Secondary Crash Frequency on Highway Networks
Abstract	Secondary crash (SC) occurrences are major contributors to traffic delay and reduced safety, particularly in urban areas. National, state, and local agencies are investing substantial amount of resources to identify and mitigate secondary crashes to reduce congestion, related fatalities, injuries, and property damages. Though a relatively small portion of all crashes are secondary, determining the primary contributing factors for their occurrence is crucial. The non-recurring nature of SCs makes it imperative to predict their occurrences for effective incident management. In this context, the objective of this study is to develop prediction models to better understand causal factors inducing SCs Given the count nature of secondary crash frequency data, the authors used count modeling methods including the standard Poisson and Negative Binomial (NB) models and their generalized variants to analyze secondary crash occurrences. The models developed account for possible effects of geometric design features, traffic composition and exposure, land use and other segment related attributes on frequency of SCs on freeways. The models were estimated using data from Shelby County, TN and results show that annual average daily traffic (AADT), traffic composition, land use, number of lanes, right side shoulder width, posted speed limits and ramp indicator are among key variables that effect SC occurrences. Also, the elasticity effects of these different factors were also computed to quantify their magnitude of impact. The model results were also validated by examining the ability of the developed models to replicate the observed SC frequency distribution. The ability to predict the occurrence of SCs would enable the traffic incident management agencies to contain the effects of the primary incident and disseminate the information to the users accordingly to prevent the occurrence of SCs.

Authors	Neal Johnson, Texas A&M Transportation Institute Katie Womack, Texas A&M Transportation Institute
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-5784
Paper Title	Measuring the Traffic Safety Culture of Texas: 2015 Results
Abstract	The concept of traffic safety culture assesses how much traffic safety is highly valued and rigorously pursued by society. The Texas A&M Transportation Institute is now in its third iteration of a survey to measure the safety culture in the state of Texas. This paper presents the 2015 results. The survey showed an increase in concern for many traffic safety problems, but mixed support for countermeasures. The results also showed a "do as I say, not as I do" mentality, with respondents engaging in driving behaviors that they also cite as unacceptable. A comparison to the traffic safety culture of the United States reveals that Texans self-report engaging in risky driving behaviors at much higher rates. The traffic safety culture of Texas appears to be evolving with increased awareness of the problems, but more support is needed for taking the steps to combat them.

Authors	Andreas Leich, German Aerospace Center (DLR), Institute of Transport Research Andreas Kendziorra, German Aerospace Center (DLR), Institute of Transport Research Hagen Saul, German Aerospace Center (DLR), Institute of Transport Research Ragna Hoffmann, German Aerospace Center (DLR), Institute of Transport Research
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-5861
Paper Title	Calculation of Error Rates for Detection of Critical Situations in Road Traffic
Abstract	This article is a contribution to the development of methods for road safety analysis. A calculation scheme is derived for error rates of critical situations detected automatically using a roadside stationary detector. A situation is classified as critical, if the time to collision is below some threshold. Calculated error rates are provided on different experiments with camera based vehicle detectors. The experiements demonstrate the best case of measurement accuracy that can be achieved using state of the art automated video surveillance technology. In the experiments, the false positive rate is five and four times higher than the true positive rate. This finding leads to the conclusion, that studies known from literature, stating there is correlation between the number of near crashes and real crashes should be faced with skepticism as long as no reliable information on error rates is provided.

Authors	Sabyasachee Mishra, University of Memphis
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-5972
Paper Title	Consideration of Conflicting Objectives in Highway Safety Resource Allocation
Abstract	There is increasing awareness among planning agencies to reduce occurrence of traffic crashes to reduce economic and societal cost. This awareness calls for creation of a transportation system free from fatalities, serious injuries, and property damages. Allocating resources to identified crash location is challenging problem in the era of economic competitiveness and constrained budget. Non-strategic approaches and unavailability of methods for evaluating policies may lead to sub-optimal funding allocation. This paper identified typical performance measures considered by the state planning agencies and quantified them in an optimization modeling framework. Three performance measures considered are: safety benefit, net present cost, and equity. These three measures are considered as unique objective functions subjected to policy and budget constraints. Further all three objective functions are combined in a multi-objective optimization framework. The proposed methodology is analyzed considering selected intersections in four counties of southeast Michigan. Results suggests that when performance measures are analyzed separately they provide specific policy recommendations. When performance measures are analyzed in combination, the results provide an array of solutions to further consider and strengthen highway safety resource allocation decision making. The proposed methodology and results indicate the need for applicability of strategies and policies to further enhance safety resource allocation.

