ANB10 – Transportation Safety Management
ANB20 – Safety Data, Analysis and Evaluation
ANB25 – Highway Safety Performance

Synthesis Report

on safety-related papers presented at the 93rd TRB Annual Meeting

Prepared by
Alfonso Montella, Mohamed Abdel-Aty, Mohamad Banihashemi, Frank Gross, Tomas Hall, Francesca La Torre, Tarek Sayed, Raghavan Srinivasan, and Andrew Tarko

TRB 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.rsip.lsu.edu/anb10-

Membership as of January 2014

Co-chairs

Robert E. Hull, Utah Department of Transportation
Jake Kononov, DiExSys, LLC

Secretary

Terecia W. Wilson, Clemson University

TRB Staff Representative

Bernardo B. Kleiner, Transportation Research Board

Members

Geni B. Bahar, NAVIGATS Inc.
Timothy E. Barnett, Alabama Department of Transportation
Matts-Ake Belin, Swedish Transport Administration (TRAFIKVERKET)
Salvatore Damiano Cafiso, University of Catania
Kevin N. Chang, King County Department of Transportation
Michael Curtit, Missouri Department of Transportation
T. Bella Dinh-Zarr, FIA Foundation
Catherine Durso, University of Denver
Pam Fischer, Pam Fischer Consulting
Ian Grossman, American Association of Motor Vehicle Administrators (AAMVA)
Susan B Herbel, Cambridge Systematics, Inc.
Steven Hersey, Colorado Department of Transportation
J. R. Peter Kissinger, AAA Foundation for Traffic Safety
Nadine R. Levick, EMS Safety Foundation
Josef Mikulik, Transport Research Centre (CDV), Czech Republic
Alfonso Montella, University of Naples Federico II
Mark Poppe, Arizona Department of Transportation
Kimberly Kolody Silverman, CH2M HILL
Edward R. Stollof, Institute of Transportation Engineers (ITE)
Priscilla A. Tobias, Illinois Department of Transportation
Marie B. Walsh, Louisiana Department of Transportation and Development
Jennifer Warren, Federal Highway Administration (FHWA)
Fred C. M. Wegman, SWOV Institute for Road Safety Research
Roger A. Wentz, American Traffic Safety Services Association (ATSSA)
Brent Wilhite, Penna Powers Brian Haynes
Yuanchang Xie, University of Massachusetts, Lowell
Kathren S. Zahul, Georgia Department of Transportation

Young Members

Andrea Bill, University of Wisconsin, Madison
Frank Gross, Vanasse Hangen Brustlin, Inc. (VHB)

TRB 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/

Membership as of January 2014

Co-chairs

Christopher M. Monsere, Portland State University
Bhagwant Persaud, Ryerson University

Secretary

Kimberly A. Eccles, Vanasse Hangen Brustlin, Inc. (VHB)

TRB Staff Representative

Bernardo B. Kleiner, Transportation Research Board

Members

Mohamed A. Abdel-Aty, University of Central Florida (UCF)
Mohamadreza Banihashemi, GENEX Systems
Karin M. Bauer, MRIGlobal
Gary Arnold Davis, University of Minnesota
Alberto Miguel Figueroa, University of Puerto Rico, Mayaguez
Feng Guo, Virginia Polytechnic Institute and State University (Virginia Tech)
John N. Ivan, University of Connecticut
Karl E. Kim, University of Hawaii
Dominique Lord, Texas A&M University
Craig A. Lyon, Persaud and Lyon Inc.
Jianming Ma, Texas Department of Transportation
Patrick T. McGowen, Montana State University
Alfonso Montella, University of Naples Federico II
Mehdi Nassirpour, Illinois Department of Transportation
Jennifer Harper Ogle, Clemson University
Richard D. Paddock, Traffic Safety Analysis Systems and Services, Inc.
Xiao Qin, South Dakota State University
Nicolas Saunier, Ecole Polytechnique de Montreal
Tarek A. Sayed, University of British Columbia
Venkataraman N. Shankar, Pennsylvania State University
Raghavan Srinivasan, University of North Carolina, Chapel Hill
Seymour D. Stern, National Highway Traffic Safety Administration (NHTSA)
Carol H. Tan, Federal Highway Administration (FHWA)
Andrew P. Tarko, Purdue University
Richard S. Tay, La Trobe University
Shane Alan Turner, Beca Infrastructure, Ltd.
Simon Washington, Queensland University of Technology

Young Members

Karim El-Basyouny, University of Alberta
Erin M. Ferguson, Kittelson & Associates, Inc. (KAI)
R. J. Porter, University of Utah
Craig P. Thor, Federal Highway Administration (FHWA)

Emeritus Members

Forrest M. Council, UNC Highway Safety Research Center
Ezra Hauer

TRB 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 January 2014

Chair

John C. Milton, Washington State Department of Transportation

Secretary

Elizabeth Ann Wemple, Cambridge Systematics, Inc.

Members

Melissa A. Anderson, U.S. Access Board
Geni B. Bahar, NAVIGATS Inc.
James A. Bonneson, Kittelson & Associates, Inc. (KAI)
Craig A. Copelan, California Department of Transportation (CALTRANS)
Michael A. Dimaiuta, GENEX Systems
Karen K. Dixon, Texas A&M Transportation Institute
Brelend C. Gowan,
Michael S. Griffith, Federal Highway Administration (FHWA)
Douglas W. Harwood, MRIGlobal
Robert E. Hull, Utah Department of Transportation
John N. Ivan, University of Connecticut
Jake Kononov, DiExSys, LLC
Francesca La Torre, University of Florence
Dominique Lord, Texas A&M University
Yingyan Lou, Arizona State University
John M. Mason, Jr., Auburn University
John J. Nitzel, CH2M HILL
Jennifer Harper Ogle, Clemson University
Jose M. Pardillo-Mayora, Universidad Politecnica de Madrid
Stanley F. Polanis,
Stephen W. Read, Virginia Department of Transportation
Venkataraman N. Shankar, Pennsylvania State University
Xiaoduan Sun, University of Louisiana
Larry Francis Sutherland, Parsons Brinckerhoff
Priscilla A. Tobias, Illinois Department of Transportation
Daniel S. Turner, University of Alabama, Tuscaloosa
Ida van Schalkwyk, Washington State Department of Transportation
Simon Washington, Queensland University of Technology

Young Members

Cheryl L. Bornheimer, Kansas Department of Transportation
Daniel L. Carter, UNC Highway Safety Research Center
Erin M. Ferguson, Kittelson & Associates, Inc. (KAI)
Srinivas Reddy Geedipally, Texas A&M Transportation Institute

Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 93rd 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 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. Highway safety is a major worldwide social challenge which requires synergic research in several strategic areas. Effective cooperation between the TRB Committees is crucial to enhance roadway safety.

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

- Four Committee meetings (see Table 1);
- Seventeen Subcommittee meetings (see Table 1);
- Six workshops (see Table 2);
- Nine lectern sessions (see Table 3); and
- Six poster sessions (see Table 4).

The Committee meetings will be held on Monday 8:00AM – 12:00PM (ANB10), Tuesday 1:30PM – 5:30PM (ANB20), Wednesday 1:30PM – 5:30PM (ANB25), and Thursday 8:00AM – 12:00PM (ANB25).

Thirty-one papers sponsored by ANB10 are identified. They will be presented in the following sessions:

- Twenty in the poster session 426 (Monday, 4:15PM- 6:00PM);
- Six in the poster session 567 (Tuesday, 10:45AM- 12:30PM); and
- Five in the lectern session 699 (Tuesday, 7:30PM- 9:30PM).

[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.

Sixty-six papers sponsored by ANB20 are identified. They will be presented in the following sessions:

- Five in the lectern session 224 (Monday, 8:00AM – 9:45AM);
- Twenty-three in the poster session 562 (Tuesday, 10:45AM – 12:30PM);
- Eight in the poster session 762 (Wednesday, 8:30AM – 10:15AM); and
- Thirty in the poster session 767 (Wednesday, 8:30AM – 10:15AM).

Twenty papers sponsored by ANB25 are identified. They will be presented in the following sessions:

- Nineteen in the poster session 368 (Monday, 2:00PM – 3:45PM); and
- One in the lectern session 788 (Wednesday, 10:15AM – 12:00PM).

There are five presentation-only sessions and one poster session with no paper available. These are sessions 437 “Case Studies in Performance-Based Analysis of Geometric Design”, 455 “To the Future! Emerging Methods in Road Safety Analysis”, 487 “Rural Road Safety Research and Practical Applications”, 535 “International Benchmarking on Road Safety”, 733 “Legal and Policy Implications of Using Quantitative Safety Analysis” and 740 “Toward Zero Deaths: International and U.S. Effort at Saving Lives”.

The papers address the following topics (some papers were 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;
g) Applications of the Highway Safety Manual; and
h) Transportation Safety Management.

Table 1 ANB 10, ANB20, and ANB25 Committee and Subcommittee Meetings

Time	Title	Location
Monday, 8:00AM – 12:00PM	Transportation Safety Management Committee	Marriott, Balcony A
Monday, 10:15AM – 1:00PM	Traffic Speed and Safety - Cross-cutting Issues Joint Subcommittee of ANB20, AHB65, ANB10	Marriott, Taft
Monday, 1:30AM – 3:15PM	Surrogate Measures of Safety Subcommittee, ANB20(3)	Marriott, Park Tower Suite 8206
Monday, 3:45AM – 5:30PM	Future Directions in Safety Analysis Joint Subcommittee of ANB20, ANB25	Marriott, Park Tower Suite 8206
Tuesday, 8:00AM – 9:45AM	School Transportation Subcommittee, ANB10(6)	Marriott, Park Tower Suite 8206
Tuesday, 1:30PM- 5:30PM	Safety Data, Analysis and Evaluation Committee	Marriott, Washington B1
Tuesday, 1:30PM – 3:15PM	Transportation Safety Planning Subcommittee, ANB10(3)	Marriott, Park Tower Suite 8216
Tuesday, 3:45PM – 5:30PM	Rural Road Safety Policy, Programming, and Implementation Joint Subcommittee of ANB10, AFB30	Marriott, Truman
Tuesday, 7:30PM- 9:30PM	Bicycle and Pedestrian Crash Relationships Joint Subcommittee of ANB20, ANF10, ANF20	Marriott, Truman
Wednesday, 10:15AM – 12:00PM	Global Road Safety Subcommittee, ANB10(8)	Marriott, Park Tower Suite 8212
Wednesday, 1:30PM – 5:30PM	Highway Safety Performance Committee	Marriott, Washington B1
Wednesday, 2:30PM – 4:00PM	Toward Zero Deaths Goal Subcommittee, ANB10(9)	Marriott, Park Tower Suite 8212
Wednesday, 6:15PM – 7:15PM	Policy and Legal Aspects Subcommittee, ANB25(1)	Marriott, Wilson A
Wednesday, 6:30PM – 8:30PM	Predictive Methods Subcommittee, ANB25(2)	Marriott, Harding
Wednesday, 7:00PM – 9:00PM	User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marriott, Virginia C
Wednesday, 7:30PM – 9:30PM	Conferences and Meetings Subcommittee, ANB25(4)	Marriott, Wilson A
Wednesday, 7:30PM – 9:30PM	Crash Modification Factors Subcommittee, ANB25(6)	Marriott, Coolidge
Wednesday, 7:30PM – 9:30PM	Highway Safety Management Subcommittee, ANB25(7)	Marriott, Hoover
Wednesday, 7:30PM – 9:30PM	International Research Subcommittee, ANB25(5)	Marriott, Madison A
Thursday, 8:00AM – 12:00PM	Highway Safety Performance Committee	Marriott, Wilson B & C
Thursday, 8:00AM – 12:00PM	Emergency Medical Services Safety Subcommittee, ANB10(5)	Keck, Room 103

Table 2 ANB 10, ANB20, and ANB25 Workshops

Time	Title	Location
Sunday, 9:00AM - 12:30PM	(111) Preserving the Lost Art of Geometric Design: Tools, Techniques, and Talent – Where We Have Been and Where We Are Going in Design Decision Making, ADD30, AFB10, AFB40, AFB50T, AHB40, AHB65, ANB25	Marriott, Virginia B
Sunday, 9:00AM - 5:00PM	(155B) HF-B Human Factors Issues for Safety of Emergency Responder Vehicles, ANB10, ANB10(5)	Ticket Required
Sunday, 1:30PM – 4:30PM	(158) Applications of the Systemic Approach to Safety, AFB30, ANB10, ANB10(7)	Marriott, Virginia C
Sunday, 1:30PM- 4:30PM	(162) Comparison of Surrogate Measures of Safety Extracted from Video Data, ABJ70, ANB20	Marriott, Madison A
Sunday, 1:30PM- 4:30PM	(194) Bike, Pedestrian, and Motorized Local Traffic Counting on All Roads, ABJ20, ABJ35, ANB20, ANF10, ANF20	Hilton, Jefferson East
Thursday, 8:00AM - 12:00PM	(869) Pedestrian Safety Across the Five Pillars of the United Nations Decade of Action, ANB10, ANB10(8)	Marriott, Maryland B

Table 3 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(224) Safety Data, Analysis, and Evaluation, ANB20	Marriott, Maryland C
Monday, 7:30PM – 9 :30PM	(455) To the Future! Emerging Methods in Road Safety Analysis, ANB20, ANB25	Marriott, Maryland B
Tuesday, 8:00AM – 9:45AM	(487) Rural Road Safety Research and Practical Applications Sponsors: AFB30, ANB20, ANB10(7)	Marriott, Maryland B
Tuesday, 10:15AM – 12:00PM	(535) International Benchmarking on Road Safety, ANB10, ANB10(8)	Marriott, Maryland B
Tuesday, 7:30PM – 9:30PM	(699) Data-Driven Decision Making in Highway Safety Management, ANB10	Marriott, Maryland C
Wednesday, 8:00AM – 9:45AM	(733) Legal and Policy Implications of Using Quantitative Safety Analysis, AL070, ANB10	Marriott, Maryland B
Wednesday, 8:00AM – 9:45AM	(740) Toward Zero Deaths: International and U.S. Effort at Saving Lives, ANB10	Marriott, Maryland C
Wednesday 10:15AM – 12:00PM	(788) Saving the World: Overview of Road Safety Initiatives Around the Globe, ANB20, ANB25	Marriott, Maryland B

Table 4 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 2:00PM – 3:45PM	(368) Highway Safety Performance, ANB25	Marriott, Salon 2
Monday, 4:15PM – 6:00PM	(426) Transportation Safety Management, ANB10	Marriott, Salon 2
Monday, 7:30PM – 9:30PM	(437) Case Studies in Performance-Based Analysis of Geometric Design, AHB65, ANB25	Marriott, Salon 2
Tuesday, 10:45AM – 12:30PM	(567) School Transportation Research, ANB10, ANB10(6)	Marriott, Salon 2
Wednesday, 8:30AM – 10:15AM	(762) Crash Severity Analysis, ANB20	Marriott, Salon 2
Wednesday, 8:30AM – 10:15AM	(767) Safety Data and Methods Madness, ANB20	Marriott, Salon 2

2 Crash Data and Data Analysis

The Subcommittee identified several papers related to the safety data collection, mining, mapping, merging, and special data issues.

Development of databases and crash data mapping are investigated by Wu et al. (14-3047), Burns et al. (14-4605), Lu et al. (14-5311), Imprialou et al. (14-3868), and Zheng et al. (14-3971). Video datasets and tools for automated analysis to be used in road safety research are proposed by Saunier et al. (14-2379).

Different methods of crash risk assessment are proposed: Severity-Based Hierarchical Bayesian Model (Demiroluk and Ozbay, 14-5127), Ensemble Empirical Mode Decomposition (Kim et al., 14-2119), and Lognormal Hurdle Model with Flexible Scale Parameter (Ma, 14-3703).

Das and Sun (14-1540), Deka and Quddus (14-3971), Deogratias et al. (14-5668), Lin et al. (14-4172), and Lopez et al. (14-0086) present different uses of Data Mining techiniques to analyze crash data and extract useful information. Other methods used for crash data analysis include: Multiple Correspondance (Das and Sun, 14-2411), Full Bayesian Multivariate Models (El-Basyouny et al., 14-2133), GIS-Based Community-Level (Ouyang and Bejleri, 14-5554), Generalized Waring distribution (Peng et al., 14-1352), and Kernel Regression (Thakali et al., 14-3064).

Chen and Tjandra (14-1135) use Seasonal Autoregressive Integrated Moving Average model with External Regressors for short-term crash prediction. Harootunian et al. (14-0715) explore the vulnerabilities of foreign drivers. Chang et al. evaluate the effectiveness of LiDAR data (14-0256). Yang et al. offer an article related to intersection data collection (14-4212). Linking police and hospital data is investigated by Amorim et al. (14-0455) and Flannagan et al. (14-5195). Dixit and Rashidi offer insights about “Carshare” users crash data (14-4221) and Abay investigates biases in crash data (14-1985).

Authors	Kibrom Araya Abay, University of Copenhagen, Denmark
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-1985
Paper Title	Investigating Nature and Impact of Reporting Bias in Road Crash Data
Abstract	This paper investigates the nature and impact of the reporting bias associated with the police-reported crash data on inferences made using this data. In doing so, we merge a detailed emergency room data and the commonly employed police-reported crash data for a specific region in Denmark. To disentangle potentially common observable and unobservable factors that affect drivers' injury severity risk and their crash reporting behavior, we formulate a bivariate ordered-response probit model of injury severity risk and crash reporting propensity. The empirical analysis confirms the existence of substantial reporting bias in the police-reported road crash data. This non-random sample selection associated with the police-reported crash data leads to biased estimates on the effect of some of the explanatory variables in injury severity analysis. For instance, estimates based on the police-reported crash data substantially underestimate the effectiveness of seat belt use in reducing drivers' injury severity risk.
Authors	Marco Amorim, University of Porto, Portugal Sara Pinho Ferreira, University of Porto, Portugal António Fidalgo Couto, University of Porto, Portugal
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	224
Session Title	Safety Data, Analysis, and Evaluation
Paper Number	14-0455
Paper Title	Linking Police and Hospital Road Accident Records: How Consistent Can It Be?
Abstract	This paper presents the description of various steps to be applied in the linkage of road traffic accident records using the case study of the city of Porto, Portugal. The importance of this process is well recognized by institutions such as IRTAD (OECD/ITF) that are promoting the combination of various data sources to fully assess the consequences of road accidents and monitoring progress. The complexity of this process is mainly concerned with several issues found in the data sets; mistakes and missing values are frequently detected and there are only a few common data fields that can be matched by the linkage process. This study shows the application of a mixed deterministic and weight-based probabilistic method to link the police and hospital records. The tolerance calibration and weights computation are critical for the final linkage rate, as well as for the correct matching of the results. The results obtained lie within the range of rates found by other authors. Additionally, to improve the linkage record results, a validation process based on the emergency ambulance data is performed. Despite the missing values, it was possible to check 98% of the matched records as true matches. Finally, a preliminary investigation of bias after data linkage is described, showing that the variables selected for comparison indicate similar statistical values. The main outcome of this study is a road accident linkage process that can be adapted, developed and applied in different contexts, aiming to promote future developments on police, hospital and emergency ambulance data in Portugal and in other countries. Future developments are being planned for each one of the steps present in this paper.
Authors	Shaun Burns, McGill University, Canada Luis Fernando Miranda-Moreno, McGill University, Canada Joshua Stipancic, McGill University, Canada Nicolas Saunier, Polytechnique Montreal, Canada Karim Ismail, Carleton University, Canada
Sponsoring Committee	ABJ60
Session Number	353
Session Title	Advances in Geospatial Technology Applications in Transportation
Paper Number	14-4605
Paper Title	Accessible and Practical Geocoding Method for Traffic Collision Record Mapping: Quebec Case Study
Abstract	There have been numerous studies of geocoding systems used to assign geographical coordinates to incident reports identified simply with textual address references. These studies have typically focused on the level of accuracy achieved by various geocoding systems, and have found that acceptable results can be achieved. Depending on the quality of the input data, a match rate between 70% and 83% can be expected, with varying levels of accuracy. However, few studies have looked at the potential of freely available online geocoding services to spatially locate traffic accident records. It is proposed that although limitations currently exist, services such as the Google Maps API provide sufficient functionality and adequate accuracy for use among a wide variety of geocoding applications.

A case study using traffic accident records from a municipality in the Province of Quebec is presented, with the goal of quantifying the geocoding results. It was found that although a competitive match rate is obtained, manual revision is required to ensure that the results returned by the geocoder refer to the same intersection that exists in the input address field.

Authors	Jeffrey C. Chang, North Carolina State University, Raleigh Daniel J. Findley, North Carolina State University, Raleigh Christopher M. Cunningham, North Carolina State University, Raleigh Mary Kaitlyn Tsai, North Carolina State University, Raleigh
Sponsoring Committee	AHD10, Maintenance and Operations Management
Session Number	267
Session Title	Data Collection and Analysis Methodologies in Support of Maintenance Programming Decisions
Paper Number	14-0256
Paper Title	Considerations for Effective LiDAR Deployment by Transportation Agencies
Abstract	Light Detection and Ranging (LiDAR) is becoming increasingly popular across the United States, and state transportation agencies are adopting practical use of the technology for transportation related applications. This is quite evident by the growing number of agencies acquiring LiDAR scanners and contracting LiDAR services. The primary factors behind this trend are that (1) surveyors, engineers, and technicians are becoming more educated and increasingly open to LiDAR and its applications, and (2) LiDAR is potentially more cost-effective than traditional surveying technologies. LiDAR can provide transportation agencies with the benefits of safety, data collection productivity, cost effectiveness, applicability, high levels of detail, and technologic advancement. Many of the more practical uses and benefits of LiDAR have come to fruition in recent years, and transportation agencies have been more open to its utilization. However, there is little more than anecdotal evidence to support when a specific LiDAR platform should be applied verses a traditional surveying method under various applications. Decision makers within geomatic and surveying departments who use LiDAR must regularly weigh the options of which surveying method to utilize for specific projects and base decisions on performance tradeoffs. The methodology presented in this paper aims to provide guidance on how agencies may determine whether or not LiDAR can be practically utilized within their organizations. It is recommended that interested parties systematically consider the aspects and performance measures outlined for effective deployment of LiDAR equipment or contracted services.

Authors	Subasish Das, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-1540
Paper Title	Investigating the Pattern of Traffic Crashes Under Rainy Weather by Association Rules in Data Mining
Abstract	Rainy weather and wet roads are considered hazardous conditions for driving. Countermeasures should be taken to reduce the risks of driving in such conditions, but measuring the added risk and key crash contributing factors under such conditions is very challenging. With a humid subtropical climate, the annual precipitation in Louisiana is about 64 inches, twice above the national average. Approximately 11% of total crashes in Louisiana happened during rainy weather, and nearly 25% of total fatal crashes happen in rainy weather annually. Reducing the number of crashes and crash severity is critical to the state “Zero Deaths Destination” highway safety strategies. The data mining technique is becoming immensely popular in dealing with huge dataset. It helps to identify the hidden patterns from a large and complex database, which is why these methods are being utilized in diversified areas. There are many data mining techniques that have been applied to traffic crash data analysis in the recent past. However, very little research work utilizes the association rules mining technique to discover knowledge from the traffic crash dataset. This data mining technique generates simple rules that indicate which crash characteristics are associated with each other. This paper demonstrates how to apply this data mining methods to discover crash patterns during rainy weather with eight years of Louisiana crash data (2004-2011). Being a non-parametric method, no dependent variable is developed in this application contrary to many popular safety performance models. The data mining results generate important crash patterns, which demonstrate the most significant crash type as ‘single vehicle run-off crashes’. This crash type is predominant during rainy weather and is particularly associated with a few roadway features like on grade-curve aligned roadways, curved roadways, and roadways with no streetlights at night. In rainy weather, Property Damage Only (PDO) and sideswipe (same direction) crashes are also significant in numbers. Moderate injuries are dominant in single vehicle crashes. Roadways with poor illumination are associated with straight level aligned roadways in rainy weather crashes. Young drivers (15-24) are vulnerable in run-off crashes when the roadways had poor illumination and are curve-aligned. Based on the results, the paper also

gives recommendations for future research.

Authors	Subasish Das, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-2411
Paper Title	Exploring Clusters of Contributing Factors for Single-Vehicle Fatal Crashes Through Multiple Correspondence Analysis
Abstract	Approximately 60% of roadway fatalities in Louisiana involve single vehicle crashes. In 2012, 384 out of a total of 652 fatal crashes in Louisiana were single vehicle crashes. In order to reduce the number of these crashes through effective crash countermeasures, safety policies, regulations and technological advancements, it is critical that causation factors of single vehicle Run-Off-Road (ROR) crashes are identified. The persistently high rate of ROR crashes in Louisiana, as well as the overall United States, calls for innovative research that can further benefit the on-going research in assessing the performance of roads, vehicles and humans. A single vehicle crash can be caused by various factors such as those related to roadway design, vehicle mechanical problems and, most importantly, the driver performance or behavior. More often than not, it is the combination of these factors that leads to a single vehicle crash being fatal. The current commonly used crash analysis methods lack the ability to identify the cluster of factors simultaneously. The Multiple Correspondence Analysis (MCA) method is an exploratory data analysis method that can visualize the patterns of the cluster consisting of crash contributing factors. This paper uses the MCA method to analyze eight years (2004-2011) of single vehicle fatal crashes in Louisiana in order to identify the important contributing factors and their degree of association with the crashes. The results reveal that the combination of impaired driving, particularly on undivided roadways with no streetlights at night, is most likely responsible for run-off fatal crashes. Other combinations resulting in ROR fatal crashes include: young males driving on a wet surface during the weekend, older female drivers (64 plus in age) on hilly terrain, distracted motorcycle drivers, and female drivers age 35-44 using cell phones while driving. The results of the MCA can guide the selection of crash countermeasures. The future work on the degree of association of the identified crash contributing factors can help safety management systems select the most effective and efficient crash reduction strategies.