Authors	Cesar Quiroga, Texas A&M Transportation Institute Ioannis Tsapakis, Texas A&M Transportation Institute
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-6335
Paper Title	Correlations Between Oil and Gas Energy Developments and Crashes
Abstract	Recent advancements in well development technologies have resulted in a substantial increase in oil and gas well activities that have generated high volumes of truck traffic. Many of the roads involved were never designed to carry heavy, repetitive truckloads. The result has been accelerated pavement deterioration and degradation of roadside infrastructure. There is relatively little documentation on the correlation between unconventional energy developments and crashes. This paper identifies crash trends in relation to oil and gas well developments in Texas and introduces statistical models that could be applicable for diagnostic, planning, and decision-making purposes. We examined crash trends from 2006 2013. The most significant changes were in connection with rural crashes that involved commercial motor vehicles (CMVs). In most cases, as the severity of the injuries worsened, the changes in the corresponding number of crashes were more noticeable. The correlation analysis revealed a very strong correlation between the number of new wells and rural CMV crashes, particularly in the case of serious crashes. The correlation was stronger for horizontal wells than for vertical wells.

Authors	Alireza Ermagun David Levinson
Sponsoring Committee	ANB10
Session Number	655
Session Title	Transportation Safety Management
Paper Number	16-6745
Paper Title	Public Transit in School Trips: Active or Nonactive
Abstract	This paper considers school access by active (walk, bike), quasi-active (walk to transit) and non-active modes (car) in a two-level cross-nested logit framework. A sample of 3,272 middle and high school students was collected in Tehran. The results of the cross-nested logit model suggest that for people who choose walking, increasing a one percent in home-to-school distance reduces the probability of walking by 3.51 percent. While, this reduction is equal to 2.82 and 2.27 percent as per the multinomial and nested logit models, respectively. This is a direct consequence of the model specification that results in underestimating the effect of distance by 1.24 percent. It is also worth mentioning that, a one percent increase in home-to-school distance diminishes the probability of taking public transit by 1.04 among public transit users, while increases the probability of shifting to public transit from walking by 1.39 percent. Further, a one percent increase of the distance to public transport decreases the probability of students' physical activity, approximately, 0.04 percent.

9 Interacting Committees

Other Committees sponsored several papers which are within the scopes of ANB10, ANB20, and ANB25. Below, names and scopes of these Committeees are reported.

ABE30, Transportation Issues in Major Cities

This committee will address the transportation problems and issues facing the largest cities in the United States. The focus will be on passenger and freight transportation from the perspective of central city transportation agencies, with emphasis on management, planning, design, maintenance, operations, and finance and coordination with regional and state agencies. The committee will identify problems and issues that large cities have in common, assess the state-of-the-art of transportation in these cities, and define needed research, studies, and information exchange activities to assist in the resolution of large city transportation problems**.**

ABE90, Transportation in the Developing Countries

The committee will foster research, global communications and interaction, and avenues for transfer of intellectual technology on issues related to transportation in the developing countries. Emphasis will be on integrated planning and implementation strategies which consider the appropriate role for all modes: Public transport, MVs, NMVs and Pedestrians, and include the consideration of economic, environmental and social issues as well as the framework of administrative reform and management, private-public sector roles, environmental management, needs of the poor, and the need for appropriate mix of modes for urban and regional transport**.**

ABJ80, Statistical Methods

This committee is concerned with the appropriate application of statistical methods in the field of transportation. The committee will serve as a resource on statistical matters for all other TRB committees or activities; will foster understanding and use of statistics through dissemination and education activities; and will identify and foster research needed in statistics for use in transportation.

ADD50, Environmental Justice in Transportation

The Committee on Environmental Justice identifies, advances and publishes research to expand understanding of the effects and implications of transportation policies, procedures and actions on minority and low-income populations (EJ populations), and seeks to improve evaluation tools and methodologies.

AFB10, Geometric Design

This committee focuses on expanding knowledge regarding highway and street geometric design elements that affect safe and efficient operations for all users and contexts. The committee develops research needs statements and communicates findings that advance design criteria, guidance, methods, and performance-based roadway design objectives. The committee facilitates domestic and international dialogues and idea exchanges between researchers and practitioners while supporting emerging and developing professionals.

AHB50, Traffic Control Devices

This committee is concerned with the development, design, application, and evaluation of traffic control devices, and their effect on traffic operation and safety.

ANB75, Roundabouts

The committee is concerned with all factors encompassing modern roundabouts. The Task Force provides focus within TRB on current issues and future research needs pertaining to modern roundabouts. It serves as a forum for discussions about roundabout research, projects, and policy for all interested stakeholders; identifies research needs and develops research problem statements to meet the needs; and facilitates the exchange of knowledge by various media, meetings, and conferences.

AND40, Visibility

This committee is concerned with those factors which affect visibility in all forms of transportation, including relevant human, vehicular and environmental considerations, as well as safety, economics and energy conservation.

ANF10, Pedestrians

This committee is concerned with research on pedestrians and pedestrian facilities which will provide safe, comfortable, and efficient walking environments along sidewalks, along and across roadways, and connecting to other modes of transportation. It addresses the planning, design, operation, and maintenance of roadways as they affect use of public rights-of-way by pedestrians. It aims to integrate pedestrian considerations into broader transportation issues.

ANF20, Bicycle Transportation

This committee is concerned with all aspects of bicycling and bicyclists and criteria for bicycle facilities to assure that the bicycle rider has safe, convenient and efficient travel.