Authors	Lipika Deka, Loughborough University, United Kingdom Mohammed A. Quddus, Loughborough University, United Kingdom
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	224
Session Title	Safety Data, Analysis, and Evaluation
Paper Number	14-3971
Paper Title	Network-Level Accident Mapping: Distance-Based Pattern Matching Using Artificial Neural Network
Abstract	The objective of an accident-mapping algorithm is to snap traffic accidents onto the correct road segments. Assigning accidents onto the correct segments facilitate to robustly carry out some key analyses in accident research including the identification of accident hot-spots, network-level risk mapping and segment-level accident risk modelling. Existing risk mapping algorithms have some severe limitations: (i) they are not easily 'transferable' as the algorithms are specific to given accident datasets; (ii) they do not perform well in all road-network environments such as in areas of dense road network; and (iii) the methods used do not perform well in addressing inaccuracies inherent in and type of road environment. The purpose of this paper is to develop a new accident mapping algorithm based on the common variables observed in most accident databases (e.g. road name and type, direction of vehicle movement before the accident and recorded accident location). The challenges here are to: (i) develop a method that takes into account uncertainties inherent to the recorded traffic accident data and the underlying digital road network data, (ii) accurately determine the type and proportion of inaccuracies, and (iii) develop a robust algorithm that can be adapted for any accident set and road network of varying complexity. In order to overcome these challenges, a distance based pattern-matching approach is used to identify the correct road segment. This is based on vectors containing feature values that are common in the accident data and the network data. Since each feature does not contribute equally towards the identification of the correct road segments, an ANN approach using the single-layer perceptron is used to assist "learn" the relative importance of each feature in the distance calculation and hence the correct link identification. The performance of the developed algorithm was evaluated based on a reference accident dataset from the UK confirming that the accuracy is much better than other methods.

Authors	Sami Demiroluk, Rutgers University

	Kaan Ozbay, Rutgers University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-5127
Paper Title	Spatial Analysis of County-Level Crash Risk in New Jersey Using Severity-Based Hierarchical Bayesian Models
Abstract	This study presents an innovative hierarchical Bayesian model for spatial modeling of county level crashes in New Jersey. First, the model is estimated using raw crash counts. Then, weights are applied to crashes with different severities to obtain a weighted crash count. The goal in incorporating severities in the spatial model is to demonstrate the importance of representing spatial variation of crashes as well as their severity. As a contribution to existing literature, crash rates are also analyzed by road type. Finally, crash rate maps are developed based on modeling results to visualize the effects of spatial covariates. The results of the study indicate that the most influential covariate for the crashes is the road curvature, followed by roadway mileage and roadway defects. It is also found that it is possible to represent the crash risk better by applying severity weights to the individual crashes. The developed crash rate maps can help transportation professionals on identifying and ranking the locations at an aggregate level, which requires closer attention.

Authors	Vinayak V. Dixit, University of New South Wales, Australia Taha Hossein Rashidi, University of New South Wales, Australia
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-4221
Paper Title	Modeling Crash Propensity of Carshare Users
Abstract	Carshare systems are seen as an appropriate solution for sustainable development in the future. To promote carsharing it is imperative to make it cost effective, which includes reduction in costs associated to crashes and insurance. To achieve this goal, it is important to characterize carshare users involved in crashes and understand factors that can explain at-fault and not-at fault drivers. This study utilizes data from GoGet carshare users in Sydney, Australia. Based on this study it was found that driving experience, higher insurance excess, needing car on weekends, owning a car reduced the likelihood of being in crash and being at fault. Further, the likelihood of not being at-fault reduced with higher insurance excess, not having previous instance of traffic offences, preference for luxurious cars and living near a dedicated parking. Marginal reduction in the propensity of being not-at-fault was also observed due to having a driver's license from a country having a left hand drive, similar to that in Australia. The analysis of not-at-fault drivers also provides insights for quasi-induced exposure methods, suggesting that when applying quasi-induced exposure methods it is critical to control for insurance type, previous instance of traffic offences, vehicle type and what type of license the individual has. Finally, based on this study it is recommended that having higher insurance excess on risky drivers and also providing some incentives based on training and experience (based on kilometres driven), possibly on insurance excess could improve safety and reduce costs associated to crashes for carshare systems.

Authors	Deogratias Eustace, University of Dayton Omar Eid Almutairi, University of Dayton Peter Hovey, University of Dayton Gary Eugene Shoup, Montgomery County Engineers Office
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-5668
Paper Title	Using Decision Tree Modeling to Analyze Factors Contributing to Injury and Fatality of Run-Off-Road Crashes in Ohio
Abstract	The main objective of this study was to determine the factors that contribute significantly to the levels of injury severity when run-off-road (ROR) crashes occur. This study used a 5-year crash data for years 2008 - 2012 from the state of Ohio. The decision tree model in conjunction with generalized ordered logit model was used to investigate characteristics of injury and fatality of run-off-road crashes in Ohio. The decision tree modeling was used for exploratory data analysis identified eight factors that explain a large amount of the variation in the response variable, injury severity. These predictor variables include road condition, ROR crash types, posted speed limit, vehicle type, gender, alcohol-related, road contour, and drug-related. Also, complex interactions between parameters were identified. The results from the generalized ordered logit regression show that the following are

significant factors in increasing the likelihood of ROR injury severity levels: alcohol and drugs use, curves and grades, female victims, overturn/rollover crashes, ROR crashes on dry roadway surfaces. Additionally, buses, truck, and emergency vehicles, and ROR crashes on roadways with posted speed limits of 40 mph or higher increase the probability of injury severity.

Authors Carol A. Flannagan, University of Michigan
Michael Elliott, University of Michigan
Clay Mann, University of Utah
Jonathon Rupp, University of Michigan

Sponsoring Committee ANB20, Safety Data, Analysis, and Evaluation
Session Number 762
Session Title Crash Severity Analysis
Paper Number 14-5195
Paper Title Sampling Serious Injuries in Traffic Crashes at the State Level

The Moving Ahead for Progress in the 21st Century Act, known as MAP-21, requires a new emphasis on measurement and prevention of serious injuries in crashes. Current practice in states that measure serious injuries is to use a police-reported injury severity of "A," or "Suspected Serious Injury," on the KABCO scale to define serious injury. However, serious injury is more appropriately defined in terms of medical diagnosis using, for example, a Maximum Abbreviated Injury Scale score of 3 or greater (MAIS 3+). The biggest challenge to using MAIS 3+ as the definition of serious injury is that medical outcome data are typically not part of a state crash dataset. The most comprehensive solution is to link state crash databases with state trauma registries or state hospital discharge datasets. This is being done in some states and others are working towards that goal. However, for most states, data linkage is still many years away. This paper discusses sampling of medical records as an interim solution that can be implemented in a short time frame. Sampling approaches are discussed and a stratified sampling approach is recommended. Stratified sampling involves defining a set of mutually exclusive and exhaustive categories, or strata, and sampling from these at different rates. Optimal allocation of a sample provides a framework for determining the proportion of cases to sample from each stratum, and the desired precision of the estimate as well as cost per sample determine how many cases should be sampled in total. A specific sampling plan for a given state requires decisions to be made by involved agencies, so it cannot be developed in a paper. However, we present a roadmap for defining a stratified sampling plan, accompanied by an example using crash data from Michigan. Sampling as an interim solution has several advantages. First, sampling promotes comparability because it allows measurement of serious injury in the near term to be comparable across states that are using different methods. Second, sampling promotes further progress towards direct linkage of state crash and medical outcome databases. Many of the hurdles to setting up a sampling plan, such as implementing data use agreements and privacy protection, must also be overcome to set up data linkages. Finally, sampling is scalable. A sample can be scaled up or down based on available resources. The logistical challenges and costs of sampling are also discussed in the paper. Although sampling is not free, it represents an important way to move ahead with the necessary step of enabling measurement of serious injuries using a diagnosis-based definition.

Authors Lei Lin, State University of New York, Buffalo
Qian Wang, State University of New York, Buffalo
Adel W. Sadek, State University of New York, Buffalo

Sponsoring Committee ABJ80, Statistical Methods
Session Number 811
Session Title Analytical Models for Safe and Sustainable Transport
Paper Number 14-4172
Paper Title Data Mining and Complex Network Algorithms for Traffic Accident Analysis

Abstract The field of traffic accident analysis has long been dominated by traditional statistical analysis. With the recent advances in data collection, storage and archival methods, the size of accident datasets has grown significantly. This in turn has motivated research on applying data mining and complex network analysis algorithms, which are specifically designed to handle datasets with large dimensions, to traffic accident analysis. This paper explores the potential for using two such methods, namely a modularity-optimizing community detection algorithm and association rules learning algorithm, to identify important accident characteristics. As a case study, the algorithms are applied to an accident dataset compiled for Interstate 190 in the Buffalo-Niagara metropolitan area. Specifically, the community detection algorithm is used first to cluster the data in order to reduce the inherent heterogeneity, and then the association rule learning algorithm is applied to each cluster to discern meaningful patterns within each, particularly related to high accident frequency locations (hotspots) and incident clearance time. To demonstrate the benefits of clustering, the association rule algorithm is also applied to the whole dataset (before clustering) and the results are compared to those discovered

from the clusters. The study results indicate that: (1) the community detection algorithm was quite effective in identifying clusters with discernible characteristics; (2) clustering helped in unveiling relationships and accident causative factors that remained hidden when the analysis was performed on the whole dataset; and (3) the association rule learning algorithm yielded useful insight into accident hotspots and incident clearance time along I-190. Key Words: Data mining, complex network analysis, accident hotspots, incident clearance time, association rules, community detection.

Authors Qianwen Lu, University of Wisconsin, Madison
Steven Parker, University of Wisconsin, Madison
Scott Janowiak, University of Wisconsin, Madison
Susie Forde, Wisconsin Department of Transportation
Bin Ran, University of Wisconsin, Madison
David A. Noyce, University of Wisconsin, Madison

Sponsoring Committee ABJ60
Session Number Advances in Geospatial Technology Applications in Transportation
Session Title 353
Paper Number 14-5311
Paper Title Wisconsin High-Risk Rural Road GIS Data Integration and Risk Factor Analysis

Abstract In order to address emerging federal reporting requirements, along with the need to more efficiently manage limited safety improvement resources, DOTs are continuing to expand capabilities for data driven approaches to supporting operations and planning decisions. A key component of this approach is the use of enterprise-wide Linear Referencing Systems (LRS) to integrate multiple data sources such as crashes, traffic volumes, and roadway inventory information. Within this context, the Wisconsin DOT (WisDOT) has recently completed a GIS-based crash map that was subsequently leveraged to develop an automated approach to identifying a statewide list of high risk rural roads (HRRR) for potential Highway Safety Improvement Program (HSIP) projects. This paper describes the integration process and ranking methodology that were developed to generate the Wisconsin statewide HRRR list. The ranking process leveraged the Wisconsin Information System for Local Roads (WISLR) LRS along with the mapped crash and traffic volume data to compute corridor crash rates. Different ranking criteria were applied to produce a final "filtered K-A crash rate" ranking method. GIS maps and crash data details were provided for the top ten corridors as a basis to investigate potential HSIP projects. In addition to identifying specific high risk corridors, however, the automated approach and statewide list provides an opportunity to conduct systematic, aggregated analysis of the corridor rankings to identify HRRR risk factors. As a second component of this research, results are presented from an analysis of the 2012 HRRR list for a selected set of crash data attributes.

Authors Maria-Ioanna Imprialou, Loughborough University, United Kingdom
Mohammed A. Quddus, Loughborough University, United Kingdom
David Pitfield, Loughborough University, United Kingdom
Liang Li, Loughborough University, United Kingdom

Sponsoring Committee ANB20, Safety Data, Analysis, and Evaluation
Session Number 767
Session Title Safety Data and Methods Madness
Paper Number 14-3868
Paper Title High-Accuracy Generic Method for Automatic Crash Mapping Using Fuzzy Logic

Abstract Accurate crash location data in crash databases can be shown to be essential for crash modelling, crash mapping, hazardous road segment identification and other studies that aim to decrease the number of crashes within a network area. In this paper a generic and high accuracy automatic crash mapping method is developed and presented. The methodology is based on a transformed map-matching method for candidate road link identification and on a fuzzy logic inference system for the final road link selection. The method is implemented by employing all injury and fatal crashes that occurred during 2012 in the UK Strategic Road Network but can be transferable to other network/crash data. The accuracy of the developed method is estimated to be 98.3% (±1.25%) correct matches. The results of this method are compared to other less advanced crash mapping methods.

Authors Nicolas Saunier, Polytechnique Montreal, Canada
Hakan Ardo, Lund University, Sweden
Jean-Philippe Jodoin, Polytechnique Montreal, Canada
Aliaksei Laureshyn, Lund Institute of Technology, Sweden
Mikael Nilsson, Lund University, Sweden
Ase Svensson, Lund University, Sweden
Luis Fernando Miranda-Moreno, McGill University, Canada
Guillaume-Alexandre Bilodeau, Polytechnique Montreal, Canada

	Kalle Astrom, Lund University, Sweden
Sponsoring Committee	ABJ50, Information Systems and Technology
Session Number	527
Session Title	Emerging Information Technology Advances in Transportation
Paper Number	14-2379
Paper Title	Public Video Data Set for Road Transportation Applications
Abstract	Video data and the tools for automated analysis have a great potential to be used in road traffic research, particularly road safety. In this project a video dataset is built and made public so that researchers can evaluate their algorithms on it. The dataset focuses on the traffic research applications (data from real research projects) and provides recordings of the traffic scenes, meta-data, camera calibration, ground truth, protocols for comparing algorithms and software tools and libraries for reading/presenting the data. To the authors' knowledge, this public dataset is the first of its kind. With the proposed dataset, researchers get access to a large variety of recordings representing different traffic, weather and lighting conditions to evaluate and compare different tools and applications. As a consequence, discussions between computer vision and transportation researchers are expected to increase, contributing to more collaborations and better tools, more accurate and user-friendly, to obtain automatically rich traffic data from video.

Authors	Yichuan Peng, Texas A&M University Dominique Lord, Texas A&M University Yajie Zou, University of Washington
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	370
Session Title	Research in Statistical Methods in Transportation
Paper Number	14-1352
Paper Title	Applying the Generalized Waring Model for Investigating Sources of Variance in Motor Vélib' Bikesharing System Vehicle Crash Analysis
Abstract	As one of the major analysis methods, statistical models play an important role in traffic safety analysis. They can be used for a wide variety of purposes, including establishing relationships between variables and understanding the characteristics of a system. The purpose of this paper is to document a new type of model that can help with the latter. This model is based on the Generalized Waring (GW) distribution. The GW model yields more information about the sources of the variance observed in datasets than other traditional models, such as the negative binomial (NB) model. In this regards, the GW model allows the observed variability to be split into three components: 1) the randomness, which explains the model's uncertainty; 2) the proneness, which refers to the internal differences between entities or observations; and, 3) the liability, which is defined as the presence of other external factors that have not been included as covariates in the model. The study analyses were accomplished using simulated and observed data to explore potential sources of variation. The results show that the GW model can provide useful information about sources of variances in crash data and also performs better than the NB model.

Authors	Kristine Harootunian, University of Vermont Brian H. Y. Lee, Vermont University Lisa Aultman-Hall, University of Vermont
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-0715
Paper Title	Odds of Fault for Out-of-State Drivers in Crashes in Four U.S. States
Abstract	Drivers outside their country of residents are at a safety disadvantage when compared to native counterparts. This research aimed to identify if out-of-state drivers in the United States experienced the same vulnerabilities as foreign drivers using crash data from Florida, Maine, Minnesota, and Nevada to model fault using logistic regressions. Univariate regressions showed that out-of-state drivers had increased odds of fault, ranging from 17% to 92%, for a single-vehicle crash compared to in-state drivers in all states except Florida, where there was no difference between groups. Odds were elevated for out-of-state drivers in two-vehicle crashes by 3% to 19% in all states except Florida and Minnesota, where, again, there was no difference between groups. Factors such as age, sex, driving conditions, and seasons were tested with multivariate regressions for in- and out-of-state groups separately and their odds ratios were compared. For single-vehicle crashes age, sex, road grade, surface condition, light conditions, and day of week were factors that increased at least one of the two groups' odds of fault in all states, while sex, surface condition, and light conditions increased the odds of fault for at least one of the groups in two-vehicle crashes in all four states. Factors that consistently increased odds of fault for both single- and two-vehicle crashes were males, non-vehicle

owners, curves, and during inclement weather. Although there were several factors in each state that increased odds of fault for out-of-state drivers, no factors consistently increased odds of fault for out-of-state drivers across all four states.

Authors	Lu Ma, Beijing Jiaotong University, China
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-3703
Paper Title	Traffic Accident Risk Estimation Based on Lognormal Hurdle Model with Flexible Scale Parameter
Abstract	Comprehensive measures of accident risks are critical for the risk assessment of specific transportation facilities during a safety planning process. Different with the frequently used accident rate, this study introduces a criterion that integrates both information of accident occurrence and more importantly the overall harmfulness resulted from accidents. It also forms a general definition of accident risks, which provides a single value to comprehensively capture the losses brought by accidents. In order to understand the distributional characteristics of the introduced risk measures as well as construct its relationship with factors, a hurdle model with lognormal specifications is suggested for regression purposes. An observed dataset is adopted in this study for application of the proposed model which in fact provides preponderance of regression on both location and scale parameters for the right-hurdle part, whereas the traditional lognormal analysis assumes constant scale parameters across all observations. Based on the regression results, the impacts of explanatory variables on the accident risks are also examined in this study.

Authors	Griselda Lòpez Maldonado, University of Granada, Spain Joaquin Abellan, Universtiy of Granada Alfonso Montella, University of Naples Federico II, Italy Juan de Ona, University of Granada, Spain
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-0086
Paper Title	Patterns of Single-Vehicle Crashes on Two-Lane Rural Highways in Granada Province: In-Depth Analysis Through Decision Rules
Abstract	In Spain, 74% of injury crashes occur on rural two-lane highways. Hence, one of the strategic priorities set out in the highway safety plans is the specific study of these highways. This paper aims to investigate crash patterns and crash contributory factors on rural two-lane highways in order to propose specific road safety countermeasures. Analysis method consists in identifying Decision Rules extracted from Decision Trees (DTs). As the traditional method of rule extraction is limited by the DT's structure, some important relationships between variables may not be identified. To overcome this problem, an in-depth method for extracting rules from DTs has been used. Since the implementation of any corrective road safety measure is constrained by the available resources, we must extract the strongest patterns that describe the road safety issue. In order to identify the strongest rules, a new criterion, named Lift Increase Criterion, has been defined. Single-vehicle crashes on two-lane rural highways in the province of Granada (Spain) have been analyzed. Crash data are relative to the 7-year period 2003 to 2009. Rules have been obtained using both the Gain Information and the Info Gain Ratio as splitting criterion. Since the rules obtained by application of both criteria are consistent and complementary, it is recommended to use both methods to build decision trees. Results of the study have highlighted several patterns contributing to severe crashes and potentially effective countermeasures. Main patterns are pedestrian crashes, run-off-the-road crashes, run-off-the-road crashes involving powered-two-wheelers, crashes involving powered-two-wheelers, and crashes in night-time without illumination.

Authors	Yongsheng Chen, City of Edmonton, Canada Stevanus Tjandra, City of Edmonton, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-1135
Paper Title	Daily Collision Prediction by SARIMAX and GLM Models Based on Temporal and Weather Variables
Abstract	Short-term collision prediction is a relatively new area of research in the field of traffic safety due to the high randomness of data and the methodological complexity. Motivated by requirements from frontline traffic operations and enforcement services, this study was conducted to develop models to predict daily total collisions. The study started with a time series data decomposition analysis to

determine trends, seasonality, and randomness of the daily collisions before proceeding with an investigation of potential collision contributors. Temporal factors (i.e., months, weekdays and holidays) and weather forecasts (i.e., daily mean temperature, amount of rainfall and amount of snowfall) were selected as predictive factors. Accordingly, the Seasonal Autoregressive Integrated Moving Average model with External Regressors (SARIMAX) was identified and a series of SARIMAX models with different orders was estimated and diagnosed. A Generalized Linear Model (GLM) was also developed and compared to the SARIMAX models by validation measures. Finally, a calibration mechanism was recommended to optimize predictions. Model validations provided evidence that both SARIMAX and GLM models are adaptable; however, the SARIMAX models are a viable and preferable option as they can gain better accuracy than GLM in terms of short-term collision prediction. In practice, the models developed in this paper are now being applied to support scheduling of traffic operations, maintenance and enforcement, dispatch of material and personnel resources, and to also provide situation awareness for all road users and stakeholders.

Authors Lalita Thakali, University of Waterloo, Canada
Liping Fu, University of Waterloo, Canada
Tao Chen, University of Waterloo, Canada
Sponsoring Committee ANB20, Safety Data, Analysis, and Evaluation
Session Number 767
Session Title Safety Data and Methods Madness
Paper Number 14-3064
Paper Title Comparison Between Parametric and Nonparametric Approaches for Road Safety Analysis: Case Study of Winter Road Safety

Abstract

In road safety research, a parametric approach is commonly applied in modeling road collisions, which have resulted in many different types of models such as Poisson, Negative Binomial and Poisson lognormal. While easy to apply and interpret, a parametric approach has several critical limitations due to the modeling requirement of assuming a specific probability distribution form for each model variable (e.g. collision frequency) and a pre-specified functional relationship between each model parameter and the predictors. These assumptions, if violated, could lead to biased and/or erroneous inferences on the effect of these predictors on the dependent variable. This paper introduces a data-driven, nonparametric alternative called Kernel regression, which circumvents the need for the aforementioned assumptions. This paper compares the parametric and nonparametric approaches through an empirical study using a large dataset consisting of hourly observations of collisions, road weather and surface conditions, and traffic counts from highways in Ontario, Canada, over six winter seasons. It is shown that the nonparametric approach has the advantage of being able to capture the significant nonlinear and interacting effects of some condition factors. The paper also illustrate the practical implications of the differences between the two approaches, including evaluation of the risk levels of road surface conditions for the road users and quantification of safety benefits of maintenance operations for transportation authorities.

Authors Karim El-Basyouny, University of Alberta, Canada
Sudip Barua, University of Alberta, Canada
Tazul Islam, University of Alberta, Canada
Sponsoring Committee ANB20, Safety Data, Analysis, and Evaluation
Session Number 767
Session Title Safety Data and Methods Madness
Paper Number 14-2133
Paper Title Full Bayesian Multivariate Models to Assess Time and Weather Effects on Crash Types

Abstract

Previous research has shown that various weather elements have significant effects on crash occurrence and risk; however, little is known about how these elements affect different crash types. Consequently, this study investigates the impact of weather elements and sudden extreme snow or rain weather changes on crash types. Multivariate models were developed for seven crash types using five years of daily weather and crash data gathered for the entire City of Edmonton. In addition, the time trend and random variation of parameters across the years was analyzed by developing four different modeling formulations. The proposed models were estimated in a Full Bayesian context via Markov Chain Monte Carlo simulation. The Multivariate Poisson Lognormal model with time varying coefficients provided the best fit for the data according to Deviance Information Criteria. Overall, results showed that temperature and snowfall were statistically significant with intuitive signs (crashes decrease with increasing temperature; crashes increase as snowfall intensity increases) for all crash types, while rainfall was mostly insignificant. Previous snow and snow on the ground showed mixed results, being statistically significant and positively related to certain crash types, while negatively related or insignificant in other cases. Major snow or rain events following a dry weather condition were highly significant and positively related to three crash types: Follow-Too-Close, Stop-

Sign-Violation, and Ran-Off-Road crashes. The day-of-week analysis showed that, when compared to Sundays, all days had significantly higher numbers of crashes for all types, except Ran-Off-Road crashes.

Authors	Nam-Seog Kim, University of California, Berkeley Koohong Chung, California Department of Transportation Seongchae Ahn, Ajou University, South Korea Jeong Whon Yu, Ajou University, South Korea Keechoo Choi, Ajou University, South Korea
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-2119
Paper Title	De-noising Traffic Collision Data Using Ensemble Empirical Mode Decomposition and Its Application for Constructing Continuous Risk Profile
Abstract	Filtering out the noise in traffic collision data is essential in reducing false positive rates (i.e., requiring safety investigation of sites where it is not needed) and can assist government agencies in better allocating limited resources. Previous studies have demonstrated that denoising traffic collision data is possible when there exists a true known high collision concentration location (HCCL) list to calibrate the parameters of a denoising method. However, such a list is often not readily available in practice. To this end, the present study introduces an innovative approach for denoising traffic collision data using the Ensemble Empirical Mode Decomposition (EEMD) method which is widely used for analyzing nonlinear and nonstationary data. The present study explains how to transform the traffic collision data before the data can be decomposed using the EEMD method to obtain set of Intrinsic Mode Functions (IMFs) and residue. The attributes of the IMFs were then carefully examined to denoise the data and to construct Continuous Risk Profiles (CRPs). The findings from comparing the resulting CRP profiles with CRPs in which the noise was filtered out with two different empirically calibrated weighted moving window lengths are also documented, and the results and recommendations for future research are discussed.

Authors	Yiqiang Ouyang, University of Florida Ilir Bejleri, University of Florida
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-5554
Paper Title	GIS-Based Community-Level Method to Evaluate Influence of Built Environment on Traffic Crashes
Abstract	Most of the current traffic crash analysis research is done either at spot level or at regional level. Less attention is placed at the community level. Additionally the effects of changes in land use, population growth, transportation networks, etc. on the community traffic safety have not been systematically studied. Although some studies have defined some variables to describe the built environment influence on traffic crashes, no research has looked at this problem using a comprehensive framework of relevant built environment variables. This study explored a GIS based community level method to understand the effects of built environment on traffic crashes. The census block-group was selected as the analysis unit for the study. The D transportation variables framework which includes dimensions of density, diversity, design, destination accessibility and distance to transit, is utilized to characterize the built environment. Most importantly, the land use mix indicator is used as part of the Design dimension. This variable is better at summarizing the land use patterns of a community compared to other variables used previously. The crash and built environment data were processed in GIS and the negative binomial model was applied. The result shows that the density has little influence on any type of crash; however the mixed land use is positively associated with all crash categories. The result also indicates that the street length and the number of segments under the Design variables resulted in positive coefficients. On the contrary, the number of intersections is negative to all crash types. Moreover, while the number of bus-stops shows a positive influence to crashes, the coefficient that designates the distance of crashes from bus stops and commercial sites is negative.

Authors	Hui Wu, University of Texas, Austin Kan Long, University of Texas, Austin Zhanmin Zhang, University of Texas, Austin Mike Murphy, University of Texas, Austin
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-3047
Paper Title	Development of Web-Based Database for Highway Safety Analysis in Texas
Abstract	Improving highway safety is one of the strategic goals for most of the state Department of Transportation. Texas Department of Transportation (TxDOT) has several well-maintained statewide databases to support transportation management and decision-making processes. While these databases collect a broad range of data, from pavement conditions, traffic information, and highway geometrics to crash records, there is not an integrated database that combines all the information needed to facilitate safety analysis and management. In this study, a framework is presented for developing a comprehensive database that can facilitate improved access and application of safety-related information for safety management at the network level. Major issues for the development of such a database, including identifying data sources, selecting variables of interest, reviewing data quality, merging data from multiple data resources and multiple referencing systems, preparing data in a format that is efficient for safety analysis, are discussed in detail. A database with extensive web application capabilities and options was developed according to the proposed methodology, providing a reliable data source for analyzing various safety problems. The analysis results can potentially assist TxDOT in monitoring its highway safety performance at the network level, understanding safety problems on roadways, and improving the overall safety performance of the highway system. Suggestions are also made for future improvement of the database.

Authors	Fan Yang, University of Wisconsin, Madison Steven Parker, University of Wisconsin, Madison Bin Ran, University of Wisconsin, Madison David A. Noyce, University of Wisconsin, Madison
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-4212
Paper Title	Automated Statewide Highway Intersection Safety Data Collection and Evaluation Strategy
Abstract	Effective evaluation of intersection safety requires the ability to develop meaningful benchmarks to help assess the relative safety risk for a given intersection. This paper introduces an automated intersection safety data collection and evaluation method, including an algorithm to update intersection crash rates and geometric features from existing sources. The automation algorithm involves the integration of five separate Wisconsin Department of Transportation (WisDOT) databases through association with a common Linear Referencing System (LRS). The result of the QA/QC suggests the methodology is feasible and can improve the quality of intersection safety data collection. This paper also presents results of a comparative intersection safety analysis for different intersection types based on the automated algorithm. Although the methodology introduced is specific to Wisconsin data, the results can also be applied to other state DOTs that manage traffic data with respect to a LRS.

Authors	Dongxi Zheng, University of Wisconsin, Madison Madhav V. Chitturi, University of Wisconsin, Madison Andrea R. Bill, University of Wisconsin, Madison David A. Noyce, University of Wisconsin, Madison
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-2138
Paper Title	Secondary Crash Identification on A Large-scale Highway System
Abstract	The annual cost of congestion in the United States reportedly exceeds $120 billion. Freeway incidents are major sources of non-recurrent congestion and the resulting secondary crashes can prolong the traffic impact and increase the cost. Research on secondary crashes to support statewide transportation system management has been limited. In the current study, a two-phase automated procedure is developed to identify secondary crashes on large scale regional transportation systems. In the first phase, a crash pairing algorithm is developed to extract spatially and temporally near-by crash pairs. The accuracy and efficiency of the algorithm were

validated by comparing to an ArcGIS based program. In the second phase, two filters are proposed to reduce the crash pairs for secondary crash identification: the first filter selects crash pairs whose earlier crashes were on mainline highways; the second filter selects crash pairs whose later crashes happened within the dynamic impact areas (i.e., backup queues) of the earlier crashes. Shockwave theory is used to model the dynamic impact of a primary incident. The two-phase procedure uses a linear referencing system for crash localization and can be applied to any regional transportation system with a similar data structure. A case study was conducted on nearly 1,500 miles of freeways in Wisconsin using 2010 data. Among the crash pairs produced by the two-phase procedure, 79 secondary crashes were confirmed via police reports. Preliminary analyses showed that 1) secondary crashes occurred in the same traffic direction as the primary incidents were about three times greater in frequency compared to secondary crashes in the opposing direction, and 2) two-vehicle rear-ends, multiple-vehicle rear-ends, and sideswipes were three major types of secondary crashes (over 85%).

3 Network Screening

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, different methods to obtain performance measures were used:

- Non-linear aggregation (Coll et al., 14-0030);
- Random effect poisson log-normal models (Jiang et al., 14-0289);
- Random forest models (Jiang et al., 14-0337); and
- Nearest Neighborhood Hierarchical Clustering (Kundakci and Tuydes-Yaman, 14-3811).

Jiang et al. (14-0337) compared the random effect poisson log-normal model with the traditional empirical Bayesian method and the conventional Bayesian Poisson Log-Normal model. Wu et al. (14-3350) compared Sichel and Negative Binomial Models.

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

- Network level (Coll et al., 14-0030);
- Four lane divided arterials (Jiang et al., 14-0289);
- Traffic analysis zones (Jiang et al., 14-0337); and
- Urban regions (Kundakci and Tuydes-Yaman, 14-3811).

Authors	Bronagh Coll, Queen's University Belfast Salissou Moutari, Queen's University Belfast Adele H. Marshall, Queen's University Belfast
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-0030
Paper Title	Ranking Spatial and Temporal Hot Spots for Road Safety Interventions Using Nonlinear Aggregation Approach
Abstract	In recent years, the concept of a composite performance index, brought from economic and business statistics, has gained popularity in the field of road safety. The construction of the Composite Safety Performance Index (CSPI) involves the following key steps: the selection of the most appropriate indicators to be aggregated and the method used to aggregate them. Over the last decade, various aggregation methods for estimating the CSPI have been suggested in the literature. However, recent studies indicates that most of these methods suffer from many deficiencies at both the theoretical and operational level; these include the correlation and compensability between indicators, as well as their high “degree of freedom” which enables one to readily manipulate them to produce desired outcomes. The purpose of this study is to introduce an alternative aggregation method for the estimation of the CSPI, which is free from the aforementioned deficiencies. In contrast with the current aggregation methods, which generally use linear combinations of road safety indicators to estimate a CSPI, the approach advocated in this study is based on non-linear combinations of indicators and can be summarized into the following two main steps: the pairwise comparison of road safety indicators and the development of marginal and composite road safety performance functions. The introduced method has been successfully applied to identify and rank temporal and spatial hotspots for Northern Ireland, using road traffic collision data recorded in the UK STATs19 database. The obtained results highlight the promising features of the proposed approach including its stability and consistency, which enables significantly reduced deficiencies associated with the current aggregation methods. Progressively, the introduced method could evolve into an intelligent support system for road safety assessment.

Authors	Ximiao Jiang, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Samir Alamili, University of Central Florida
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-0289
Paper Title	Application of Poisson Random Effect Models for Highway Network Screening
Abstract	In recent years, Bayesian random effect models that account for the temporal and spatial correlations of crash data became popular in traffic safety research. This study employs random effect Poisson Log-Normal models for crash risk hotspot identification. Both the temporal and spatial correlations of crash data were considered. Potential for Safety Improvement (PSI) were adopted as a measure of the crash risk. Using the fatal and injury crashes that occurred on urban 4-lane divided arterials from 2006 to 2009 in the Central Florida area, the random effect approaches were compared to the traditional Empirical Bayesian (EB) method and the conventional Bayesian Poisson Log-Normal model. A series of method examination tests were conducted to evaluate the performance of different approaches. These tests include the previously developed site consistence test, method consistence test, total rank difference test, and the modified total score test, as well as the newly proposed total safety performance measure difference test. Results show that the Bayesian Poisson Log-Normal model accounting for both temporal and spatial random effects (PTSRE) outperforms the model that with only temporal random effect, and both are superior to the conventional Poisson Log-Normal model (PLN) and the EB model in the fitting of crash data. Additionally, the method evaluation tests indicate that the PTSRE model is significantly superior to the PLN model and the EB model in consistently identifying hotspots during successive time periods. The results suggest that the PTSRE model is a superior alternative for road site crash risk hotspot identification.

Authors	Ximiao Jiang, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767

Session Title	Safety Data and Methods Madness
Paper Number	14-0337
Paper Title	Investigating Macrolevel Hotzone Identification and Variable Importance Using Random Forest Models
Abstract	An increasing number of studies have contributed to the literature of micro-level network screening. However, research on macro-level hotzone identification is limited, and until this point, the contribution of various macroscopic features on the macro-level crash risks is still in dispute. This paper investigates the feasibility of using random forest for hotzone identification at the Traffic Analysis Zone (TAZ) level. At the same time, a series of random forest models in combination with the cross validation methods were employed to identify and select the most important macro-level crash risk determinants. Crash data of three counties in Florida during 2008 and 2009 were employed. Crash risks by different injury levels, non-motorized crashes and collision types were investigated separately. The results suggest that crashes per square mile (number of crashes over total area) is superior to crashes per mile (number of crashes over total road length) and crashes per million vehicles miles travel (MVMT) as a measure of the TAZ level crash risk. The variable importance analysis recognized the significance of various macroscopic variables on different types of crash risks. The research results suggest that the distribution of road network, socio-economics and land use should be taken as the first priority during the transportation planning stage to proactively alleviate traffic safety issues. For the pedestrian and bicycle safety, it is suggested that additional attention should be paid to areas of high population density and/or high minority percentage. Moreover, there is a need to improve intersection design and management to reduce angle crashes.

Authors	Ezgi Kundakci, Middle East Technical University Hediye Tuydes-Yaman, Middle East Technical University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-3811
Paper Title	Understanding the Distribution of Traffic Accident Hot Spots in Urban Regions
Abstract	Knowing the geographic distribution of accident prone locations in an urban region is important; but relating these hot spots with the urban land use is more important to understand the underlying problems and develop preventive measures. Despite a more strict “black spot” definition in highway safety, accident prone locations in urban regions are regarded as “hot spots”, which can be defined differently based on the focus of the analysis. One way of definition hot spot is to find clusters which are the representations of dense crash occurrence areas. This paper presents “Nearest Neighborhood Hierarchical (NNH) Clustering” method to find hot spots of injury accidents in an urban region using CrimeStat software. After locating hot spots, it focuses on the distribution of these clusters in different regions of the city such as Central Business District (CBD), urban zone, etc., and during different time periods to find statistically significant relation between these factors and hot spot occurrences. Results suggested that hot spots are not distributed over the region or the time uniformly, and CBD and urban regions have more pedestrian accidents than expected while the non-pedestrian accidents have more frequency.

Authors	Lingtao Wu, Texas A&M University Yajie Zou, University of Washington Dominique Lord, Texas A&M University
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	811
Session Title	Analytical Models for Safe and Sustainable Transport
Paper Number	14-3350
Paper Title	Comparison of Sichel and Negative Binomial Models in Hot Spot Identification
Abstract	The identification of crash hotspots is the critical component of the highway safety management process. Errors in hotspot identification (HSID) may result in the inefficient use of resources for safety improvements. One HSID method that is based on the empirical Bayesian (EB) method has been widely used as an effective approach for identifying crash-prone sites. For the EB method, the negative binomial (NB) model is usually needed for obtaining the EB estimates. Recently, some studies have shown that the Sichel (SI) model can be easily used within the EB modeling framework and potentially yield better EB estimates. The objective of this study is to compare the performance of the two crash prediction models (SI and NB models) in identifying hotspots using the EB method. To accomplish the objective of this study, empirical crash data collected at

highway segments in Texas were used to generate simulated crash counts. Three commonly used HSID methods (simple ranking, confidence interval and EB) were applied using simulated data. False positives, false negatives and false identifications were calculated and compared across the methods. The simulation results in this study suggest that the SI-based EB method can consistently provide a better HSID result than the NB-based EB method. Moreover, EB methods yield lowest error percentage among the three HSID methods. This study confirms that the EB technique is an effective method for identifying hazardous sites. Based on the findings in this study, transportation safety researchers are recommended to consider the SI model as an alternative crash prediction model when using the EB approach.

4 Safety Performance Functions

Thirty-five papers were identified by the subcommittee to address safety performance functions (SPFs). Among these papers, thirty developed or calibrated SPFs for either micro-level (road segments and intersections) or macro-level (area) crash predictions. Three papers implemented the SPFs developed in the Highway Safety Manual (HSM) for case studies. Two paper developed crash modification functions based on SPFs to cope with the limitations posed by crash modification factors. When developing SPFs, various traditional and novel methods were applied; traditional methods included Poisson model, Negative Binomial (NB) model, and extensions based on Poisson or NB model such as zero inflated Poisson/ NB model, random parameter models, count models considering random effects and spatial correlations, Bayesian computation techniques. Some novel methods included hyper-Poisson regression, Poisson Inverse Gaussian generalized linear models, Tobit model and non-parametric methods. The research interests extended to the prediction of crash frequency under different severity levels and collision types on the macro-level, freeway segments, ramps, interchange influence areas, highway segments, intersections and roundabouts.

From an application point of view, micro-level SPFs evaluated highway sections, freeway sections and intersections safety performance. Several papers addressed freeway sections' safety (Shi et al. 14-0303, Wu et al. 14-0760, Islam et al. 14-2933, Pande et al. 14-5291, Hemzehei et al. 14-5726), intersections' safety (Wang et al. 14-0374, Ahmed et al. 14-0397, Xie et al. 14-1466, Khezraee et al. 14-4511), and highway sections' safety (Jiang et al. 14-0289, Chen et al. 14-0549, Ma et al. 14-0768, Qin et al. 14-1053, Zha et al. 14-1522,Mubassira et al. 14-1740, Thakeli et al. 14-2064, Zeng et al. 14-3306). Among macroscopic crash analysis papers, different spatial scales were studied, such as the roadway networks (Xu et al. 14-1829, Stempfel et al. 14-2016, Li et al. 14-2025, Mohommadi et al. 14-4755), Traffic Analysis Zones (TAZ) (Lee et al. 14-0424), and census tracts (Zhan et al. 14-0056). Among others are papers that specifically focused on roundabouts (Fawez et al. 14-0055, Dixon et al. 14-5636), interchange areas or ramps (Sun et al. 14-3640, Wenkogere et al. 14-5034), freeway toll plazas (Abuzwideh et al. 14-3788), railway-highway crossings (Khezraee et al. 14-4511), freeway weigh stations (Fawez et al. 14-0055), highway work zones (Chen et al. 14-2041), and areas adiacent to schools (McArthur et al. 14-0050).

Several papers considered the influence of spatial heterogeneity and correlations on crash patterns (Jiang et al. 14-0289, Shi et al. 14-0303, Ahmed et al. 14-0397, Lee et al. 14-0424). A few papers were dedicated to explore specific SPFs for clustered roadways, intersections, ramps, roundabouts, toll plazas, spatial zones, and crashes based on various features (Chen et al. 14-2041, Pei et al. 14-2505, Sun et al. 14-3640, Mohommadi et al. 14-4755, Hemzehei et al. 14-5726). Two papers have investigated the temporal variability of SPFs (Jiang et al. 14-0289, Hemzehei et al. 14-5726). Other topics included the prediction of the crash frequency

for each severity level (Zhan et al. 14-0056, Stempfel et al. 14-2016, Pei et al. 14-2505, Alkhatni et al. 14-5053), the calibration of HSM SPFs in specific states (Qin et al. 14-1053, Heyderi et al. 14-1519, Md Saidul et al. 14-2933), and network screening (Jiang et al. 14-0289).

Methodologically, traditional count models, such as the Poisson-gamma and Poisson-lognormal model, are still the mainstream (Fawez et al. 14-0055, Zhan et al. 14-0056, Jiang et al. 14-0289, Zha et al. 14-1522, Thakeli et al. 14-2064, Islam et al. 14-2933, Sun et al. 14-3640, Mohommadi et al. 14-4755, Pande et al. 14-5291). Three papers further used the zero inflated models based on Poisson and Poisson-gamma models (Sun et al. 14-3640, Xu et al. 14-1829, Chen et al. 14-0549). Other extensions of basic Poisson models include hyper-Poisson Generalized Linear Models (Khezraee et al. 14-4511), and Poisson Inverse Gaussian regression (Zha et al. 14-1522). On the basis of these traditional count models, several papers further considered spatial heterogeneity and correlations by using random effect models (Chen et al. 14-2041, Jiang et al. 14-0289), and random parameter models (Chen et al. 14-2041, Shi et al. 14-0303). In addition, both the full Bayesian and Empirical Bayesian computation techniques were widely employed (Zeng et al. 14-3306, Mubassira et al. 14-1740, Wang et al. 14-0374, Abuzwideh et al. 14-3788, Li et al. 14-2025, Mohommadi et al. 14-4755, Ahmed et al. 14-0397, Zhan et al. 14-0056, Shi et al. 14-0303, Xie et al. 14-1466, Jiang et al. 14-0289, Lee et al. 14-0424). The other methodologies include, nonparametric models (Hamzehei et al. 14-5726, Thakali et al. 14-2064), visible network approach (Wu et al. 14-0760), bootstrap resampling approach (Xin et al. 14-2505), and Tobit model to handle endogeneity issues (Yu et al. 14-0540).

Authors	Jian Sun, Tongji University, China Jianbing Wang, Tongji University, China Jie Sun, Tongji University, China
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-3640
Paper Title	Safety Influencing Factor Assessment of Expressway Exit Ramps in Shanghai
Abstract	Since many differences exist in terms of the design of expressway mainline and ramps between Shanghai and foreign countries, it is necessary to evaluate the safety influencing factors on Shanghai Expressway exit ramps. 71 exit ramps were selected for statistical analysis and regression analysis with 4 models including Poisson (PO), Zero-inflated Poisson (ZIP), Negative binomial (NB), and negative binomial (ZINB). The results of ZINB model showed that ramp AADT, number of exit ramp lanes, the ramp slope, and the deceleration length significantly affect the safety of expressway exit ramps. Meanwhile, ramp type, the length from ramp terminal to the stop line of downstream intersection and the lane arrangement at downstream intersection are also significant factors in the PO, NB, ZIP models. The study demonstrated that: 1) The crash frequency of Type 4 (not lane-balanced) exit ramp is 46% more than that of Type 2 (lane-balanced) exit ramp; 2) within the 3 exit ramp slope types, uphill-to-ground shows the worst safety, while the best one is downhill-to-ground exit ramp; 3) compared with the conventional lane arrangement, crash frequency increases by 38% with the downstream left-turn lane placed on the right side. Finally, comparing the results of 4 models, it was founded that ZINB model can fit the crash data on exit ramps better. Furthermore, several suggestions about the design of exit ramp on expressways were put forward in the last.

Authors	Yongsheng Chen, City of Edmonton, Canada Bhagwant Persaud, Ryerson University, Canada
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-1131
Paper Title	Methodology to develop crash modification functions for road safety treatments with fully specified and hierarchical models
Abstract	Crash modification factors (CMFs) for road safety treatments are developed as multiplicative factors that are used to reflect the expected changes in safety performance associated with changes in highway design and/or traffic control features. However, current CMFs have methodological drawbacks. For example, variability with application circumstance is not well understood, and, as important, correlation is not addressed when several CMFs are applied multiplicatively. These issues can be addressed by developing safety performance functions (SPFs) with components of crash modification functions (CM-Functions), an approach that includes all CMF related variables, along with others, while capturing quantitative and other effects of factors and accounting for cross-factor correlations. CM-Functions can capture the safety impact of factors through a continuous and quantitative approach, avoiding the problematic categorical analysis that is often used to capture CMF variability. There are two formulations to develop such SPFs with CM-Function components -- fully specified models and hierarchical models. Based on sample datasets from two Canadian cities, both approaches are investigated in this paper. While both model formulations yielded promising results and reasonable CM-Functions, the hierarchical model was found to be more suitable in retaining homogeneity of first-level SPFs, while addressing CM-Functions in sub-level modeling. In addition, hierarchical models better capture the correlations between different impact factors.

Authors	Elisha Jackson Wankogere, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-5034
Paper Title	Safety Performance Functions for Partial Cloverleaf On-ramp Loops for Michigan
Abstract	Safety performance functions (SPFs) have become an integral part of the safety analysis and evaluation processes to ensure safety of roadway users at optimal costs. Highway Safety Manual SPFs or developed their jurisdiction–specific SPFs. Most of these SPFs have been for intersections and roadway segments. A limited number of states have developed SPFs for

interchanges and especially on-ramps and their related sections such as ramp segments and point of freeway entry. This research paper is a documentation of the effort to develop SPFs for urban partial cloverleaf (parclo) on-ramp loops at freeway entry in Michigan. A number of factors associated with crash frequency on these facilities were examined, and the SPFs developed for partial cloverleaf loops, are presented.

Authors Md Saidul Islam, University of Connecticut
John N. Ivan, University of Connecticut
Nicholas E. Lownes, University of Connecticut
Reda Ammar, University of Connecticut
Sanguthevar Rajasekaran, University of Connecticut

Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-2933
Paper Title Safety Performance Function for Freeways Considering Interactions Between Speed Limit and Geometric Variables

Abstract Safety performance functions (SPFs) are crash prediction models which quantitatively relate expected number of crash counts with traffic volume and roadway and roadside geometries. Thus, it helps traffic safety officials identify unsafe locations and take appropriate counteractive measures. This paper presents a study where we assembled crash and roadway geometry data of freeways (only interstate highway data were used for this study) in the State of Connecticut for developing SPFs. Models were estimated separately for single vehicle and multi-vehicle crashes. Also total and fatal/injury crashes were considered for model estimation for both single and multi-vehicle crashes. For each crash category, three different model estimations were performed using negative binomial distribution, namely models using all geometric variables, model using speed limit only, and models using interaction between speed limit and roadway geometric variables. Best models were selected for each crash category comparing goodness-of-fit measure Akaike information criterion (AIC). Interaction models were found to be the best models for all crash categories. This finding suggests the importance of incorporating interaction effect between variables, in particular between speed limit and geometric variables such as number of lanes, shoulder width, and median type, during crash prediction model estimation. Future research will include data of all freeways in Connecticut for substantiating the current findings. Also calibration of the Highway Safety Manual (HSM) SPFs and comparison between the calibrated SPFs and the best models found in this paper are the subjects of continuing investigation by the authors.

Authors Huanghui Zeng, University of Virginia
Michael Daniel Fontaine, Virginia Center for Transportation Innovation and Research
Brian Lee Smith, University of Virginia

Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-3306
Paper Title Estimation of Safety Effect of Pavement Condition on Rural Two-Lane Highways

Abstract The condition of the pavement surface can have an important effect on highway safety. For example, skidding crashes are often related to pavement rutting, polishing, bleeding, and dirty pavements. When transportation agencies develop paving schedules for their roadways, they often make decisions based on asset management condition targets but do not explicitly account for the role of pavement condition in roadway safety. The Virginia Department of Transportation (VDOT) began automated pavement condition data collection using digital images and an automated crack detection methodology in 2007. This development enabled the DOT to track historical pavement condition information, and thus facilitates research regarding pavement condition impacts on safety. Information on how pavement condition influences safety could be used to inform paving decisions and better set priorities for maintenance. The objective of this study is to quantitatively evaluate the safety effectiveness of good pavement conditions versus deficient pavement conditions on rural two-lane undivided highways in Virginia. Using the Empirical Bayes method, it was found that good pavements are able to reduce fatal and injury (FI) crashes by 26 percent over deficient pavements, but do not have a statistically significant impact on overall crash frequency. Further analysis indicated that the safety benefit of pavement condition improvement on FI crashes does not statistically significantly change as the lane or shoulder width increases. In conclusion, improving pavement condition from deficient to good can offer a significant safety benefit in terms of reducing crash

severity.

Authors	Xiao Qin, South Dakota State University Chen Zhi, South Dakota State University Kim Vachal, North Dakota State University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-1053
Paper Title	Calibration of Highway Safety Manual Predictive Methods for Rural Local Roads
Abstract	Establishing performance-based safety goals and objectives becomes more attainable with the Highway Safety Manual (HSM). However, the safety performance functions (SPFs) in the HSM may not be accurate as they are not calibrated to local conditions. In addition, each SPF and crash modification factor (CMF) assumes a set of base site conditions which may not be realistic for local roadways. Although calibration procedures are available in HSM Part C Appendix A, they should be refined or modified to accommodate local data availability and roadway, traffic, and crash characteristics. It is also necessary to determine a set of base conditions applicable to local highways. This paper presents the application of the HSM for rural local two-lane two-way highway segments in South Dakota (SD). The calibration was based on three-year (2009-2011) crash data from 657 roadway segments constituting more than 750 miles of roadways. The calibration process includes establishing new base conditions, developing SPFs, converting CMFs to base conditions as well as substituting default values with state-specific values. Five models have been developed and compared based on statistical goodness-of-fit and calibration factors. Results show that the jurisdiction-specific crash type distribution for CMFs can be drastically different from what is presented in the HSM. The HSM method without modification underestimates SD crashes by 35 percent. The method based on SPFs developed from a full model has the best performance. This study provides important guidance and empirical results regarding how to calibrate HSM models.

Authors	Mubassira Khan, University of Texas, Austin Ahmed Abdel-Rahim, University of Idaho Christopher J. Williams, University of Idaho
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-1740
Paper Title	Potential Crash Reduction Benefits of Shoulder Rumble Strips in Two-Lane Rural Highways
Abstract	This paper examines the effectiveness of shoulder rumble strips in reducing run-off-the-road (ROR) crashes on two-lane rural highways using the Empirical Bayes (EB) Before-and-After analysis method. The comprehensive procedure adopted for developing the safety performance function of EB analysis also considers the effects of roadway geometry and paved right shoulder width on the effectiveness of shoulder rumble strips. The results of this study demonstrate the safety benefits of shoulder rumble strips in reducing the ROR crashes on two-lane rural highways using the State of Idaho 2001-2009 crash data. The study finds a 14% reduction in all ROR crashes after the installation of shoulder rumble strips on 178.63-miles of two-lane rural highways in Idaho. The results indicate that shoulder rumble strips were most effective on roads with relatively moderate curvature and right paved shoulder width of 3 feet and more.

Authors	Shahram Heydari, University of Waterloo, Canada Luis Fernando Miranda-Moreno, McGill University, Canada Dominique Lord, Texas A&M University Liping Fu, University of Waterloo, Canada
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-1519
Paper Title	Bayesian Methodology Incorporating Highway Safety Manual for Fitting and Updating Safety Performance Functions
Abstract	In road safety studies, one often must cope with limited data conditions in the decision making process. In these circumstances, the maximum likelihood estimation which relies on asymptotic theory is not efficient. Besides, it has been reported in the literature that (a) Bayesian estimates might be significantly biased on account of using non-informative prior distributions and (b) the calibration of limited data is plausible when existing evidence in the form of proper priors is

introduced into analyses. However, the road safety literature lacks a methodological approach to overcome the aforementioned problem. We present a method to estimate and/or update safety performance function (SPF) parameters combining the information available from limited data with the SPF parameters values reported in the Highway Safety Manual (AASHTO, 2010). This method contributes to unification of the SPF parameters updating process. The proposed technique is validated by conducting a sensitivity analysis through an extensive simulation study with 15 different models (with various prior combinations), which in turn contributes to our understanding of the comparative aspects of a large number of prior distributions. The results evince the accuracy of the developed methodology. Therefore, the suggested approach offers considerable promise as a methodological tool to estimate and/or update baseline SPFs under limited data conditions.

Authors Jung-Han Wang, University of Central Florida
Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-0374
Paper Title Comparison of Safety Evaluation Approaches for Intersection Signalization in Florida
Abstract In this study, we evaluate the safety effectiveness of introducing traffic signals to stop controlled intersections. According to the Highway Safety Manual (HSM), various Crash Modification Factors (CMFs) have been identified to predict safety performance after updating a stop to a signal controlled intersection. Different CMFs may be expected for the same treatment under different circumstances. Therefore, one CMF may not be able to represent the safety performance under all settings. This paper presents CMFs for signalization and attempts to investigate the relationship between CMF and Annual Average Daily Traffic (AADT). CMFs are examined at different ranges of AADT. According to the 2009 Manual on Uniform Traffic Control Devices (MUTCD), signalizing a stop controlled intersection would be expected to have positive effects on the safety performance. This assumption needs to be proven under different intersection configurations. Our study focuses on grouping intersections into five AADT levels and comparing the safety performance of these levels. In addition, the effects on total crashes and severe crashes (fatal and injury crashes) are analyzed separately; two Safety Performance Functions (SPFs) are estimated, one for total and the other is for fatal and injury crashes. After calculating CMFs based on the Empirical Bayes (EB) method, the result points out that potential risk may occur when the AADT of the target intersections are between 20,000-25,000 vpd for total crashes and 20,000-35000 for fatal and injury (F+I) crashes. Therefore, based on this result, it is suggested that the MUTCD signalization warrant could consider AADT levels and other considerations when making the signalization decision.

Authors Muamer Abuzwidah, University of Central Florida
Mohamed A. Abdel-Aty, University of Central Florida
Mohamed M. Ahmed, University of Wyoming
Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-3788
Paper Title Safety Evaluation of Hybrid Mainline Toll Plazas
Abstract Traditional mainline toll plazas on expressways may have both safety and operational challenges. While many studies demonstrated the operational and environmental impacts of the conversion from traditional toll plazas to a barrier-free system (Open Road Tolling), there is a lack of research that quantifies the safety benefits of new tolling systems. This study evaluated the safety effectiveness of the conversion from Traditional Mainline Toll Plaza (TMTP) design to Hybrid Mainline Toll Plaza (HMTP) system. HMTP combines both an Open Road Tolling (ORT) on the mainline and separate traditional toll collection to the side. Various observational before-after studies were applied on ninety-eight mainline toll plazas (two directions) located on approximately 750 miles of toll roads in the State of Florida; thirty of them were upgraded to HMTPs. The multivariate Empirical Bayes (EB) method produced the best crash modification factors with low standard errors, and its results indicated that the conversion from TMTP to HMTP system resulted in an average crash reduction of 47 percent, 46 percent and 54 percent for total crashes, fatal–and-injury crashes and property damage only crashes, respectively. The use of HMTP system also significantly reduced rear end crashes and lane change related crashes by an average of 65 percent and 55 percent, respectively. Overall, the use of HMTP system was proven to be an excellent solution to several traffic operations, environmental and economic

problems. The results of this study proved that the safety effectiveness across all locations that were upgraded to HMTP was significantly improved.

Authors	Karen K. Dixon, Texas A&M Transportation Institute Jianfei Zheng, Oregon State University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-5636
Paper Title	Safety Performance for Roundabout Applications in Oregon
Abstract	This paper documents a research effort to quantify the safety performance of roundabouts in the State of Oregon. The primary goal of this effort was to provide the Oregon Department of Transportation with safety performance functions that can be used to evaluate the safety performance of single-lane, four-leg roundabouts. These safety metrics generally conform to the statistical models and methodologies outlined in the Highway Safety Manual (HSM) published by the American Association of State Highway and Transportation Officials. Included in the paper is a graphic that contrasts the roundabout crash model to values predicted using the HSM STOP controlled and signalized intersections for rural two-lane highways.

Authors	Seyed Hadi Khazraee, Texas A&M University Antonio Jose Saez-Castillo, University of Jaen, Spain Srinivas Reddy Geedipally, Texas A&M Transportation Institute Dominique Lord, Texas A&M University
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	370
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-4511
Paper Title	Application of Hyper-Poisson Generalized Linear Model for Analyzing Motor Vehicle Crashes
Abstract	The hyper-Poisson distribution can handle both over- and under-dispersion, and its generalized linear model formulation allows the dispersion of the distribution to be observation-specific and dependent on model covariates. This study's objective is to examine the potential applicability of a newly proposed generalized linear model framework for the hyper-Poisson distribution in analyzing the motor vehicle crash count data. The hyper-Poisson generalized linear model was first fitted to the intersection crash data from Toronto, characterized by over-dispersion, and then to the crash data from railway-highway crossings in Korea, characterized by under-dispersion. The results of this study are promising. When fitted to the Toronto data set, the hyper-Poisson model with a variable dispersion parameter provided a statistical fit almost as good as the traditional negative binomial model. The hyper-Poisson model was also successful in handling the under-dispersed data from Korea; the model performed as well as the gamma probability model and the Conway-Maxwell-Poisson model previously developed for the same data set. The advantages of the hyper-Poisson model studied in this paper are noteworthy. Unlike the negative binomial model, which has difficulties in handling under-dispersed data, the hyper-Poisson model can handle both over- and under-dispersed crash data. Although not a major issue for the Conway-Maxwell-Poisson model, the effect of each variable on the expected mean of crashes is easily interpretable in the case of this new model.

Authors	Liteng Zha, Texas A&M University Dominique Lord, Texas A&M University Yajie Zou, University of Washington
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	370
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-1522
Paper Title	The Poisson Inverse Gaussian (PIG) Generalized Linear Regression Model for Analyzing Motor Vehicle Crash Data
Abstract	This paper documents the application of the Poisson Inverse Gaussian (PIG) regression model for modeling motor crash data. The PIG distribution, as its name indicates, mixes the Poisson distribution and Inverse Gaussian distribution and is well suited for modeling highly dispersed count data (e.g., long right tail) due to the flexibility of Inverse Gaussian distribution. The objectives of this paper were to evaluate the application of PIG regression model for analyzing highly skewed crash data and compare the results with NB model. To accomplish the objectives, both NB and PIG models were developed with fixed and varying dispersion parameters and compared using two datasets. The Texas undivided rural segments dataset includes five years of

crash data, while the divided segments Washington dataset includes four years. The results of this study show that in terms of goodness-of-fit (GOF) statistics, PIG models are slightly better than the NB models in modeling the highly dispersed crash data. Moreover, PIG models can perform similarly well in capturing the variance of crash to the NB models. Lastly, PIG models demonstrate almost the same prediction performance compared to NB models. Considering the simple form of PIG model and its easiness of applications, we recommend PIG model as a potential alternative to the NB model for analyzing highly dispersed crash data.

Authors Asso Hamzehei, Queensland University of Technology, Australia
Edward Chung, Queensland University of Technology, Australia
Mark Miska, Queensland University of Technology, Australia

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Safety and Human Factors
Paper Number 14-5726
Paper Title Traffic Safety Risks, Trends, and Pattern Analysis on Motorways

Abstract Crashes that occur on motorways contribute to a significant proportion (40-50%) of non-recurrent motorway congestions. Hence, reducing the frequency of crashes assist in addressing congestion issues (Meyer, 2008). Analysing traffic conditions and discovering risky traffic trends and patterns are essential basics in crash likelihood estimations studies and still require more attention and investigation. In this paper we will show, through data mining techniques, that there is a relationship between pre-crash traffic flow patterns and crash occurrence on motorways, compare them with normal traffic trends, and that this knowledge has the potentiality to improve the accuracy of existing crash likelihood estimation models, and opens the path for new development approaches. The data for the analysis was extracted from records collected between 2007 and 2009 on the Shibuya and Shinjuku lines of the Tokyo Metropolitan Expressway in Japan. The dataset includes a total of 824 rear-end and sideswipe crashes that have been matched with crashes corresponding traffic flow data using an incident detection algorithm. Traffic trends (traffic speed time series) revealed that crashes can be clustered with regards to the dominant traffic patterns prior to the crash occurrence. K-Means clustering algorithm applied to determine dominant pre-crash traffic patterns. In the first phase of this research, traffic regimes identified by analysing crashes and normal traffic situations using half an hour speed in upstream locations of crashes. Then, the second phase investigated the different combination of speed risk indicators to distinguish crashes from normal traffic situations more precisely. Five major trends have been found in the first phase of this paper for both high risk and normal conditions. The study discovered traffic regimes had differences in the speed trends. Moreover, the second phase explains that spatiotemporal difference of speed is a better risk indicator among different combinations of speed related risk indicators. Based on these findings, crash likelihood estimation models can be fine-tuned to increase accuracy of estimations and minimize false alarms.

Authors Julie Stempfel, Swiss Federal Institute of Technology, Zurich, Switzerland
S. Ilgin Guler, Swiss Federal Institute of Technology, Zurich, Switzerland
Monica Menendez, Swiss Federal Institute of Technology, Zurich, Switzerland
Wernher Brucks, Zurich, Switzerland

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Safety and Human Factors
Paper Number 14-2016
Paper Title Effects of Traffic Conditions on Safety of Urban Networks

Abstract The objective of this work is to understand if a relationship between traffic congestion and safety on urban roadways exist. To do so, crash data over the network of Zurich, Switzerland, is linked to speed and traffic flow data from the same network. By aggregating the data, the crash risk in relation to traffic states is analyzed: (i) over the entire network for different times of day; and (ii) for different links on the network for a given time period. In addition, the influence of speed on the severity of the crashes is also investigated. It is found that at the network level the crash risk (number of crashes per car) is higher during times when the average network speed is lower (5-7 pm). Lower speeds are observed during this time period typically due to congestion. Hence, at the network level, there is evidence for congestion being an indicator of increased crash risk. During the same (congested) time period, it is also observed that crashes mostly happened on links with medium speeds, which could be due to speed variations on individual links being higher during the congested time periods. It is also found that, as expected, more severe crashes happen at higher speeds throughout the day.

Authors	Haojie Li, Imperial College London, United Kingdom Daniel J. Graham, Imperial College London, United Kingdom Arnab Majumdar, Imperial College London, United Kingdom
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Safety and Human Factors
Paper Number	14-2025
Paper Title	Effects of Changes in Road Network Characteristics on Road Casualties: Application of Full Bayes Models Using Panel Data
Abstract	In order to ensure a high level of road safety, the road network planning needs to be based on the best knowledge available of the effects of the road design on road safety. In this study, we look into how changes in road network characteristics affect road casualties. We apply a widely used approach for before-after evaluation studies, the Bayesian method. We also use a panel semi-parametric model to estimate the dose-response function for continuous treatment variables. The result suggests that there are more casualties in the area with a better connectivity and accessibility, where more attention should be paid to the safety countermeasures.

Authors	mojtaba ale mohammadi, Missouri University of Science and Technology V. A. Samaranayake, Missouri University of Science and Technology Ghulam Hussain Bham, University of Alaska, Anchorage
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Safety and Human Factors
Paper Number	14-4755
Paper Title	Safety Effect of Missouri's Strategic Highway Safety Plan: Missouri's Blueprint for Safer Roadways
Abstract	This study systematically evaluates the changes in motor vehicle crashes occurred on the Missouri interstate highways following the implementation of the Missouri's Strategic Highway Safety Plan (MSHSP) through the years 2004-2007. The MSHSP implemented injury reduction strategies in enforcement, education, engineering, and public policy. Empirical Bayesian method has been used to evaluate the effects of any changes on the safety condition. This study presents a new and simple approach to evaluating the effects of the Missouri's safety plans on roadway crashes. For crash data associated with traffic and roadway characteristics, negative binomial regression models were developed for the before-through-change conditions using a variable that is set to zero for pre-implementation years and gradually increases over the implementation years to reach a plateau at the conclusion of the safety plans. The models developed for the various collision types and crash severities were used to estimate the expected number of crashes at roadway segments in 2008 assuming with and without the implementation of MSHSP. This procedure estimated significant reductions of 10% in overall number of crashes and 30% reduction for only fatal crashes. Reductions in the number of different collision types were estimated to be 18-37%. The theoretical results indicate that the MSHSP was a successful policy in reducing the number of crashes and decreasing the fatalities by reducing the most severe collision types like head-on crashes. The results are also consistent with many international studies and suggest that the safety strategic plans should be promoted as an effective treatment for highways.

Authors	Jianjun Wu, Jiaotong University, China Mohamed A. Abdel-Aty, University of Central Florida Rongjie Yu, Tongji University Ziyou Gao, Jiaotong University, China
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Safety and Human Factors
Paper Number	14-0760
Paper Title	Novel Visible Network Approach for Freeway Crash Analysis
Abstract	Freeway crashes have attracted considerable attention in recent years leading to the development of various methodologies to unveil the crash occurrence mechanisms including two general modeling approaches: parametric and non-parametric. In this paper, a novel visible network approach has been proposed to analyze crash characteristics with real-time traffic and weather data. In the suggested model, traffic states prior to crash occurrence have been extracted from real-time data; and crashes are mapped as nodes on the network. Each node

contains information for the most hazardous factors relate to crash occurrence selected by random forest algorithm. With the help of transferring technology, links are connected between the nodes according to the state values. Therefore, complete freeway crash evolution networks can be obtained by analyzing one year crash data (including real-time weather and traffic variables) on I-70 in the state of Colorado. Additionally, the suggested method is also used to analyze single- and multi-vehicle crashes separately to identify their distinct characteristics. Compared with the traditional analysis methods, the proposed visible approach has the advantages of easy to be extended, transferred, and applied; easy to identify the effects of the various contributing factors on a traffic crash and to visually inspect the model. Moreover, the crash contributing factors identified in this study is beneficial for designing advanced early-warning and risk assessment systems in the context of real-time highway management.

Authors Xin Pei, Tsinghua University, China
Nang Ngai Sze, University of Canterbury, New Zealand
S. C. Wong, University of Hong Kong
Danya Yao, Tsinghua University, China
Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Safety and Human Factors
Paper Number 14-2505
Paper Title Differences in Effects on Different Crash Types in Hong Kong: Application of Bootstrap Resampling Approach
Abstract Road safety affects health and development worldwide, thus it is essential to examine the factors that influence crashes and injuries. As the relationships between crashes, crash severity, and possible risk factors could vary depending on the type of collision, we attempt to develop separated prediction models for different crash types (i.e. single- versus multi-vehicle crashes and slight injury versus killed and severe injury [KSI] crashes) respectively. Taking the advantage of the availability of disaggregated crash and traffic data by time and space, it is possible to identify the possible factors including traffic flow, road design and weather conditions contributing to the crash risks in Hong Kong. To get rid of the impacts of excess zeros on prediction performance in highly disaggregated crash prediction model, a bootstrap resampling method is applied. Results indicated that more accurate and reliable parameter estimates, with reduced standard error, could be obtained with the use of bootstrap resampling method.

Authors Mohamed M. Ahmed, University of Wyoming
Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee ANB40, Traffic Law Enforcement
Session Number 707
Session Title Safety and Human Factors
Paper Number 14-0397
Paper Title Evaluation and Spatial Analysis of Safety Effectiveness of Red-Light-Running Enforcement Cameras
Abstract Red Light cameras may have a demonstrable impact on reducing the frequency of red light running violations; however, their effect on the overall safety at intersections is still up for debate. This paper examined the safety impacts of Red Light Cameras (RLCs) on traffic crashes at signalized intersections using the Empirical Bayes (EB) method. Data were obtained from the Florida Department of Transportation for twenty-five RLC equipped intersections in Orange County, Florida. Additional fifty intersections that remained with no photo enforcement in the vicinity of the treated sites were collected to examine the spillover effects on the same corridors. The safety evaluation was performed at three main levels; only target approaches where RLCs were installed, all approaches on RLC intersections, and non-RLC intersections located on the same travel corridors as the camera equipped intersections. Moreover, the spatial spillover effects of RLCs were also examined on an aggregate level to evaluate the safety impacts on a regional scale. The results from this study indicated that there was a consistent significant reduction in angle and left-turn crashes and a significant increase in rear-end crashes on target approaches, in addition, the magnitude and the direction of these effects, to a lesser degree, were found similar on the whole intersection. Similar trends in shift of crash types were spilled-over to non-RLC intersections in the proximity of the treated sites. On an aggregate county level, there was a moderate spillover benefits with a notable crash migration to the boundary of the county.

Authors Ahmad Fawaz, Wayne State University
Peter Tarmo Savolainen, Wayne State University

	Timothy Jordan Gates, Wayne State University
Sponsoring Committee	ANB75, Roundabouts
Session Number	708
Session Title	Design, Operations and Traffic Management, Planning and Forecasting, Safety and Human Factors
Paper Number	14-0055
Paper Title	Comparison of Safety Performance of Single- and Multilane Roundabouts
Abstract	The extant research literature has shown that roundabouts generally provide for improved safety performance in comparison to alternate intersection treatments, such as signalization or stop-control. However, while these safety benefits have been clearly demonstrated for roundabouts with a single circulating lane, evidence is mixed with respect to the safety performance of multi-lane roundabouts. Related to this point, the safety performance functions (SPFs) presented in the Roundabouts: An Informational Guide implicitly assume that the effects of exposure (i.e., traffic volume) are consistent regardless of the number of circulating lanes. This study examines this issue through the development of SPFs for various roundabout configurations. Negative binomial regression models are estimated for total and injury crashes. The results show that total crashes tend to increase at similar rates with respect to traffic volume at roundabouts with one or two circulating lanes. However, total crashes are found to increase at a significantly higher rate at roundabouts with three circulating lanes. These results suggest that existing SPFs may severely underestimate total crashes at these higher volume locations. Injury crashes are found to increase at slightly higher rates at roundabouts with higher numbers of circulating lanes, as well. However, the limited number of injury crashes experienced at the study locations does not allow for a more rigorous assessment of this issue.

Authors	Fathi Alkhatni, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	710
Session Title	Freight Transportation, Safety and Human Factors
Paper Number	14-5053
Paper Title	Investigating Crash Frequency and Injury Severity at Freeway Weigh Stations in Michigan
Abstract	The movement of CMVs from and back to the mainline traffic near fixed weigh stations could create conflicts in the traffic stream. The objective of this study was to examine the effects of presence of weigh stations on injury severity and frequency of crashes on Michigan freeways. The study investigated crash patterns in the vicinity of 12 fixed weigh stations as compared to crash patterns in the vicinity of 65 rest areas and 77 selected comparison segments. The study used eight years (2004 to 2011) crash data recorded in Michigan freeways. Three major influential segments (ISs) were identified: before facility, at facility, and after facility. Comparisons segments (CSs) with similar traffic and geometric characteristics as the ISs were also identified. Among 13 variables found to significantly affect the level of injury outcome, presence of fixed weigh station was shown to have positive impact. This indicates that crashes occurring near fixed weigh stations tend to be more severe than those occurring at rest areas and comparison segments. Other factors influencing injury severity include traffic and driver characteristics as well as crash types. The crash frequency model indicated that the incremental segment between 5280-ft and 3000-ft from the exit gore of fixed weigh stations is more likely to experience high crash frequency compared to similar segments at rest areas and at comparison segments.

Authors	Lalita Thakali, University of Waterloo, Canada Liping Fu, University of Waterloo, Canada Tao Chen, University of Waterloo, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	553
Session Title	Planning and Forecasting, Public Transportation
Paper Number	14-2064
Paper Title	Comparison Between Parametric and Nonparametric Approaches for Road Safety Analysis: Case Study of Winter Road Safety
Abstract	In road safety research, a parametric approach is commonly applied in modeling road collisions, which have resulted in many different types of models such as Poisson, Negative Binomial and Poisson lognormal. While easy to apply and interpret, a parametric approach has several critical limitations due to the modeling requirement of assuming a specific probability distribution form for each model variable (e.g. collision frequency) and a pre-specified functional relationship

between each model parameter and the predictors. These assumptions, if violated, could lead to biased and/or erroneous inferences on the effect of these predictors on the dependent variable. This paper introduces a data-driven, nonparametric alternative called Kernel regression, which circumvents the need for the aforementioned assumptions. This paper compares the parametric and nonparametric approaches through an empirical study using a large dataset consisting of hourly observations of collisions, road weather and surface conditions, and traffic counts from highways in Ontario, Canada, over six winter seasons. It is shown that the nonparametric approach has the advantage of being able to capture the significant nonlinear and interacting effects of some condition factors. The paper also illustrate the practical implications of the differences between the two approaches, including evaluation of the risk levels of road surface conditions for the road users and quantification of safety benefits of maintenance operations for transportation authorities.

Authors	Jian Xu, Southeast University, China Kara Kockelman, University of Texas, Austin Yiyi Wang, Montana State University, Bozeman
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	553
Session Title	Planning and Forecasting, Public Transportation
Paper Number	14-1829
Paper Title	Modeling Crash and Fatality Counts Along Main Lanes and Frontage Roads Across Texas: Roles of Design, Built Environment, and Weather
Abstract	Traffic safety is a top priority for most transportation agencies and many governments. In this study, the geometric details of Texas' extensive highway network were mapped to a variety of traffic, demographic, and built environment variables, including land use, truck volumes, traffic intensity, local population and jobs density, rainfall, income, and education levels. A zero-inflated negative binomial (ZINB) model was used to allow for excess zeros and over-dispersion, and was statistically preferred to the zero-inflated Poisson (ZIP) and negative binomial (NB) models, thanks to lower prediction errors and more robust parameter inference. Estimation results show how crash frequencies and fatality rates clearly rise with local jobs and population densities (as proxies for land use intensities), as well as rainfall. Interestingly, speed limits and distances to the nearest hospitals have negative associations with segment-based crash rates (everything else constant) but, as expected, (slightly) positive associations with fatality rates (presumably due to more severe collision impacts at higher speeds and time lost in transporting crash victims).

Authors	Xianyuan Zhan, Purdue University H. M. Abdul Aziz, Purdue University Satish V. Ukkusuri, Purdue University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	704
Session Title	Safety and Human Factors
Paper Number	14-0056
Paper Title	Multivariate Poisson-Lognormal Model for Pedestrian-Vehicle Crashes in New York City Accounting for General Correlations Among Severity Levels
Abstract	This study estimates a multivariate Poisson-lognormal (MVPLN) model using the New York City pedestrian-vehicle crash data collected from 2002 to 2006. The data is aggregated to census tract level. The MVPLN model overcomes the limitations of the ordinary univariate count models that analyze crashes of different severity level separately and ignores the correlations among different crashes severity levels. In addition, the MVPLN model can capture the general correlation structure in crashes frequency data, and takes account of the over-dispersion in the data, which provides a superior fitting result. A MATLAB code implementing parallel computing is developed to estimate the MVPLN model via a Markov Chain Monte Carlo (MCMC) approach. A comparison study is conducted to compare the model fit of MVPLN, univariate Poisson-lognormal, univariate Poisson and Negative Binomial model, and the estimation results shows a better fit of the pedestrian-vehicle crash data.

Authors	Erdong Chen, Purdue University Andrew P. Tarko, Purdue University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-2041

Paper Title	Modeling Safety of Highway Work Zones with Random Parameter and Random Effect Models
Abstract	This paper investigates traffic safety in highway work zones using detailed data obtained from a project engineer survey and existing datasets. The observations were organized in monthly clusters corresponding to individual work zones. The state-of-the-art two-level random parameter Negative Binomial (NB) model that reflected the structure of the observations was estimated. The safety effects of various work zone design and traffic management features were identified, including lane shift, lane split and detour, whose safety effect was not evaluated before. This new insight to highway work zone safety was accomplished thanks to the better data and the adequate statistical model. Then, a fixed parameter NB model with random effects was estimated to check if it is a viable alternative to the random parameter model when a large size of a sample makes estimation of the latter model challenging. From the practical standpoint, the marginal effects computed from the model with random effects were quite similar to the marginal effects computed from the random parameter model. This result indicates that, at least in some cases, convenient fixed parameter models may be a practical alternative to random parameter models. Utilization of an entire sample to estimate these conventional models may further compensate the less favorable model specification. The obtained NB model with random effects is useful for programming police enforcement in highway work zones in Indiana.

Authors	Qi Shi, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida Rongjie Yu, Tongji University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-0303
Paper Title	Identifying Risk Factors for Urban Expressway Traffic Crashes Using Multilevel Bayesian Models with Unprocessed Automatic Vehicle Identification Data
Abstract	Crash frequency analysis of total crashes is the foremost step in aggregate traffic safety studies. A multi-level Bayesian framework has been developed to identify the risk factors contributing to crashes on State Road 408, a segment of an urban expressway. The incorporation of unprocessed Automatic Vehicle Identification (AVI) data in traffic safety study was evaluated and justified. The effects of traffic data and roadway geometric data were modeled as a two-level structure. The Random-parameters approach is utilized at both levels for its flexibility in accounting for heterogeneity at different levels. A mixture of fixed and random parameters for the geometric variables outperforms models with only fixed or random parameters. It is proven that heavier traffic at lower speed and higher speed variation could significantly increase the crash likelihood. As for the implication on practice, Dynamic Message Signs could be used to display warning signs about the traffic conditions. Geometric design of segments with auxiliary lanes, markings and signs at these segments need close examination to provide drivers with clear guidance and some leeway for driving errors.

Authors	Ximiao Jiang, Federal Highway Administration Mohamed A. Abdel-Aty, University of Central Florida Samer Alamili, University of Central Florida
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-0289
Paper Title	Application of Poisson Random Effect Models for Highway Network Screening
Abstract	In recent years, Bayesian random effect models that account for the temporal and spatial correlations of crash data became popular in traffic safety research. This study employs random effect Poisson Log-Normal models for crash risk hotspot identification. Both the temporal and spatial correlations of crash data were considered. Potential for Safety Improvement (PSI) were adopted as a measure of the crash risk. Using the fatal and injury crashes that occurred on urban 4-lane divided arterials from 2006 to 2009 in the Central Florida area, the random effect approaches were compared to the traditional Empirical Bayesian (EB) method and the conventional Bayesian Poisson Log-Normal model. A series of method examination tests were conducted to evaluate the performance of different approaches. These tests include the previously developed site consistence test, method consistence test, total rank difference test, and the modified total score test, as well as the newly proposed total safety performance measure difference test. Results show that the Bayesian Poisson Log-Normal model accounting for both temporal and spatial random effects (PTSRE) outperforms the model that with only

temporal random effect, and both are superior to the conventional Poisson Log-Normal model (PLN) and the EB model in the fitting of crash data. Additionally, the method evaluation tests indicate that the PTSRE model is significantly superior to the PLN model and the EB model in consistently identifying hotspots during successive time periods. The results suggest that the PTSRE model is a superior alternative for road site crash risk hotspot identification.

Authors Jaeyoung Lee, University of Central Florida
Mohamed A. Abdel-Aty, University of Central Florida
Ximiao Jiang, Federal Highway Administration
Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation
Session Number 767
Session Title Data and Information Technology, Safety and Human Factors
Paper Number 14-0424
Paper Title Macroscopic Multivariate Crash Modeling for Motor Vehicle, Bicycle, and Pedestrian Crashes
Abstract The objective of this study is to develop multivariate models for crashes by transportation modes (i.e., motor vehicle, bicycle and pedestrian) which accounts for potential correlations and spatial effects at the macroscopic level. A Bayesian multivariate Poisson model accounting for the spatial correlation (MVS) was developed using TAZ based crash data and MVS was compared with the multivariate model without spatial error terms (MV), univariate model with spatial terms (UVS) and univariate model without spatial terms (UV). It was found that the MVS performs much better than MV, UVS and UV, in terms of DIC. Moreover, there are significant correlations between zone-mode specific random errors of crashes by each transportation mode. The best model (i.e., MVS) showed that significant variables for crashes are different by transportation modes. Admittedly, some variables, which represent traffic volume and the complexity of the traffic network, are common and have significant positive coefficient signs for the three target crash counts. Other variables are not significant for all, or may have opposite signs for different crash types. For instance, the proportion of high-speed roads is significant and positive for motor vehicle and has a negative relationship with pedestrian crashes. It is expected that the findings from this study can contribute to more reliable traffic crash modeling, especially when focusing on crashes by different transportation modes in the context of transportation safety planning (TSP). Also, variables that are found significant for each mode can be used to guide traffic safety policy decision makers to allocate resources more efficiently for the zones with higher risk of a particular transportation mode.

Authors Xiaoming Chen, Texas Southern University
Yi Qi, Texas Southern University
Yan Lu, Texas Southern University
Sponsoring Committee AFB10, Geometric Design
Session Number 686
Session Title Design, Safety and Human Factors
Paper Number 14-0549
Paper Title Safety Impacts of Using Short Left-Turn Lanes at Unsignalized Median Openings
Abstract The AASHTO Greenbook specifically encourages the use of left-turn lanes at median openings on divided roadways to eliminate stopping in through-traffic lanes. However, in urban areas, it is often impractical to provide the Greenbook required lengths for median left-turn lanes when the available length between two adjacent openings is inadequate, which is particularly evident in the case of heavy left-turn volumes. Thus, short left-turn lanes are in wide use on urban divided roadways. The objective of this study was to investigate the safety performance of short left-turn lanes at unsignalized median openings. To this end, six years of crash data were collected from fifty-two median left-turn lanes in Houston, Texas, which included thirty-nine lanes shorter than the Greenbook requirements and thirteen lanes meeting the requirements. A zero-inflated Poisson regression model was developed to relate traffic and geometric attributes to the total count of rear-end, sideswipe, and object-motor vehicle crashes at a left-turn lane. Crash modification factors (CMFs) were calculated for future applications in projecting the crash frequency, given a specific change of the lane length. It was statistically evidenced that the difference between actual lane length and the Greenbook required length had significant effects on the crash frequency. However, the increase of crash frequency due to short left-turn lanes might be acceptable in some cases, in which engineers' judgments should be involved to determine whether a short left-turn lane is appropriate.

Authors Zhuanglin Ma, Chang'an University, China
Chunjiao Dong, University of Tennessee, Knoxville
Shao Chunfu, Jiaotong University, China

	Ting Xu, Chang'an University, China
Sponsoring Committee	AFB10, Geometric Design
Session Number	686
Session Title	Design, Safety and Human Factors
Paper Number	14-0786
Paper Title	Crash Prediction Model and Its Prevention Method for Consecutive Downgrade Section
Abstract	This paper attempts to examine the relationship between crash occurrence and the geometric characteristics of consecutive downgrade section in China. A sample of 13 km of a consecutive downgrade section was selected in this paper. A total of 325 crashes were collected for the 2 years period. Two section divided method were adopted, which produced one km fixed-length segment and the longitudinal grade consistent segment. According to different divided segment, primary independent variables were selected. Three general form of crash frequency prediction models were constructed, which are crash frequency hourly prediction model, crash frequency weekly prediction model and crash frequency monthly prediction model. Three indicators of goodness of fit, which are Deviance, Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC), are also used to evaluate the suitability of the proposed model. Based on the p-values of the t-tests, p-values of a certain independent variable below 0.05 indicate statistically significant non-zero correlations at the 95% confidence level and this independent variable will be retained in the model. The backward stepwise procedure was implemented in order to filter independent variables. Four kinds of prevention schemes were put forward, and three crash prevention models were used to re-estimate the crash frequency under the condition of four kinds of prevention schemes. A before-and-after study was carried out to analyse the prevention effect of four kinds of prevention schemes under the condition of both with and without prevention scheme. Finally, the method of cost-benefit was used to evaluation economic benefit of four kinds of prevention schemes.

Authors	Anurag Pande, California Polytechnic State University, San Luis Obispo James Loy, California State Polytechnic University, San Luis Obispo Vinayak V. Dixit, University of New South Wales, Australia Katherine Spansel, Louisiana State University Brian Wolshon, Louisiana State University Joshua Kent, Louisiana Department of Transportation
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-5291
Paper Title	Exploration of Naturalistic Driving Data for Identifying High Crash Risk Highway Locations
Abstract	This paper describes a project that was undertaken using naturalistic driving data collected via Global Positioning System (GPS) devices to examine the relationship between long-term crash frequency and repeated occurrences of high magnitude jerks while decelerating in the driving data. The motivation to look for correlations between abrupt/abnormal driving maneuvers and long-term crash frequency was to demonstrate a proof-of-concept for proactive safety assessments of crash prone locations. Linear referencing in ArcMap was used to link the GPS data with roadway characteristic data from a roadway base map. The linear referencing methodology was the key to relate the GPS driving data with the freeway corridor of interest, i.e., US 101 northbound (NB) and southbound (SB) in San Luis Obispo California. The process used to merge GPS data with quarter-mile freeway segments for traditional crash frequency analysis is also discussed in the paper. Negative binomial regression analyses showed that proportion of high magnitude jerks while decelerating on freeway segments (from the driving data) was significantly related with the long-term crash frequency of those segments. Applying the same model, average daily traffic (ADT), roadway curvature and presence of an auxiliary lane were found to be insignificant. The results from this exploration are promising since the data used to derive the variable(s) used in the analysis can be collected using most off-the-shelf GPS devices, including many smartphones.

Authors	Rongjie Yu, Tongji University Yingge Xiong, Purdue University Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-0540
Paper Title	Correlated Random Parameter Approach to Investigate Effects of Weather Conditions on Crash

Risk for a Mountainous Freeway

Abstract Freeway crashes are highly influenced by weather conditions, especially for a mountainous freeway affected by adverse weather conditions. In order to reduce crash occurrence, a variety of weather monitoring systems and Intelligent Transportation Systems (ITS) have been introduced to address the weather impact. The effects of weather conditions on crash occurrence have not been fully investigated and understood. With detailed weather information from weather monitoring stations, this study seeks to investigate the complex effects of weather factors, such as visibility and precipitation, on crash occurrence based on safety performance functions. Unlike conventional traffic safety studies which deal with crash frequency, crash rates per 100-million vehicle miles travelled were adopted as the dependent variable in this study. Three years of weather related crash data from a 15-mile mountainous freeway on I-70 in Colorado were utilized. First, a fixed parameter Tobit model was estimated to unveil the effects of explanatory variables on crash rates. Then, in order to characterize the heterogeneous effects of weather conditions across the homogeneous segments, a traditional random parameter Tobit model was developed. Furthermore, for the purpose of monitoring the intricate interactions between weather conditions and geometric characteristics, a multivariate structure for the distribution of random parameters was introduced; which result in a correlated random parameter Tobit model. Likelihood ratio test results demonstrated that the correlated random parameter Tobit model was superior to the uncorrelated random parameter and fixed parameter Tobit models. Moreover, visibility and precipitation variables were found to have substantial correlation effects with geometric characteristics like steep downgrade slopes and curve segments. Results from the models would shed lights on future applications of weather warning systems to improve traffic safety.

Authors Adam McArthur, Wayne State University
Peter Tarmo Savolainen, Wayne State University
Timothy Jordan Gates, Wayne State University

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 567
Session Title Transportation Safety Management
Paper Number 14-0050
Paper Title Spatial Analysis of Child Pedestrian and Bicycle Crashes: Development of a Safety Performance Function for Areas Adjacent to K-8 Schools

Abstract Pedestrian and bicycle safety are particular concerns among school aged children as traffic crashes continue to be among the leading causes of death for children ages 5 to 14. To address this concern, Safe Routes to School (SRTS) programs have been implemented in communities across the country, with one of the primary objectives of such programs being to provide for safe and convenient routes for children to walk or bike to school. Unfortunately, SRTS programs allow for the allocation of a very limited pool of funds for such projects. Consequently, it is imperative that programs are implemented at locations where they are likely to result in the greatest impact. The primary focus of this study was to develop a safety performance function (SPF) for use in prioritizing candidate schools for SRTS programs. Traffic crashes over a five-year analysis period were examined with respect to school enrollment, roadway classification, socioeconomic, and demographic data for each school. Schools on local roads experienced more crashes than schools located on other, higher class road facilities. Crashes also varied with average family size, the number of parents per household, population density, and median family income. Interestingly, crashes were less frequent in school districts that exhibited greater ethnic diversity. The SPF developed as a part of this research can be used for prioritization of candidate schools, as well as to assess the efficacy of SRTS programs on a longitudinal basis, providing a valuable tool for K-8 schools.

5 Crash Severity Prediction

Identifying factors and understanding their effects on injury severity is critical in planning and implementing highway safety improvement programs.

From a methodological perspective, several methodologies were used.

Numerous papers used ordered regressions:

- Ordered logit models (Yasmin et al., 14-4544);
- Heteroscedastic ordered logit models (Lee and Li, 14-1708);
- Generalized ordered logit models (Ariannezhad et al., 14-5722; Machemehl and Khan, 14-4543*)*;
- Mixed generalized ordered logit models (Yasmin et al., 14-4581);
- Binary probit models (Yu and Abdel-Aty, 14-5303*);* and
- Ordered probit models (Habib and Forbes, 14-5303; Kamruzzaman et al., 14-5364; Russo et al., 14-0054*).*

Unordered regressions were commonly used:

- Logistic regressions (Torrao et al., 14-2085); and
- Multinomial logit models (Machemehl and Khan, 14-4543; Chen et al., 14-4474*)*.

Other papers used multivariate poisson lognormal models (Zhan et al., 14-2464), full Bayes estimates (El-Basyouny et al., 14-2128*),* latent class analysis (Pande et al., 14-3228), structural equation modeling approach (Wang and Qin, 14-0801) and severity distribution functions (Geedipally et al., 14-2831*).*

From an application point of view, the papers addressed:

- Environmental factors (Ariannezhad et al., 14-5722; El-Basyouny et al., 14-2128, Kamruzzaman et al., 14-5364; Lee and Li, 14-1708; Machemehl et al., 14-4543; Russo et al., 14-0054; Wang and Qin, 14-0801; Yasmin et al., 14-4544; Yu and A. Abdel-Aty; 14-1036; Zhan et al., 14-2464);
- Vehicle characteristics (Ariannezhad et al., 14-5722; Lee and Li, 14-1708; Machemehl et al., 14-4543; Torrao et al., 14-2085; Wang and Qin, 14-0801; Yasmin et al., 14-4544);
- Driver characteristics (Ariannezhad et al., 14-5722; Habib and Forbes, 14-5303; Lee and Li, 14-1708; Machemehl et al., 14-4543; Russo et al., 14-0054; Torrao et al., 14-2085; Wang and Qin, 14-0801; Yasmin et al., 14-4544);
- Traffic characteristics (Kamruzzaman et al., 14-5364; Lee and Li, 14-1708; Zhan et al., 14-2464); and
- Highway characteristics (Kamruzzaman et al., 14-5364; Wang and Qin, 14-0801), roadside features (Geedipally et al., 14-2831; Habib and Forbes, 14-5303; Lee and Li, 14-1708; Machemehl et al., 14-4543; Yasmin et al., 14-4544; Yu and A. Abdel-Aty; 14-1036).

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

- Pedestrians (Zhan et al. 14-2464; Ariannezhad et al., 14-5722);
- Young drivers (Machemehl and Khan, 14-4543; Pande et al. 14-3228);
- Older drivers (Ariannezhad et al., 14-5722; Machemehl and Khan, 14-4543);
- Heavy vehicle (Ariannezhad et al., 14-5722);
- Bicycles (Machemehl and Khan, 14-4543; Habib and Forbes 14-5303); and
- Motorcycles (Ariannezhad et al., 14-5722paper12_2753).

Authors	Amin Ariannezhad, Sharif University of Technology, Iran Hesamoddin Razi-Ardakani, Sharif University of Technology, Iran Mohammad Kermanshah, Sharif University of Technology, Iran
Sponsoring Committee	ANF30, Motorcycles and Mopeds
Session Number	424
Session Title	Motorcycle Use in Urban, Suburban, and City Center Roads
Paper Number	14-5722
Paper Title	Exploring Factors Contributing to Crash Severity of Motorcycles on Suburban Roads
Abstract	Recently, severity of motorcycle crashes has been considered by different researchers. One of the main reasons of such considerations is greater vulnerability of these users as compared to other vehicle drivers. In recent years, the number of fatalities caused by motorcycle crashes, particularly in suburban roads, has become a concerning issue in Iran since motorcyclists accounted for 24 percent of all traffic-related deaths in Iran in 2011. This study is the first research in Iran in which the factors associated with crash severity are identified. In this paper the crash data from police-reported motorcycle crashes in suburban roads of Iran during 2009 and 2010 is used to estimate ordered logit model to identify the factors affecting severity of suburban motorcycle crashes. In order to better understand the effect of variables on crash severity, the value of pseudo-elasticity has also been calculated for all the variables in the model. Results mainly show that factors such as occurring the crash at weekends, during winter and fall, during the dawn, in foggy and clear weather, in non-administrative areas, rider age above 60, rider without proper license, lack of helmet, motorcycle at-fault, speeding and overtaking as well as collision with bus, heavy vehicle, pedestrian and single vehicle crashes increase the crash severity of motorcyclist. Besides, head on crashes, fatigue and sleepiness, inexcusable haste, violating the rules, road imperfection and curved level roads cause increased in motorcycles crash severity. Finally, as a result of this research, several policy recommendations are presented for improving motorcycles safety at suburban roads.

Authors	Cong Chen, University of New Mexico Qiong Wu, University of New Mexico Guohui Zhang, University of New Mexico Jianming Ma, Texas Department of Transportation Heng Wei, University of Cincinnati Hongzhi Guan, Beijing University of Technology, China
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	726
Session Title	Crash Severity Analysis
Paper Number	14-4474
Paper Title	Rear-End Crash Casualty Severity Analysis using Multinomial Logit Model and Bayesian Network
Abstract	Traffic crashes are a key threat to human safety and health due to their potential for causing considerable damage, including loss of life and economic impact. Rear-end collisions are a major type of traffic crashes and an exploration of their characteristics is necessary. Multinomial logit (MNL) models and Bayesian methods have been widely used in traffic safety research, but both have their own disadvantages. This paper develops a bi-level logit-Bayesian network hybrid approach for rear-end crash severity analysis, in which a MNL model is applied to investigate the deterministic attributes for three severities: no casualty(property damage only), injury and fatality for rear-end crashes. The results indicate that seatbelt use and effective traffic signal control can significantly reduce rear-end crash severity; on the other hand, alcohol use among drivers, drivers unfamiliar with their surroundings, and disabled or functional vehicle damage are usually associated with injury or fatal rear-end crashes. The selected attributes are used as inputs for Bayesian network (BN) classification. The Bayesian network classification presents acceptable classification accuracy for both training and test dataset indicated by the Kappa, statistics the receiver operating characteristic (ROC) curve, and the area under an ROC curve (AUC). The most probable explanation (MPE) analysis illustrate that the learned BN better explains the test dataset than the training dataset. The evidence inference results show that windy weather, driver alcohol involvement, the presence of disabled vehicle damage in a rear-end crash, truck involvement, motorcycle involvement, nonlocal drivers, and accident locations are contributing factors that increase the potentials of both injury and fatal rear-end crashes. The directions for future research are also discussed.

Authors	Karim El-Basyouny, University of Alberta, Canada Sudip Barua, University of Alberta, Canada Tazul Islam, University of Alberta, Canada

	Ran Li, University of Alberta, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	224
Session Title	Transportation Safety Management and Alcohol Research
Paper Number	14-2128
Paper Title	Assessing the Effect of Weather States on Crash Severity and Types Using Full Bayesian Multivariate Safety Models
Abstract	This study investigates the effects of weather states, defined as a combination of various weather elements (i.e., temperature, snow, rain, and wind speed), on crash occurrence, rather than the isolated effects of individual weather elements. The main argument is that often a combination of weather elements might better represent a particular weather condition and subsequent safety outcome. Therefore, to explore the effect of various weather states on crash severity and type, this study defined twelve weather states based on temperature, snow, rain and wind speed, and developed multivariate safety models using 11 years of daily weather and crash data for the entire City of Edmonton. The proposed models were estimated in a Full Bayesian context via a Markov Chain Monte Carlo simulation, while a posterior predictive approach was used to assess the models goodness-of-fit. Results suggested that property damage only crashes could increase by 9.4%-54.4% due to adverse weather states. It was also shown that property damage only crashes were more affected by adverse weather states compared to severe (injury and fatal) crashes. With regard to crash type, adverse weather states were associated with an increased occurrence of 27%-105.3% for all crash types, with the highest increase being recorded for Ran-Off-Road (ROR) crashes. In addition, sudden weather changes of major snow or rain were statistically significant and positively related to all severity levels and crash types, with the highest effect observed for ROR crashes at 46.4%. Similar to crash severity, weekdays were also associated with an increased occurrence for all crash types, except ROR crashes (-19.3%).

Authors	Srinivas Reddy Geedipally, Texas A&M Transportation Institute James Bonneson, Kittelson & Associates, Inc. Michael Paul Pratt, Texas A&M Transportation Institute Dominique Lord, Texas A&M University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Highway Safety Performance
Paper Number	14-2831
Paper Title	Injury Severity Analysis of Crashes on Ramps and at Crossroad Ramp Terminals
Abstract	Travel along a ramp can present drivers with complex alignment changes and decision points. These changes and complexities can increase the potential for conflict or crash, especially for larger vehicles. A few studies have examined the effect of different variables on ramp crash frequency. However, none of these studies considered the effect of variables on crash severity distributions. As a result, relatively little or no information is available about the safety effects of design elements on severity of ramp crashes. In some cases, countermeasures (such as longitudinal barriers) are implemented with the intent to reduce fatal crashes, but the effect of these treatments on less severe crashes is not well understood. New research has been conducted to develop severity distribution functions (SDFs) for ramp segments and signalized and unsignalized crossroad ramp terminals to predict the proportion of crashes in each severity category as a function of roadway geometric design elements and traffic control features. The SDFs were calibrated using data from California, Maine and Washington. The findings from this research show that barrier presence, number of through lanes, area type, and ramp type influence the proportion of high-severity crashes on ramp segments. At the same time, access point frequency, left-turn operation, presence of non-ramp public-street leg, and area type influence the proportion of high-severity crashes at crossroad ramp terminals. These SDFs can be applied along with safety performance functions (SPFs) and crash modification factors (CMFs) to obtain more precise estimates of the safety effects of design decisions.

Authors	Muhammad Ahsanul Habib, Dalhousie University, Canada Justin Forbes, Dalhousie University, Canada
Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	526
Session Title	Cyclist Safety and Operations
Paper Number	14-5303
Paper Title	Injury Severity Study of Bicycle-Motor Vehicle Crashes
Abstract	This paper examines the factors affecting injury severity in bicycle collisions using a generalized

ordered probit model. One of the unique features of the modeling approach adopted in this paper is its flexible threshold structure, which incorporates individual variations in the thresholds to account for heterogeneity likely present in the data, but not commonly accommodated in traditional ordered probit models. Additionally, previous research has focused primarily on the factors that affect injury severity for motorists; generally, less attention has been given to understanding factors that affect injury severity levels for cyclists. Furthermore, examination of neighborhood and land use attributes in association with injury severity is surprisingly limited in the existing literature. This study attempts to fill the gap, particularly in understanding how land use and neighborhood characteristics affect injury severity levels for bicyclists. The data covers 2007-2011 bicycle collisions taken from police collision reports from the Province of Nova Scotia, supplemented with Census tabulations, provincial land use information, and point of interest data specific to the individual collision locations. The results reveal that females, impaired cyclists, and persons aged 45-54 involved in bicycle collisions have an increased likelihood of sustaining more severe injuries. Road condition and configuration, bicyclists' manoeuver, and lighting conditions also affect cyclists' injury severity levels. Finally, characteristics of the neighborhood in which collisions occur, often ignored in previous collision studies, for instance land use mix, proximity to activity centers, and demographic attributes are found to be significant in explaining injury severity of bicyclists. The results suggest that neighborhood characteristics should be given more scrutiny and be an important consideration when evaluating and planning for cyclist safety.

Authors Md. Kamruzzaman, Queensland University of Technology, Australia
Md. Mazharul Haque, Queensland University of Technology, Australia
Simon Washington, Queensland University of Technology, Australia

Sponsoring Committee ABE90, Transportation in the Developing Countries

Session Number 297

Session Title Traffic Safety and Traffic Management in Developing Countries

Paper Number 14-5364

Paper Title Analysis of Traffic Injury Severity in Dhaka, Bangladesh

Abstract This research identifies roadway, traffic, and environmental factors that influence the injury severity of road traffic crashes in Dhaka. Dhaka provides a rather unusual driving risk environment to study, since virtually anyone can obtain a drivers' license and very little traffic enforcement and fines are given due to violation of traffic rules. To examine this city with presumed heightened crash severity risk, police reported crash data from 2007 to 2011 containing about 2714 road traffic crashes were collected. The injury severity of traffic crashes—recorded as either fatal, serious injury, or property damage only—were modeled using an ordered Probit model. Significant factors increasing the probability of fatal injuries include crashes along highways (65%), absence of a road divider (80%), crashes during night time (54%), and vehicle-pedestrian collisions (367%); whereas two-way traffic configuration (21%), and traffic police controlled schemes (41%) decrease the probability of fatalities. Both similarities and differences of the findings between crash risk in Dhaka and developed countries are discussed in policy relevant terms.

Authors Chris Lee, University of Windsor, Canada
Xuancheng Li, University of Windsor, Canada

Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation

Session Number 726

Session Title Crash Severity Analysis

Paper Number 14-1708

Paper Title Analysis of Injury Severity of Drivers Involved in Single-Vehicle and Two-Vehicle Crashes on Ontario Highways Using Heteroscedastic Ordered Logit Models

Abstract The objective of this study is to analyze driver's injury severity in single-vehicle and two-vehicle crashes and compare the effects of explanatory variables between various types of crashes. The study identified factors affecting injury severity and their effects on severity levels using 5-year crash records for provincial highways in Ontario, Canada. Considering non-uniform variations in unobserved effects of explanatory variables on injury severity among observations called "heteroscedasticity", heteroscedastic ordered logit (HOL) models were developed for single-vehicle and two-vehicle crashes separately. The results show that there exists heteroscedasticity for some variables in both single-vehicle and two-vehicle crash models. The results also show that some factors have opposite effects between single-vehicle and two-vehicle crashes, and between car-car crashes and truck-truck crashes. The study demonstrates that HOL models using separate crash data sets classified by vehicle type can better capture the associations of variables with driver's injury severity.

Authors	Randy B. Machemehl, University of Texas, Austin Mubassira Khan, University of Texas, Austin
Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	526
Session Title	Cyclist Safety and Operations
Paper Number	14-4543
Paper Title	Injury Severity Study of Bicycle-Motor Vehicle Crashes
Abstract	This paper examines bicyclist injury severity in bicycle-motor vehicle crashes using the 2012 Texas Department of Transportation (TxDOT) Crash Records Information System (CRIS). Three different modeling frameworks are used: a binary logit, an ordered logit, and a multinomial logit model framework. All bike-motor crashes that involved a single motor vehicle and a single bicyclist are included. Three data sub-sets are examined to identify bike-motor crash risk factors and injury severity levels. These include all bike-motor vehicle crash data, only intersection related crashes and only non-intersection related crashes. Model results indicate that the common factors that affect all crashes include bicyclist and motor vehicle driver demographic characteristics, land use characteristics of the crash location, motor vehicle body type, and roadway speed limit. Motor vehicle driver age (age < 35 years), alcohol intoxication, and bicyclist age (age > 60 years) have larger effects on the bicyclist injury severity for intersection related crashes. Roadway speed (speed > 50 mph), road geometry (horizontal curve), and time of day have greater effects on bicyclist injury severity for non-intersection related crashes. Results of this study can help educate road users, improve traffic regulations, and also suggest roadway safety feature designs to enhance safety.

Authors	Anurag Pande, California Polytechnic State University, San Luis Obispo N. Nezamuddin, Valparaiso University James Loy, California State Polytechnic University, San Luis Obispo Abhishek Das, Cambridge Systematics, Inc.
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	726
Session Title	Crash Severity Analysis
Paper Number	14-3228
Paper Title	Understanding Characteristics of Severe Crashes by Examining Patterns in Latent Classes
Abstract	This study applied latent class analysis (LCA) approach for explaining the severity of motorist-bicycle crashes based on characteristics of the parties involved, the location of crash, and the surrounding environment. Data for the study were obtained from crashes recorded in California from 2008 through 2010. Instead of developing tailored models using explanatory variables to categorize crashes into groups, an LCA approach was used to divide the data into four statistically homogenous clusters. Each LCA cluster was defined as either a class of one of the categorical variables or as a combination thereof based on cluster composition. Defining clusters this way helps in interpreting the modeling results. Severity analysis performed on the individual clusters revealed patterns masked in the severity model for the overall dataset. For example, in the overall model, time/day of the crash did not have a significant impact on crash severity. However, a closer look at the latent clusters revealed crashes involving impaired/at-fault bicyclists (Cluster 1) or those occurring on wet pavement (Cluster 3) were more likely to be severe on a Friday/Saturday night compared to peak period crashes. Similarly, in the overall model, age of minor bicycle riders (<16 years old) did not have a bearing on crash severity. But the LCA method revealed crashes with (non-impaired) bicyclist at-fault (Cluster 4) that involve 16 years old or younger bicycle riders are more likely to be severe. Key Words: Latent class clusters, hidden patterns in crash data, injury severity, categorical data analysis.

Authors	Brendan James Russo, Wayne State University Peter Tarmo Savolainen, Wayne State University William Henry Schneider, University of Akron
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	726
Session Title	Crash Severity Analysis
Paper Number	14-0054
Paper Title	Comparison of Factors Affecting Injury Severity in Angle Collisions by Fault Status Using Bivariate Ordered Probit Model
Abstract	The contemporary traffic safety research literature includes numerous examples of studies that assess those factors affecting the degree of injury sustained by crash-involved motor vehicle occupants. An important methodological concern in such work is the potential correlation in

injury outcomes among occupants who are involved in the same crash, which may be due to common unobserved factors relating to a specific crash. To address this concern, this study jointly modeled injury severity for crash-involved drivers in angle crashes through a bivariate ordered probit model. This modeling framework allows for consideration of within-crash correlation and is found to result in improved fit as compared to independent univariate ordered probit models. While factors affecting injury severity are found to be similar for both drivers, the results demonstrate that injury severity outcomes are correlated for drivers involved in the same crash. Further, the impacts of specific factors may be over- or under-estimated if such correlation is not accounted for explicitly as a part of the analysis. The results show numerous factors to affect driver injury severity, including both crash-specific factors (speed limits, season of crash, etc.) and driver/vehicle specific factors (gender, age, alcohol/drug use, etc.). The analytical approach provides a useful framework for injury severity analysis considering intra-crash correlation. The study also contrasts the differences between at-fault and not-at-fault drivers through a binary probit model.

Authors Guilhermina Torrao, University of Aveiro, Portugal
Margarida Cabrita Coelho, University of Aveiro, Portugal
Nagui M. Rouphail, North Carolina State University, Raleigh
Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation
Session Number 726
Session Title Crash Severity Analysis
Paper Number 14-2085
Paper Title Modeling the Impact of Subject and Opponent Vehicle on Crash Severity in Two-Vehicle Collisions

Abstract This research main goal is to develop models for crash severity prediction in a subject vehicle taking into account the impact of both vehicles involved, hereafter labeled vehicle V1 and vehicle V2. Three binary targets were modeled: FatalSIK (to predict overall severity), FatalSIKV1 (to predict the probability of a serious injury and/or fatality in vehicle V1) and FatalSIKV2 (to predict the probability of a serious injury and/or fatality in vehicle V2). For the period 2006-2010, 874 collisions involving injuries and/or fatalities were analyzed. However, crash sample included few severe events. Imbalanced data introduces a bias toward the majority class (non-severe crashes), and in predictive modeling, would result in less accurate predictions of the minority class (severe crashes). To overcome the challenge imposed by small sample size and high imbalanced data, an important methodology was developed based on a resampling strategy using 10 stratified random samples for model evaluation. The effect of vehicle characteristics, such as weight, engine size, wheelbase and registration year (age of vehicle) were explored. Logistic regression analysis for overall crash severity, FatalSIK, suggested that the age of the vehicle, and collision type are significant predictors ($p<0.0084$ and 0.0346 respectively). Models FatalSIKV1 and FatalSIKV2 showed that the engine size of the opponent vehicle was statistically significant in predicting severity, ($p<0.0762$ and $p<0.03875$%, respectively). Models for FatalSIKV1 and FatalSIKV2 yielded satisfactory results when evaluated with the 10 stratified random samples: 61.2% (s.d. 2.4) and 61.4% (s.d. 3.1), respectively. Keywords: logistic regression, crash severity, injuries, resampling, engine size, vehicles.

Authors Kai Wang, South Dakota State University
Xiao Qin, South Dakota State University
Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation
Session Number 726
Session Title Crash Severity Analysis
Paper Number 14-0801
Paper Title Measuring Single-Vehicle Crash Severity: Structural Equation Modeling Approach

Abstract Injury severity and vehicle damage are two of the main indicators of the level of crash severity. Other factors such as driver characteristics, roadway conditions, highway geometrics, environmental factors, vehicle type and roadside objects may also be directly or indirectly related to crash severity. All of these factors interact in such complicated ways, meaning it is often difficult to identify their interrelationships. This study aims to find out more about how these contributors relate to single-crash severity. Structural equation modeling (SEM) offers the opportunity to explore the complex relationships among variables by handling endogenous variables and exogenous variables simultaneously. Furthermore, SEM allows latent variables to be included in the model, bridging the gap between dependent and explanatory variables. In this study, the number of latent variables is defined by understanding of the collision force, kinetic energy and mechanical process of a collision, as well as the statistical goodness-of-fit based on available data. Three structural equation models (one with one latent variable, one

with two, and one with three) representing the hypothesized relationships between collision force, speed of vehicle, severity of crash were developed and evaluated in an attempt to unravel the relationships between exogenous factors and severity of single-vehicle crashes. Based on the goodness-of-fit and model predictive power, the model with two latent variables outperformed the other two models. Additional insights about model selection were also provided through the development and comparison of the three models.

Authors Shamsunnahar Yasmin, McGill University, Canada
Naveen Eluru, McGill University, Canada
Abdul Rawoof Pinjari, University of South Florida, Tampa
Tonjanika Robinson, University of South Florida, Tampa

Sponsoring Committee ANB20, Safety Data, Analysis, and Evaluation
Session Number 767
Session Title Safety Data and Methods Madness
Paper Number 14-4581
Paper Title Analyzing Continuum of Fatal Crashes: Generalized Ordered Approach

Abstract Road traffic accidents and the resulting fatalities and injuries are acknowledged to be a serious global health concern. Given the import of the consequences of motor vehicle crashes, transportation safety researchers examined the influence of exogenous variables on vehicle occupant injury severity. In the United States, safety researchers have focused on either examining fatal crashes (involving at least one fatally injured vehicle occupant) or a random sample of traffic crashes that compile the injury severity at an individual level as an ordinal variable (no injury, possible injury, non- incapacitating injury, incapacitating injury and fatality). Our study contributes to research on fatal crashes. Specifically, rather than homogenizing all fatal crashes as the same, we recognize that fatality is not a single state but rather is a continuum ranging from dying instantly to dying within thirty days of crash (as reported in the FARS data). The fatality continuum is represented as a discrete ordered dependent variable and analyzed using the mixed generalized ordered logit (MGORL) model. By doing so, we expect to provide a more accurate estimation of critical crash attributes that contribute to death within the first hour of crash. Prolonging survival beyond the first hour can potentially help avoid fatality with proper pre-clinical care. The important control variables that affect the early fatality outcome of the drivers include: driving under the influence of alcohol, crashes occurring on medium or higher speed limit road facilities, presence of stop sign, older vehicles, and collision at dark-unlighted period.

Authors Shamsunnahar Yasmin, McGill University, Canada
Naveen Eluru, McGill University, Canada
Chandra R. Bhat, University of Texas, Austin
Richard Tay, La Trobe University, Australia

Sponsoring Committee ABJ80, Statistical Methods
Session Number 370
Session Title Research in Statistical Methods in Transportation
Paper Number 14-4544
Paper Title Latent Segmentation Generalized Ordered Logit Model to Examine Factors Influencing Driver Injury Severity

Abstract This paper formulates and estimates an econometric model, referred to as the latent segmentation based ordered logit (LSGOL) model, for examining driver injury severity. The proposed model probabilistically segments drivers (involved in a crash) into different injury risk segments based on crash characteristics to recognize that the impacts of exogenous variables on driver injury severity level can vary across drivers based on both observed and unobserved crash characteristics. The proposed model is estimated using data drawn from Victoria Crash Database from Australia for the years 2006 through 2010. The model estimation incorporates the influence of a comprehensive set of exogenous variables grouped into six broad categories: crash characteristics, driver characteristics, vehicle characteristics, roadway design attributes, environmental factors and situational factors. The results clearly highlight the need for segmentation based on crash characteristics. The crash characteristics that affect the allocation of drivers into segments include: collision object, trajectory of vehicle's motion and manner of collision. Further, the key factors resulting in severe driver injury severity are driver age 65 and above, driver ejection, not wearing seat belts, and collision in a high speed zone. The factors reducing injury severity include presence of pedestrian control, presence of roundabout, driving a panel van, unpaved road condition and presence of passenger.

Authors Rongjie Yu, Tongji University

	Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	726
Session Title	Crash Severity Analysis
Paper Number	14-1036
Paper Title	Analyzing Crash Injury Severity on Multiple Facilities with Real-Time Weather and Speed Data
Abstract	Severe crashes are causing serious social and economic loss, and because of this, reducing crash injury severity has become one of the key objectives of the high speed facilities' (freeway and expressway) management. Traditional crash injury severity analysis utilized data mainly from crash reports concerning the crash occurrence information, drivers' characteristics and roadway geometric related variables. In this study, real-time traffic and weather data were introduced to analyze the crash injury severity. The space mean speeds captured by the Automatic Vehicle Identification (AVI) system on the two roadways were used as explanatory variables in this study; and data from a mountainous freeway (I-70 in Colorado) and an urban expressway (State Road 408 in Orlando) have been used to identify the analysis result's consistence. Binary probit (BP) models were estimated to classify the non-severe (property damage only) crashes and severe (injury and fatality) crashes. Firstly, Bayesian BP models' results were compared to the results from Maximum Likelihood Estimation BP models and it was concluded that Bayesian inference was superior with more significant variables. Then different levels of hierarchical Bayesian BP models were developed with random effects accounting for the unobserved heterogeneity at segment level and crash individual level, respectively. Modeling results from both studied locations demonstrate that large variations of speed prior to the crash occurrence would increase the likelihood of severe crash occurrence. Moreover, with considering unobserved heterogeneity in the Bayesian BP models, the model goodness-of-fit has improved substantially. Finally, possible future applications of the model results and the hierarchical Bayesian probit models were discussed.

Authors	Xianyuan Zhan, Purdue University H. M. Abdul Aziz, Purdue University Satish V. Ukkusuri, Purdue University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	767
Session Title	Safety Data and Methods Madness
Paper Number	14-2464
Paper Title	Multivariate Poisson-Lognormal Model for Pedestrian-Vehicle Crashes in New York City Accounting for General Correlations Among Severity Levels
Abstract	This study estimates a multivariate Poisson-lognormal (MVPLN) model using the New York City pedestrian-vehicle crash data collected from 2002 to 2006. The data is aggregated to census tract level. The MVPLN model overcomes the limitations of the ordinary univariate count models that analyze crashes of different severity level separately and ignores the correlations among different crashes severity levels. In addition, the MVPLN model can capture the general correlation structure in crashes frequency data, and takes account of the over-dispersion in the data, which provides a superior fitting result. A MATLAB code implementing parallel computing is developed to estimate the MVPLN model via a Markov Chain Monte Carlo (MCMC) approach. A comparison study is conducted to compare the model fit of MVPLN, univariate Poisson-lognormal, univariate Poisson and Negative Binomial model, and the estimation results shows a better fit of the pedestrian-vehicle crash data.

6 Crash Mofification Factors

The Subcommittee identified eighteen papers dealing with crash modification factors and before-and-after safety evaluations. The majority of these papers employed the empirical Bayes (EB) approach (Wang et al. 14-0374, Cafiso et al. 14-1687, Mubassira et al. 14-1740, Sun et al. 14-1831, Hawkins et al. 14-2772, Zeng et al. 14-3306, Abuzwidah et al. 14-3788) while the Full Bayes approach was employed in three studies (Schultz et al. 14-1844, El-Basyouny et al. 14-2128, Li et al. 14-2025). A method to minimize the bias of the EB when the characteristics of the treatment and control groups are dissimilar has been proposed (Lord and Kuo, 14-3395).

Cross-sectional regression methods were employed in four studies (Chen et al. 14-0549, Chen 14-6681, Saha et al. 14-2293, Mohommadi et al. 14-4755). Other evaluation techniques were also proposed. The safety impact of countermeasures was generally represented by changes in collisions and collision severity. However, one study evaluated simulated traffic conflicts as a surrogate measure (Shahdah et al. 14-4289). Two studies proposed collision modification functions that include several countermeasures (Chen et al. 14-1131) and that change with volume (Wang et al. 14-0374).

The evaluated countermeasures included geometric elements (Chen et al. 14-0549, Ma et al. 14-0786, Cafiso et al. 14-1687, Mubassira et al. 14-1740, Sun et al. 14-1831, Chen 14-6681), pavement condition (Zeng et al. 14-3306), intersection elements (Wang et al. 14-0374, Schultz et al. 14-1844), dynamic digital signs (Hawkins et al. 14-2772), toll plazas (Abuzwidah et al. 14-3788), weather conditions (El-Basyouny et al. 14-2128, Saha et al. 14-2293), area-wide road safety improvement programs (Li et al. 14-2025, Mohommadi et al. 14-4755), and pedestrian countermeasures (Wang et al. 14-4686). One study dealt with general issues related to the use and estimation of collision modification factors, their accuracy, and how to combine the safety effect of multiple countermeasures (Chen et al. 14-1131).

Authors	Jung-Han Wang, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-0374
Paper Title	Comparison of Safety Evaluation Approaches for Intersection Signalization in Florida
Abstract	In this study, we evaluate the safety effectiveness of introducing traffic signals to stop controlled intersections. According to the Highway Safety Manual (HSM), various Crash Modification Factors (CMFs) have been identified to predict safety performance after updating a stop to a signal controlled intersection. Different CMFs may be expected for the same treatment under different circumstances. Therefore, one CMF may not be able to represent the safety performance under all settings. This paper presents CMFs for signalization and attempts to investigate the relationship between CMF and Annual Average Daily Traffic (AADT). CMFs are examined at different ranges of AADT. According to the 2009 Manual on Uniform Traffic Control Devices (MUTCD), signalizing a stop controlled intersection would be expected to have positive effects on the safety performance. This assumption needs to be proven under different intersection configurations. Our study focuses on grouping intersections into five AADT levels and comparing the safety performance of these levels. In addition, the effects on total crashes and severe crashes (fatal and injury crashes) are analyzed separately; two Safety Performance Functions (SPFs) are estimated, one for total and the other is for fatal and injury crashes. After calculating CMFs based on the Empirical Bayes (EB) method, the result points out that potential risk may occur when the AADT of the target intersections are between 20,000-25,000 vpd for total crashes and 20,000-35000 for fatal and injury (F+I) crashes. Therefore, based on this result, it is suggested that the MUTCD signalization warrant could consider AADT levels and other considerations when making the signalization decision.

Authors	Xiaoming Chen, Texas Southern University Yi Qi, Texas Southern University Yan Lu, Texas Southern University
Sponsoring Committee	AFB10, Geometric Design
Session Number	686
Session Title	Design, Safety and Human Factors
Paper Number	14-0549
Paper Title	Safety Impacts of Using Short Left-Turn Lanes at Unsignalized Median Openings
Abstract	The AASHTO Greenbook specifically encourages the use of left-turn lanes at median openings on divided roadways to eliminate stopping in through-traffic lanes. However, in urban areas, it is often impractical to provide the Greenbook required lengths for median left-turn lanes when the available length between two adjacent openings is inadequate, which is particularly evident in the case of heavy left-turn volumes. Thus, short left-turn lanes are in wide use on urban divided roadways. The objective of this study was to investigate the safety performance of short left-turn lanes at unsignalized median openings. To this end, six years of crash data were collected from fifty-two median left-turn lanes in Houston, Texas, which included thirty-nine lanes shorter than the Greenbook requirements and thirteen lanes meeting the requirements. A zero-inflated Poisson regression model was developed to relate traffic and geometric attributes to the total count of rear-end, sideswipe, and object-motor vehicle crashes at a left-turn lane. Crash modification factors (CMFs) were calculated for future applications in projecting the crash frequency, given a specific change of the lane length. It was statistically evidenced that the difference between actual lane length and the Greenbook required length had significant effects on the crash frequency. However, the increase of crash frequency due to short left-turn lanes might be acceptable in some cases, in which engineers' judgments should be involved to determine whether a short left-turn lane is appropriate.

Authors	Zhuanglin Ma, Chang'an University, China Chunjiao Dong, University of Tennessee, Knoxville Shao Chunfu, Jiaotong University, China Ting Xu, Chang'an University, China
Sponsoring Committee	AFB10, Geometric Design
Session Number	686
Session Title	Design, Safety and Human Factors
Paper Number	14-0786
Paper Title	Crash Prediction Model and Its Prevention Method for Consecutive Downgrade Section
Abstract	This paper attempts to examine the relationship between crash occurrence and the geometric

characteristics of consecutive downgrade section in China. A sample of 13 km of a consecutive downgrade section was selected in this paper. A total of 325 crashes were collected for the 2 years period. Two section divided method were adopted, which produced one km fixed-length segment and the longitudinal grade consistent segment. According to different divided segment, primary independent variables were selected. Three general form of crash frequency prediction models were constructed, which are crash frequency hourly prediction model, crash frequency weekly prediction model and crash frequency monthly prediction model. Three indicators of goodness of fit, which are Deviance, Akaike¡¯s Information Criterion (AIC) and Bayesian Information Criterion (BIC), are also used to evaluate the suitability of the proposed model. Based on the p-values of the t-tests, p-values of a certain independent variable below 0.05 indicate statistically significant non-zero correlations at the 95% confidence level and this independent variable will be retained in the model. The backward stepwise procedure was implemented in order to filter independent variables. Four kinds of prevention schemes were put forward, and three crash prevention models were used to re-estimate the crash frequency under the condition of four kinds of prevention schemes. A before-and-after study was carried out to analyse the prevention effect of four kinds of prevention schemes under the condition of both with and without prevention scheme. Finally, the method of cost-benefit was used to evaluation economic benefit of four kinds of prevention schemes.

Authors Yongsheng Chen, City of Edmonton, Canada
Bhagwant Persaud, Ryerson University, Canada

Sponsoring Committee ANB25, Highway Safety Performance

Session Number 686

Session Title Safety and Human Factors

Paper Number 14-1131

Paper Title Methodology to develop crash modification functions for road safety treatments with fully specified and hierarchical models

Abstract Crash modification factors (CMFs) for road safety treatments are developed as multiplicative factors that are used to reflect the expected changes in safety performance associated with changes in highway design and/or traffic control features. However, current CMFs have methodological drawbacks. For example, variability with application circumstance is not well understood, and, as important, correlation is not addressed when several CMFs are applied multiplicatively. These issues can be addressed by developing safety performance functions (SPFs) with components of crash modification functions (CM-Functions), an approach that includes all CMF related variables, along with others, while capturing quantitative and other effects of factors and accounting for cross-factor correlations. CM-Functions can capture the safety impact of factors through a continuous and quantitative approach, avoiding the problematic categorical analysis that is often used to capture CMF variability. There are two formulations to develop such SPFs with CM-Function components -- fully specified models and hierarchical models. Based on sample datasets from two Canadian cities, both approaches are investigated in this paper. While both model formulations yielded promising results and reasonable CM-Functions, the hierarchical model was found to be more suitable in retaining homogeneity of first-level SPFs, while addressing CM-Functions in sub-level modeling. In addition, hierarchical models better capture the correlations between different impact factors.

Authors Salvatore Cafiso, University of Catania, Italy
Carmelo D'Agostino, University of Catania, Italy
Bhagwant Persaud, Ryerson University, Canada

Sponsoring Committee ANF20, Roadside Safety Design

Session Number 248

Session Title Design, Safety and Human Factors

Paper Number 14-1687

Paper Title Investigating Influence on Safety of Retrofitting Italian Motorways with Barriers Meeting New European Union Standard

Abstract A new EU regulation for safety barriers, which is based on performance, has encouraged agencies to perform an upgrade of the old barriers with the expectation that there will be safety benefits at the treated sites. The new class of barriers was designed and installed in compliance with the EN 1317 standards for Road Restraint Systems created in 1998 which lays down common requirements for the testing and certification of road restraint systems in all countries of the European Committee for Standardization, (CEN). Both the older and the new barriers are made of steel and are installed in a way to avoid vehicle intrusion, but the older ones are thought to be only effective at low speeds and low angles of impact. The new standard seeks to remedy this by providing better protection at higher speeds. The paper seeks to quantify the

effect on the frequency of crashes (fatal+injuries) of retrofitting motorways with barriers meeting the new standards, by performing an empirical Bayes before/after analysis based on data from the A18 Messina-Catania motorway in Italy. The results suggest a safety benefit, which, although statistically insignificant, is enough to recommend that the retrofits are cost-effective and should continue. However, the sample size needs to be increased in order to develop a statistically robust crash modification factor.

Authors Mubassira Khan, University of Texas, Austin
Ahmed Abdel-Rahim, University of Idaho
Christopher J. Williams, University of Idaho

Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-1740
Paper Title Potential Crash Reduction Benefits of Shoulder Rumble Strips in Two-Lane Rural Highways

Abstract This paper examines the effectiveness of shoulder rumble strips in reducing run-off-the-road (ROR) crashes on two-lane rural highways using the Empirical Bayes (EB) Before-and-After analysis method. The comprehensive procedure adopted for developing the safety performance function of EB analysis also considers the effects of roadway geometry and paved right shoulder width on the effectiveness of shoulder rumble strips. The results of this study demonstrate the safety benefits of shoulder rumble strips in reducing the ROR crashes on two-lane rural highways using the State of Idaho 2001-2009 crash data. The study finds a 14% reduction in all ROR crashes after the installation of shoulder rumble strips on 178.63-miles of two-lane rural highways in Idaho. The results indicate that shoulder rumble strips were most effective on roads with relatively moderate curvature and right paved shoulder width of 3 feet and more.

Authors Xiaoduan Sun, University of Louisiana, Lafayette
Subasish Das, University of Louisiana, Lafayette
Zhongjie Zhang, Louisiana Department of Transportation and Development
Fan Wang, University of Louisiana, Lafayette
Charles Leboeuf, University of Louisiana, Lafayette
S. Rasel, University of Louisiana, Lafayette

Sponsoring Committee AFB30, Low-Volume Roads
Session Number 305
Session Title Maintenance and Preservation, Safety and Human Factors
Paper Number 14-1831
Paper Title Investigating Safety Impact of Edge Line on Narrow Rural Two-Lane Highways by Empirical Bayes Method

Abstract Narrow, rural two-lane highways are mostly characterized by low design features, light traffic volumes with high crash rates and particularly high fatal crash rates. There are about 5,000 miles of narrow, rural two-lane highways administrated by the Louisiana Department of Transportation and Development (LADOTD). Running-off-roadway (ROR) crashes are the most common type of crashes on narrow, rural two-lane highways. As it's not required by the Manual on Uniform Traffic Control Devices (MUTCD), many highways of this type do not have edge lines because of their low traffic volumes. There are two main concerns for edge line implementation on narrow two-lane highways: (1) the potential increase in head-on collisions and; (2) added maintenance cost to the already constrained annual maintenance budget. This paper introduces the second part of a study that evaluates the safety impact of edge lines on narrow, rural two-lane highways in Louisiana. The first part of the study proved that edge lines centralize the lateral position of vehicles based on the data collected from 10 locations. This second part of the edge line study evaluates the safety performance before and after the implementation of edge lines from roadway segments selected from all LADOTD districts. By using the Empirical Bayes (EB) method, the study shows that edge line implementation significantly reduces expected crash frequencies. While reducing ROR crashes, edge line implementation also reduces head-on crashes. It is interesting to note that the implementation of edge lines benefits primarily male drivers and young drivers. Because of the crash decreasing trend observed in the three year period that is classified as the after time period in the study, the final estimated crash modification factor (CMF) is 0.85 with a standard deviation of 0.039. The very high benefit-cost ratio strongly supports the idea of edge line implementation on narrow, rural two-lane highways in Louisiana.

Authors Grant G. Schultz, Brigham Young University
Ashley Dowell, Brigham Young University

	Ryan Roundy, Brigham Young University Mitsuru Saito, Brigham Young University C. Shane Reese, Brigham Young University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Safety and Human Factors
Paper Number	14-1844
Paper Title	Evaluating Safety Effects of Signal Improvements
Abstract	A large percentage of fatal and injury crashes on roadways occur at intersections. To aid in reducing these severe crashes traffic signals are often implemented. To truly understand whether the signal installations are helping to reduce severe crashes, there is a need to evaluate the effectiveness of the traffic signal improvements through the development of Crash Modification Factors (CMFs). Recent research has shown that traditional safety evaluation methods have been inadequate in developing CMFs. In recent years, Bayesian statistical methods have been utilized in traffic safety studies to more accurately analyze the effectiveness of safety improvements. The hierarchical Bayesian method is an advanced statistical technique that has the capability to account for the shortcomings of traditional methods and to more fully reflect the effectiveness of safety improvements. This report uses a hierarchical Bayesian model to analyze the effectiveness of new traffic signal installations and modifications to existing traffic signals through the development of CMFs for multiple scenarios. A benefit-to-cost (B/C) analysis was also performed for each improvement to determine how long it would take to recover the cost of installation. The results showed that there was a slight increase in overall and non-severe crashes and a decrease in severe crashes for both new signal installations and modifications to existing signals. The B/C analysis indicated that there is a benefit to both improvements and that new signal installation costs can be recovered in approximately 5 years, while the installation of a left-turn signal modification can be recovered in approximately 9 weeks.

Authors	Haojie Li, Imperial College London, United Kingdom Daniel J. Graham, Imperial College London, United Kingdom Arnab Majumdar, Imperial College London, United Kingdom
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Safety and Human Factors
Paper Number	14-2025
Paper Title	Effects of Changes in Road Network Characteristics on Road Casualties: Application of Full Bayes Models Using Panel Data
Abstract	In order to ensure a high level of road safety, the road network planning needs to be based on the best knowledge available of the effects of the road design on road safety. In this study, we look into how changes in road network characteristics affect road casualties. We apply a widely used approach for before-after evaluation studies, the Bayesian method. We also use a panel semi-parametric model to estimate the dose-response function for continuous treatment variables. The result suggests that there are more casualties in the area with a better connectivity and accessibility, where more attention should be paid to the safety countermeasures.

Authors	Karim El-Basyouny, University of Alberta, Canada Sudip Barua, University of Alberta, Canada Tazul Islam, University of Alberta, Canada Ran Li, University of Alberta, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	224
Session Title	Data and Information Technology, Safety and Human Factors
Paper Number	14-2128
Paper Title	Assessing the Effect of Weather States on Crash Severity and Types Using Full Bayesian Multivariate Safety Models
Abstract	This study investigates the effects of weather states, defined as a combination of various weather elements (i.e., temperature, snow, rain, and wind speed), on crash occurrence, rather than the isolated effects of individual weather elements. The main argument is that often a combination of weather elements might better represent a particular weather condition and subsequent safety outcome. Therefore, to explore the effect of various weather states on crash severity and type, this study defined twelve weather states based on temperature, snow, rain and wind speed, and developed multivariate safety models using 11 years of daily weather and crash data for the entire City of Edmonton. The proposed models were estimated in a Full

Bayesian context via a Markov Chain Monte Carlo simulation, while a posterior predictive approach was used to assess the models goodness-of-fit. Results suggested that property damage only crashes could increase by 9.4%-54.4% due to adverse weather states. It was also shown that property damage only crashes were more affected by adverse weather states compared to severe (injury and fatal) crashes. With regard to crash type, adverse weather states were associated with an increased occurrence of 27%-105.3% for all crash types, with the highest increase being recorded for Ran-Off-Road (ROR) crashes. In addition, sudden weather changes of major snow or rain were statistically significant and positively related to all severity levels and crash types, with the highest effect observed for ROR crashes at 46.4%. Similar to crash severity, weekdays were also associated with an increased occurrence for all crash types, except ROR crashes (-19.3%).

Authors Promothes Saha, University of Wyoming
Rhonda Kae Young, University of Wyoming
Sponsoring Committee AH010, Surface Transportation Weather
Session Number 397
Session Title Data and Information Technology, Hot Topic: Extreme Weather Events, Maintenance and Preservation, Operations and Traffic Management
Paper Number 14-2293
Paper Title Weather-Based Safety Analysis for Effectiveness of Rural Variable Speed Limit Corridors
Abstract The purpose of this research was to develop a weather-based safety analysis methodology for determining the effectiveness of the Variable Speed Limit (VSL) system. The VSL system provides variable, regulatory speed limits to drivers based on real-time traffic and weather roadway conditions. Crashes for the winter season (October 15 to April 15) from 2007 to 2012 on four VSL corridors along Interstate-80 in the state of Wyoming were analyzed. For establishing the Safety Performance Functions (SPF), a Negative Binomial (NB) modeling technique was found to be the best at modeling the frequency of crash occurrence and explanatory variables related to weather and the use of the VSL system. Weather variables were used to normalize the winter seasons before and after the VSL systems were implemented. The results from the analysis showed a significant reduction in winter crashes due to the use of the VSL systems.

Authors H. Gene Hawkins, Texas A&M University
Pei-Fen Kuo, University of Central Florida
Dominique Lord, Texas A&M University
Sponsoring Committee AND20, User Information Systems
Session Number 724
Session Title Operations and Traffic Management, Safety and Human Factors
Paper Number 14-2772
Paper Title Statistical Analysis of the Traffic Safety Impacts of On-Premise Digital Signs
Abstract For generations, most signs — including traffic and business signs — were static, displaying a message that did not change with time. Advances in information display technologies in recent years have led to an increase in the use of dynamic digital signs, particularly for on-premise business signs (i.e., signs located on the same property as the business it is advertising). From the beginning of the use of on-premise digital signs, there have been concerns related to the traffic safety impact of these types of signs. So far, no studies have actually examined the safety effects of on-premise signs on the number of crashes. The primary objective of this study sought to fill this important gap. To accomplish the study objective, the researchers conducted a before-after study using the empirical Bayes (EB) method. In the first phase, the researchers identified sites where on-premise digital signs were installed in 2006 or 2007 in California, North Carolina, Ohio, and Washington. A total of 135 sign locations were identified and analyzed in the safety analysis phase. To apply the EB method, reference data were also collected at 1,301 control group sites where no changes were performed and used predictive models available from the literature. The results show that there was no statistically significant change in crash frequency associated with the installation of on-premise digital signs. Thus, there seems to be no evidence the installation of on-premise signs at these locations led to an automatic increase in the number of crashes.

Authors Huanghui Zeng, University of Virginia
Michael Daniel Fontaine, Virginia Center for Transportation Innovation and Research
Brian Lee Smith, University of Virginia
Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors

Paper Number 14-3306
Paper Title Estimation of Safety Effect of Pavement Condition on Rural Two-Lane Highways
Abstract The condition of the pavement surface can have an important effect on highway safety. For example, skidding crashes are often related to pavement rutting, polishing, bleeding, and dirty pavements. When transportation agencies develop paving schedules for their roadways, they often make decisions based on asset management condition targets but do not explicitly account for the role of pavement condition in roadway safety. The Virginia Department of Transportation (VDOT) began automated pavement condition data collection using digital images and an automated crack detection methodology in 2007. This development enabled the DOT to track historical pavement condition information, and thus facilitates research regarding pavement condition impacts on safety. Information on how pavement condition influences safety could be used to inform paving decisions and better set priorities for maintenance. The objective of this study is to quantitatively evaluate the safety effectiveness of good pavement conditions versus deficient pavement conditions on rural two-lane undivided highways in Virginia. Using the Empirical Bayes method, it was found that good pavements are able to reduce fatal and injury (FI) crashes by 26 percent over deficient pavements, but do not have a statistically significant impact on overall crash frequency. Further analysis indicated that the safety benefit of pavement condition improvement on FI crashes does not statistically significantly change as the lane or shoulder width increases. In conclusion, improving pavement condition from deficient to good can offer a significant safety benefit in terms of reducing crash severity.

Authors Dominique Lord, Texas A&M University
Pei-Fen Kuo, University of Central Florida
Sponsoring Committee ANB20, Safety Data, Analysis, and Evaluation
Session Number 767
Session Title Safety Data and Methods Madness
Paper Number 14-3395
Paper Title Estimating the Safety Impacts in Before-After Studies Using the Adjusted Method
Abstract The before-after study is the most popular approach for estimating the safety impacts of an intervention or potential treatment. Recent research, however, has shown that the empirical Bayesian (EB) and Control Group (CG) methods can provide a biased estimate when an entry criterion is used and when the characteristics of the treatment and control groups are dissimilar (i.e., different sample mean and variance values). Recently, a new method, referred to as the Adjusted method, has been proposed to minimize the problems identified above. This new method has been shown to provide a more precise estimate than the Naïve approach and performs better than the CG and EB methods when similar control group data are not available. In previous studies, the usefulness of the Adjusted method was illustrated using theoretical derivations and simulations where the sample mean value was assumed to be fixed (and known), which may not always reflect data collected in the field. Hence, the goals of this paper are to examine the accuracy of the Adjusted method when each site in the treatment group has a different mean value and describe how the Adjusted method can be used by transportation safety analysts and practitioners based on field data. The results show that it provides a more precise estimate than the Naïve method and also outperforms the CG and the EB methods. Furthermore, the proposed method can be an easy alternative for adjusting Naïve estimators of treatment effectiveness documented in previous studies without relying on similar control group data.

Authors Muamer Abuzwidah, University of Central Florida
Mohamed A. Abdel-Aty, University of Central Florida
Mohamed M. Ahmed, University of Wyoming
Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-3788
Paper Title Safety Evaluation of Hybrid Mainline Toll Plazas
Abstract Traditional mainline toll plazas on expressways may have both safety and operational challenges. While many studies demonstrated the operational and environmental impacts of the conversion from traditional toll plazas to a barrier-free system (Open Road Tolling), there is a lack of research that quantifies the safety benefits of new tolling systems. This study evaluated the safety effectiveness of the conversion from Traditional Mainline Toll Plaza (TMTP) design to Hybrid Mainline Toll Plaza (HMTP) system. HMTP combines both an Open Road Tolling (ORT) on the mainline and separate traditional toll collection to the side. Various observational before-

after studies were applied on ninety-eight mainline toll plazas (two directions) located on approximately 750 miles of toll roads in the State of Florida; thirty of them were upgraded to HMTPs. The multivariate Empirical Bayes (EB) method produced the best crash modification factors with low standard errors, and its results indicated that the conversion from TMTP to HMTP system resulted in an average crash reduction of 47 percent, 46 percent and 54 percent for total crashes, fatal–and-injury crashes and property damage only crashes, respectively. The use of HMTP system also significantly reduced rear end crashes and lane change related crashes by an average of 65 percent and 55 percent, respectively. Overall, the use of HMTP system was proven to be an excellent solution to several traffic operations, environmental and economic problems. The results of this study proved that the safety effectiveness across all locations that were upgraded to HMTP was significantly improved.

Authors Usama Elrawy Shahdah, University of Waterloo, Canada
Frank Saccomanno, University of Waterloo, Canada
Bhagwant Persaud, Ryerson University, Canada
Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Safety and Human Factors
Paper Number 14-4289
Paper Title Developing Crash-Conflict Model for Safety Performance Analysis and Estimation of Crash Modification Factors for Urban Signalized Intersections
Abstract Surrogate safety measures based on high risk vehicle interactions and traffic conflicts have been used to provide a more causal perspective on lack of safety at a given location for different road and traffic conditions. The traffic conflict approach, however, has been criticized for lacking a formal link to observational crashes, i.e., to actual safety performance, which can be viewed as being the only verification of transportation system failure from a safety perspective. Hence, a link to observed crashes provides an observational basis for the use of simulated traffic conflicts to identify sites with potential safety problems and for suggesting and evaluating cost-effective treatments. This paper presents a statistical relationship between observed crashes and simulated traffic conflicts for a range of conflict thresholds and simulation runs. Conflicts were simulated for a sample of signalized intersections from Toronto using a VISSIM microscopic traffic simulation platform. The effect of conflict threshold and number of simulation runs in applying this relationship for estimating countermeasure crash modification factors (CMFs) is discussed. The results support the view that CMFs can be estimated more reliably when an appropriate number of simulation runs and conflict thresholds are used in the calibration of the crash-conflict relationship.

Authors Shuo Wang, University of Nebraska, Lincoln
Anuj Sharma, University of Nebraska, Lincoln
Sunil Gyawali, University of Nebraska, Lincoln
Sponsoring Committee AHB50, Traffic Control Devices
Session Number 515
Session Title Pedestrians and Bicyclists, Safety and Human Factors
Paper Number 14-4686
Paper Title The Impact of Pedestrian Countdown Signals on Driver Behavior: A Before-and-After Case-Study
Abstract The Manual on Uniform Traffic Control Devices (1) mandates that all new pedestrian signal heads used at crosswalks with pedestrian change intervals of more than 7 seconds shall include a Pedestrian Countdown Signal (PCS). In these cases, the information provided by the PCS can also be used by the drivers to make more informed decisions. A before-and-after case study was conducted on two signalized intersections in Lincoln, Nebraska analyzing the effects that PCSs have on driver behavior. On the onset of yellow, drivers could use the information from PCS to drive more readily. On the onset of green, information from PCS could be used to reduce reaction time to the imminent green. This study evaluates the impacts of PCS at a microscopic scale, using probability of stopping at onset of yellow, speed gain between speed on the onset of yellow and speed at the stop bar, and queue discharge headway. The study did not find any statistically significant negative safety impacts at either of the two study sites. The study found site-dependent positive impacts on both safety and efficiency of operations. At the 17th Street and G Street intersection, the indecision zone boundary was reduced by approximately 0.5 seconds and the speed gain of the vehicles in yellow interval was reduced by 0.6 mph in the presence of PCS. At the 27th Street and Cornhusker Highway intersection, the queue discharge time of the first vehicle from the start of green was reduced by 0.4 sec (~10%) in the presence of PCS.

Authors	Mojtaba ale mohammadi, Missouri University of Science and Technology V. A. Samaranayake, Missouri University of Science and Technology Ghulam Hussain Bham, University of Alaska, Anchorage
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Safety and Human Factors
Paper Number	14-4755
Paper Title	Safety Effect of Missouri's Strategic Highway Safety Plan: Missouri's Blueprint for Safer Roadways
Abstract	This study systematically evaluates the changes in motor vehicle crashes occurred on the Missouri interstate highways following the implementation of the Missouri's Strategic Highway Safety Plan (MSHSP) through the years 2004-2007. The MSHSP implemented injury reduction strategies in enforcement, education, engineering, and public policy. Empirical Bayesian method has been used to evaluate the effects of any changes on the safety condition. This study presents a new and simple approach to evaluating the effects of the Missouri's safety plans on roadway crashes. For crash data associated with traffic and roadway characteristics, negative binomial regression models were developed for the before-through-change conditions using a variable that is set to zero for pre-implementation years and gradually increases over the implementation years to reach a plateau at the conclusion of the safety plans. The models developed for the various collision types and crash severities were used to estimate the expected number of crashes at roadway segments in 2008 assuming with and without the implementation of MSHSP. This procedure estimated significant reductions of 10% in overall number of crashes and 30% reduction for only fatal crashes. Reductions in the number of different collision types were estimated to be 18-37%. The theoretical results indicate that the MSHSP was a successful policy in reducing the number of crashes and decreasing the fatalities by reducing the most severe collision types like head-on crashes. The results are also consistent with many international studies and suggest that the safety strategic plans should be promoted as an effective treatment for highways.

Authors	Hongyun Chen, Embry-Riddle Aeronautical University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	437
Session Title	Design, Hot Topic: Performance Management, Operations and Traffic Management, Safety and Human Factors
Paper Number	14-6681
Paper Title	Comprehensive Safety Performance Evaluations of Widely Spaced Diverging Areas, Closely Spaced Diverging Areas, Left-Side Diverging Areas, and Freeway Exit Ramps
Abstract	The purpose of the project is to understand the safety performances of freeway diverging areas and exit ramps under different geometric and traffic conditions. The freeway diverging areas under considerations include widely-spaced diverging areas, closely-spaced diverging areas, left-side diverging areas, and the exit ramps. The number and arrangement of lanes used by traffic to exit freeways is an important consideration in freeway exit ramp design, defined by AASHTO (2011). This study defined the freeway segments based on lane-balance and number of basic lane theories to evaluate the crash occurrence and injury severity at these diverging areas respectively. For the widely-spaced diverging area, the research team collected crash data at 343 freeway segments in the state of Florida. Four typical exit ramp types were considered: one-lane exit with lane-balanced design (Type 1), one lane exit with lane-unbalanced design (Type 2), two-lane exit with lane-balanced design (Type 3), and two-lane exit with lane-unbalanced design (Type 4). Cross-sectional comparison was conducted for comparing crash frequency, crash rate and crash severity between different types of freeway exit ramps. Crash prediction models were developed to identify the factors that contribute to the crashes reported at selected freeway segments and to provide quantified information regarding the safety impacts of different freeway exit ramps. It was found that the ramp and freeway AADT, posted speed limit on freeway, deceleration lane length, right shoulder width, and the type of exit ramp significantly affected the safety performance of freeway diverge areas. The results demonstrated the safety benefits of using lane-balanced exit ramps. Based on the crash prediction models, replacing a type 1 exit ramp (lane-balanced) with a type 2 exit ramp (not lane-balanced) will increase crash counts at freeway diverge areas by 68.33%. Replacing a type 3 ramp (lane-balanced) with a type 4 ramp (not lane-balanced) will increase crash counts at freeway diverge areas by 32.20%. Injury severity prediction models were developed by using partial proportional odds regression. Factors that significantly influence injury severity at freeway diverge areas include length of deceleration and ramp lanes, curve and grade at diverge areas, light and weather conditions, alcohol or drug involvement, heavy-vehicle involvement, number of lanes on main lines, average

daily traffic on main lines, surface condition, land type, and crash type. However, it was found that exit ramp types (Type 1, Type 2, Type 3, and Type 4) have no significant effects on injury severity at freeway widely-spaced diverging areas. Additionally, crash distributions and prone locations were compared based on the lane types. Lanes are classified as exit and drop lane group, impact lane group, and interior lane group. Proportionality tests results indicate that lane balanced designs (Type 1 and Type 3) have a statistically significant higher percentage of severe crashes on the impact lane group than that for lane-unbalanced designs (Type 2 and Type 4). For the interior lane group, Type 4 ramps have a statistically significant higher percentage of severe crashes than that of the other design types. Ordered probit models were developed for all crashes and severe crashes by one-lane exits and two-lane exits, respectively. Outcomes from the models suggested that more crashes occurred on the exit and drop lane group for the lane unbalanced designs and more severe crashes occurred on the interior lane group for the lane unbalanced designs. For the closely-spaced entrance and exit ramps, three different types of lane arrangements were considered. They were designated as type A (a one-lane entrance ramp is closely followed by a one-lane exit), type B (a continuous auxiliary lane between entrance and exit ramps ended with a two-lane exit) and type C (a continuous auxiliary lane between entrance and exit ramps ended with a one-lane exit) arrangements. A total of 66 sites were selected from Florida highway system. The research team compared crash frequency, crash rate, crash severity, and collision types among the different types. The crash data analysis results show that the type C arrangement has the best safety performance in terms of the lowest average crash frequency and crash rate. Freeway segments with the type B arrangement reported the highest average crash frequency, crash rate, and percentage of fatal plus severe injury crashes. Based on the crash prediction models, if other factors remain constant, a type B arrangement results in 113% more total crashes and 102% more severe crashes than does a type C arrangement. The safety performance of left-side off-ramps was evaluated by comparing that of right-side off-ramps at freeway diverge areas. Crash records at a total of 11 left side and 63 similar right-side diverge areas in Florida were collected. The average conflict rates near the ramp area were found to be approximately 10 per 1000 conflicting vehicles. The comparisons indicate that the left-side off-ramp did have higher average crash counts, crash rate and percentage of severe crashes, but the difference is only statistically significant for the severe crashes at a 10% level. A crash prediction model for one-lane exit was developed to identify the factors that contribute to the crashes that have been reported for selected freeway segments. The conclusion is consistent with cross-sectional comparison. Last, 389 exit ramps were selected throughout Florida and grouped by four ramp configurations, diamond, out connection, free-flow loop and parclo loop. The result shows that the out connection ramps appear to have the lowest average crash. The predictive model indicates that replacing an out connection exit ramp with a diamond, free-flow, and parclo loop will increase crashes counts by 26.90%, 68.47% and 48.72% respectively.

7 Surrogate Measures of Safety

The subcommittee identified fifty-six papers dealing with surrogate measures of safety, eleven more than last year. These papers are scattered across various sessions. Surrogate measures are used as a sole approach to analyzing safety or as a supplement of conventional crash-based approach.

A number of authors undertake the fundamental effort of validating, improving, and/or implementing new methods for measuring surrogate measures of safety, including computer simulation and SSAM as complementary techniques. Twenty one papers have this methodological focus (Benmimoun and Eckstein, 14-4090; Cafiso et al., 14-3819; Chen and Wang, 14-3806; Fatema et al., 14-3236; Jun et al., 14-4232; Kassim et al., 14-2095; Pande et al., 14-5291; Qiao et al., 14-1782; Saunier and Mohamed, 14-2380; Saleem et al., 14-5099; Shahdah et al., 14-4289; So et al., 14-3077; Songchitruksa and Zha, 14-3544; St-Aubin et al., 14-5363; Sun et al., 14-3348; Vasconcelos et al., 14-0229; Wang and Stamatiadis, 14-0777; Wu et al., 14-4266; Xu et al., 14-3844, 14-4038; Zaki et al., 14-0605;). Although most of the results do not yield definite answers about the method's validity, these studies are of the upmost importance because the research on proactively estimated risk of crash is furthered (Sun et al., 14-3348; Wu et al., 14-4266; Xu et al., 14-3844, 14-4038; Yu and Abdel-Aty, 14-0539). An important and challenging topic of estimating the potential crash severity from traffic conflicts is represented by two papers (Cafiso et al., 14-3819; Wang and Stamatiadis, 14-0777). This research is needed as the current surrogate-based measures of safety are limited to crash frequency.

With regards to what surrogate measures are used to study safety, traffic conflicts and speed are the measures most frequently used by researchers. There are twenty-three papers related to speed (Ardeshiri et al., 14-5556; Bartnik et al., 14-2110; Benmimoun and Eckstein, 14-4090; Bertulis and Dulaski, 14-2349; Chatterjee and Davis, 14-2207; Chen and Tarko, 14-2048; Debnath et al., 14-1333; Edara et al., 14-1108; Gambatese et al., 14-2454; Gedafa et al., 14-1155; Guo et al., 14-1921; Hamzehei et al., 14-5726; Isebrands et al., 14-5582; Jun et al., 14-4232; Liu et al., 14-4413; Montella et al., 14-4361; Ni et al., 14-1433; Qiao et al., 14-1782; Rossi et al., 14-3662; Saunier and Mohamed, 14-2380; Swake et al., 14-2225; Tymvios and Gambatese, 14-4616; Yu and Abdel-Aty, 14-0539). In addition, nineteen are associated with conflicts (Cafiso et al., 14-3819; Edara et al., 14-1020; Foster et al., 14-2893; Gedafa et al., 14-1155; Goh et al., 14-1894; Guo et al., 14-1921; Kaparias et al., 14-2751; Kassim et al., 14-2095; Ni et al., 14-1433; Qi and Zhao, 14-3914; Saleem et al., 14-5099; Shahdah et al., 14-4289; So et al., 14-3077; Songchitruksa and Zha, 14-3544; St-Aubin et al., 14-5363; Vasconcelos et al. , 14-0229; Wang and Stamatiadis, 14-0777; Wu et al, 14-4266; Yu and Abdel-Aty, 14-0539).

Time-to-collision and post-encroachment time are the most frequently used indicators of traffic conflicts (Benmimoun and Eckstein, 14-4090; Kassim et al., 14-2095; Li et al., 14-3515; Saunier and Mohamed, 14-2380; St-Aubin et al., 14-5363). Another criterion quite frequently

used is deceleration or jerk (Benmimoun and Eckstein, 14-4090; Chatterjee and Davis, 14-2207; Chen and Wang, 14-3806; Gates et al. 14-0943; Jun et al., 14-4232; Pande et al., 14-5291; Zaki et al., 14-0605). Seven papers considered the frequency or risk of red light running in relation to safety evaluation or identification of troublesome locations (Gates et al., 14-0942, 14-0943; Guo et al., 14-1921; Lu et al., 14-5613; Songchitruksa and Zha, 14-3544; Wu et al., 14-4258; Wu et al. 14-4266). Violating yield or stop signs was investigated in six papers (Bartnik et al., 14-2110; Bertulis and Dulaski, 14-2349; Foster et al., 14-2893; Gedafa et al., 14-1155; Gomez at al., 14-1834; Van Houten and Bennett, 14-0222), scanning or glancing in three papers (Bartnik et al., 14-2110; Gomez at al., 14-1834; Swake et al., 14-2225), and lane-keeping in two papers (Edara et al., 14-1108; Swake et al., 14-2225).

In terms of data sources and techniques, multiple methods were utilized. Field observations, which included video-based observations in many cases, were directly used in twenty-one papers (Bertulis and Dulaski, 14-2349; Chen and Tarko, 14-2048; Debnath et al., 14-1333; Fatema et al., 14-3236; Foster et al., 14-2893; Gambatese et al., 14-2454; Gedafa et al., 14-1155; Guo et al., 14-1921; Isebrands et al., 14-5582; Kaparias et al., 14-2751; Kassim et al., 14-2095; Ni et al., 14-1433; Qi and Zhao, 14-3914; Qiao at al., 14-1782; Saunier and Mohamed, 14-2380; St-Aubin et al., 14-5363; Tymvios and Gambatese, 14-4616; Van Houten and Bennett, 14-0222; Vasconcelos et al. , 14-0229; Wu et al, 14-4258; Zaki et al., 14-0605). Also popular were simulation-related tools, which were utilized in fifteen papers (Edara et al., 14-1020; Fang et al., 14-1568; Goh et al., 14-1894; Hadiuzzaman et al., 14-1564; Li et al., 14-3515; Ni et al., 14-1433; Qi and Zhao, 14-3914; Saleem et al., 14-5099; Shahdah et al., 14-4289; So et al., 14-3077; Songchitruksa and Zha, 14-3544; Vasconcelos et al 14-0229.; Wang and Stamatiadis, 14-0777, 14-1308; Yu and Abdel-Aty, 14-0539). Driver simulators were important for seven papers (Ardeshiri et al., 14-5556; Bartnik et al., 14-2110; Chen and Wang, 14-3806; Gomez et al., 14-1834; Liu et al., 14-4413; Rossi et al., 14-3662; Swake et al., 14-2225), naturalistic driving-related data in eight papers (Benmimoun and Eckstein, 14-4090; Chatterjee and Davis, 14-2207; Edara et al., 14-1108; Gates et al., 14-0942, 14-0943; Jun et al., 14-4232; Montella et al., 14-4361; Pande et al., 14-5291), detector data for five papers (Lu et al., 14-5613; Sun et al., 14-3348; Wu et al, 14-4266; Xu et al., 14-3844, 14-4038), as well as survey (Cai and Lu, 14-2465) and other methods (Cafiso et al., 14-3819).

Certain topics particularly stand out among this year's papers. The safety impact and other safety-related aspects of signage and control devices were studied with methods involving surrogates measures in eighteen papers (Edara et al., 14-1020; Fang et al., 14-1568; Foster et al., 14-2893; Gambatese et al., 14-2454; Gates et al., 14-0943; Gedafa et al., 14-1155; Gomez et al., 14-1834; Guo et al., 14-1921; Hadiuzzaman et al., 14-1564; Isebrands et al., 14-5582; Lu et al., 14-5613; Ni et al., 14-1433; Qi and Zhao, 14-3914; Rossi et al., 14-3662; Swake et al., 14-2225; Tymvios and Gambatese, 14-4616; Van Houten and Bennett, 14-0222; Yu and Abdel-Aty, 14-0539), while fourteen papers dealt with intersection safety (Gates et al., 14-0942, 14-0943; Gomez et al., 14-1834, Guo et al., 14-1921; Isebrands et al, 14-5582; Kassim et al., 14-2095; Lu et al., 14-5613; Ni et al., 14-1433; Saleem et al., 14-5099; Shahdah

et al., 14-4289; Songchitruksa and Zha, 14-3544; Vasconcelos et al., 14-0229; Wu et al., 14-4258; Wu et al., 14-4266). Reduction in speed as an indirect indicator of safety improvement was studied or used in twelve papers (Bertulis and Dulaski, 14-2349; Chen and Tarko, 14-2048; Debnath et al., 14-1333; Edara et al., 14-1020; Fang et al., 14-1568; Fatema et al., 14-3236; Hadiuzzaman et al., 14-1564; Isebrands et al., 14-5582; Li et al., 14-3515; Rossi et al., 14-3662; Tymvios and Gambatese, 14-4616; Yu and Abdel-Aty, 14-0539). Ten papers examined safety and safety factors for pedestrian and cyclists using surrogate measures (Bertulis and Dulaski, 14-2349; Cafiso et al., 14-3819; Foster et al., 14-2893; Gedafa et al., 14-1155; Gomez et al., 14-1834; Guo et al., 14-1921; Kaparias et al., 14-2751; Kassim et al., 14-2095; Van Houten and Bennett, 14-0222; Wu et al., 14-4258). Safety of work zones and their improvement continues to be a focus of highway agencies. Due to the temporary nature of work zones and consequent scarcity of crash data, surrogate measures, primarily speed, were used in eight papers (Chen and Tarko, 14-2048; Debnath et al., 14-1333; Edara et al., 14-1020; Gambatese et al., 14-2454; Qi and Zhao, 14-3914; Qiao et al., 14-1782; Swake et al., 14-2225; Tymvios and Gambatese, 14-4616). Gambatese et al., 14-2454 studied nighttime conditions.

Authors	Anam Ardeshiri, Morgan State University Shawn Ellerbe, Morgan State University Mansoureh Jeihani, Morgan State University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-5556
Paper Title	Driver Behavior Analysis Under Simulated Animal Crossing Scene
Abstract	Animal-vehicle collisions (AVC) have an increasing impact on U.S. roadway safety; this trend necessitates comprehensive analysis of the variety of factors involved in such hazardous events. Human factor as a complicated component in this context has yet to be thoroughly studied. This study concentrates on drivers' speed behavior and utilizes synthetic driving simulator data to better identify heterogeneity of driving behavior with AVC. More than 100 subjects were recruited to drive on a fairly large network in four different animal passing scenarios. The animal passing occurred on a freeway and a highway. The effect of driver-specific and road-related factors on the risk of AVC was determined using statistical analysis, such as Pearson's chi-square and a logistic regression model. Drivers' socio-economic characteristics were associated with their speeding behavior and collision probability. Using the driving simulator method, the study could reveal interesting facts regarding animal-driver interactions.

Authors	Bryan Bartnik, University of Tennessee, Knoxville Jun Liu, University of Tennessee, Knoxville Stephen Richards, University of Tennessee, Knoxville Asad J. Khattak, University of Tennessee, Knoxville
Sponsoring Committee	AHB60, Highway/Rail Grade Crossings
Session Number	442
Session Title	Highway-Rail Grade Crossings: Human Factors Research and Analysis
Paper Number	14-2110
Paper Title	Driver Behavior at Railway-Highway Grade Crossings with Passive Traffic Controls: A Driving Simulator Study
Abstract	Research to evaluate driver behavior at rail-highway grade crossings with passive traffic control attempts to find an answer to a much debated subject. This study examines the difference in driver behavior and safety at several different types of passive traffic control at grade crossings utilizing a driving simulator. Specifically, this project utilized the University of Tennessee's high fidelity driving simulator to perform the study. Although the crash rates at grade crossings have decreased in recent years, there is still more work to be done. Safety improvements can be made to both passive and active grade crossings. However, with increasingly tight budgets for transportation infrastructure, there is not enough money to upgrade and improve every grade crossing. Upgrading a passive grade crossing with flashing lights or gates is expensive and can be costly. This paper investigates the use of STOP and YIELD signs as viable alternatives to upgrading a passive grade crossing to an active grade crossing. By utilizing a driving simulator, several variables were tested on sixty-four drivers in a safe environment. The driving simulator allows tests to be run on grade crossings that range from safe to fairly unsafe, based on looking behavior, stopping behavior, and approach speed. By varying the visibility at the crossing, which sign the driver saw at the crossing, the presence of a train, and the presence of other traffic, reasonable results were obtained about the safety of various types of passive grade crossings, in terms of travel speed, looking and stopping behavior at crossings. Rigorous statistical methods were used to analyze the data and the implications of the findings are discussed in the paper.

Authors	Mohamed Benmimoun, RWTH Aachen University, Germany Lutz Eckstein, RWTH Aachen University, Germany
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-4090
Paper Title	Dealing with Large Data Sets in Naturalistic Driving Tests: Effective Approach for Detection of Critical Driving Situations Without Video Data
Abstract	Field operational tests (FOT) and Naturalistic Driving Studies (NDS) are more and more conducted to analyse the impact of advanced driver assistance systems and the driver behavior under naturalistic driving conditions in free traffic. Within these studies a high amount of data is collected, which adds up to several terabytes. The analysis of this data is

time-consuming, especially if video data is collected as well, because the video data has to be analysed manually. The video data is mainly used for detection of relevant driving situations, which are needed to answer the defined research questions. Especially the detection of critical driving situations (incidents, near-crashes) is mainly carried out by means of manual video analysis. At the Institut für Kraftfahrzeuge of the RWTH Aachen University (ika) an automated detection process for recognition of relevant driving situations based on vehicle data has been developed. By means of the automation the analysis can be conducted within a reasonable time period. Moreover the algorithm for detection of the relevant situations is in free traffic under naturalistic driving conditions and validated, in order to ensure a reliable detection. Main objective of this paper is to present how critical driving situations (CDS) can be reliably detected by means of vehicle data (data from vehicle CAN-bus).

Authors Tom Bertulis, Northeastern University
Daniel M. Dulaski, Northeastern University
Sponsoring Committee ANF10, Pedestrians
Session Number 731
Session Title Designing Roadways to Improve Pedestrian Safety
Paper Number 14-2349
Paper Title Driver Approach Speed and Its Impact on Pedestrian Yielding Behavior at Unsignalized Crosswalks

Abstract

This report is an evaluation of the effect of motor vehicle speed on yielding rates to pedestrians in marked crosswalks. The experimental design was to measure the 85th percentile speed at nine locations and then run 100 tests at each of the nine locations to check for motorist yielding for different speeds. After calculating the 85th percentile speed and using AASHTO guidelines to calculate Stopping Sight Distance (SSD), a cone was placed that distance away from the marked crosswalk and a pedestrian was asked to step out in the street to test yielding behavior used a staged experiment. Data were collected on site and recorded for analysis. Overall, there was an inverse correlation: the higher the motor vehicle speed, the lower the yield rate. Out of the eight two-lane roadways, the range started at a 75% yield rate for the 20 mph street and went to a 17% yield rate for the 37 mph street, a significantly lower yield rate. The one street that was four-lanes wide had only a 9% yield rate. The results are unequivocal in that speed was the major factor in the changing yield rates. The strong correlation pointed to a likelihood of low yield rates regionally on high-speed roadways, information that may prove useful for agencies looking to develop a pedestrian-friendly environment.

Authors Salvatore Cafiso, University of Catania, Italy
Alessandro Di Graziano, University of Catania, Italy
Giuseppina Pappalardo, University of Catania, Italy
Sponsoring Committee AND30, Simulation and Measurement of Vehicle and Operator Performance
Session Number 454
Session Title Simulation and Measurement of Driver Performance
Paper Number 14-3819
Paper Title Traffic Conflict Investigation Using Georeferenced Stereovision: Case Study on Bus-Pedestrian Interaction

Abstract

The Traffic Conflict Technique (TCT) was developed as “surrogate measure of road safety” by using near-accident indicators based on the measurement of the spatial and temporal proximity of road users. Traditionally, TCT focuses on a specific site by the way of manually or automated supervision. Nowadays the development of In-Vehicle (IV) technologies provide new opportunities for monitoring driver behavior and interaction with other road users. In this paper a novel IV stereo-vision and GPS system for traffic conflict investigation is presented. The system employs geo-referenced stereo sequences and tracking procedure to provide much greater information regarding pre-conflict and conflict events than what is currently available. As case study, an urban Bus was equipped with a prototype of the system and a trial of some runs along route 2_5 in the city of Catania (Italy) was conducted analyzing conflicts with pedestrian crossing in front of the Bus. Experimental results showed the performance of the system for collection of data that can be used to get suitable Traffic Conflict measures. Specifically, a Risk indicator of the conflict between pedestrians and vehicles was developed and how this measure can be used for evaluation of both probability and severity of the collision is proved. Finally, examples of application of the procedure for Risk maps output and driver warning systems are presented.

Authors	Xiaonan Cai, Jiaotong University, China Jian John Lu, University of South Florida
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-2465
Paper Title	Risk Assessment and Early Warning of Driving on Freeways Under Rainy Weather Conditions
Abstract	With pavement friction and visibility distance reduced, rainy weather has significant negative impacts on driving on freeways. This paper attempts to develop a procedure of risk assessment and early warning of driving on freeway under rainy weather conditions. Based on the data derived from 1216 driversi¯ questionnaires, an ordered logit model was developed to estimate the impacts of vehicle type, rain intensity, traffic volume, and location on driving safety on freeway for the purposes of risk assessment. With such a model, weighted driving risk (the impact on driving multiplied by corresponding probability and weight) under different conditions could be obtained. Then, weighted driving risk was divided into four levels of early warning (specified by colors) using the rank order cluster analysis. Furthermore, a risk matrix combined by effects of impact and probability is established for risk early warning to determine which warning color should be disseminated to drivers under certain conditions. Finally, to reduce vehicle crash probability, other warning information including release time of early warning, suggested speeds, and corresponding spacing between vehicles is provided. The procedure in the study could also be used for other adverse weather conditions such as fog and snow and help some countries to develop their own travel weather warning system in a short time.

Authors	Indrajit Chatterjee, University of Minnesota, Twin Cities Gary A. Davis, University of Minnesota, Twin Cities
Sponsoring Committee	AND10, Vehicle User Characteristics
Session Number	338
Session Title	Naturalistic Driving Data and Driver Behavior
Paper Number	14-2207
Paper Title	Using Naturalistic Driving Data to Characterize Driver Behavior in Freeway Shock Waves
Abstract	Recent years have witnessed significant efforts at developing and evaluating vehicle-based passive and active safety systems to reduce traffic accidents. In addition, there is a growing interest in using microscopic simulation models to evaluate operational strategies. Both these activities require quantitative characterization of driver behavior in real world situations. Historically such characterizations have been difficult to obtain, but the data available from large-scale naturalistic driving studies (NDS) have the potential to change this situation. However, identifying relevant events from within an NDS database and then reducing the NDS data so as to estimate relevant features of the events are still something of a challenge. Using freeway brake-to-stop events on congested freeways as examples, this study describes methods for identifying relevant events and then estimating event features, such as initial speeds for leading and following vehicles, reaction times for leading and following drivers, and changes in the drivers' braking rates. A suitably representative sample of such estimates could then be used to support evaluation of vehicle-based safety countermeasures, or provide inputs to traffic simulation models.

Authors	Erdong Chen, Purdue University Andrew P. Tarko, Purdue University
Sponsoring Committee	AHB55, Work Zone Traffic Control
Session Number	590
Session Title	Vehicle Speeds in Work Zones
Paper Number	14-2048
Paper Title	Estimating the Effect of Speed Control Strategies on Speed Distribution in Work Zones with Quantile Regression
Abstract	Speeding has long been a safety concern for transportation and law enforcement agencies, and speed control strategies also have received great attention; however, a review of the literature revealed several issues. To overcome these identified issues and better evaluate the effectiveness of some enforcement strategies, the authors used a new method, Quantile Regression, to analyze the speed data collected from a designed experiment. Quantile Regression is capable of simultaneously estimating the entire distribution of speed, free of distributional assumption, and represents a significant improvement over the current methodologies. Quantile Regression was used in this study to estimate the effectiveness of police enforcement on speed control in work zones, and its strengths compared to

traditional methodologies were fully demonstrated. New knowledge was obtained, and the best speed enforcement strategy was identified. Based on the theoretical merits and the empirical results from this study, it is strongly recommended that Quantile Regression be considered for all future studies concerning speed control strategies. Key Words: Highway Safety, Speed Control, Police Enforcement, Variable Message Sign, Highway Work Zone, Quantile Regression.

Authors Ming Chen, Tongji University, China
Xuesong Wang, Tongji University, China
Sponsoring Committee AND10, Vehicle User Characteristics
Session Number 694
Session Title Anger, Volatility, Decisions, Impairments, and Warnings: The Drama of Modeling Driver Behavior
Paper Number 14-3806
Paper Title Development of Kinematic-Based Forward Collision Warning Algorithm
Abstract Forward Collision Warning (FCW) systems have been shown to be effective in assisting drivers to avoid rear-end collisions. One key characteristic of FCW is that the warnings must compatible with driver's natural behavior and risk perception. In a previous classical warning algorithm, the warning onset range was found incompatible with driver's risk perception. This incompatible issue referred to that when a lead vehicle (LV) brakes harder (in a larger deceleration rate), while the warning is presented later (with a shorter warning onset range). In order to solve this problem, the predicting model for expected response deceleration, which measures how hard the driver of subject vehicle (SV) would brake under the pre-crash scenario, was improved with a nonlinear function. This nonlinear function models the expected response deceleration with an additional interaction term of LV deceleration rate and relative speed. Then a new kinematic-based warning algorithm was developed based on this predicting model. In this study, a total of 30 driver's braking behavior under different risk level of rear-end scenarios were collected in the Tongji University Driving Simulator. The database includes a total of 173 rear-end events, but only 111 of them in which drivers only take the braking maneuver and no collision occurred were used to model the expected response deceleration. Domain of validity was examined through theoretical computations for a wide range of initial conditions of subject vehicle speed, relative speed, and LV deceleration rate. The proposed algorithm was also implemented and tested in the driving simulator. The general effectiveness of warnings was significant and the algorithm performed well under the test scenarios. The results of this study can be helpful in improving the design of forward collision warning algorithm to be more effective and robust.

Authors Ashim Kumar Debnath, Queensland University of Technology, Australia
Ross Alexander Blackman, Queensland University of Technology, Australia
Narelle Lorraine Haworth, Queensland University of Technology, Australia
Sponsoring Committee AHB55, Work Zone Traffic Control
Session Number 590
Session Title Vehicle Speeds in Work Zones
Paper Number 14-1333
Paper Title Effectiveness of Pilot Car Operations in Reducing Speeds in Long-Term Rural Highway Work Zone
Abstract Pilot cars are used in one-lane two-way work zones to guide traffic and keep their speeds within posted limits. While many studies have examined the effectiveness of measures to reduce vehicle speeds in work zones, little is known about the reductions achievable through the use of pilot cars. This paper examines the effectiveness of a pilot car in reducing travel speeds in a rural highway work zone in Queensland, Australia. Analysis of speed data covering a period of five days showed that a pilot car reduced average speeds at the treatment location, but not downstream. The proportion of vehicles speeding through the activity area was also reduced, particularly those traveling at 10 km/h or more above the posted limit. Motorists were more likely to speed during the day, under a 40 km/h limit, when traffic volumes were higher and when there were fewer vehicles in the traffic stream. Medium vehicles were less likely to speed in the presence of a pilot car than light vehicles. To maximize these benefits, it is necessary to ensure that the pilot car itself is not speeding.

Authors Praveen Edara, University of Missouri, Columbia
Carlos Sun, University of Missouri, Columbia
Yi Hou, University of Missouri, Columbia

Sponsoring Committee	AHB55, Work Zone Traffic Control
Session Number	253
Session Title	Work Zone Traffic Control for Safety and Mobility
Paper Number	14-1020
Paper Title	Work Zone Deployment of Variable Advisory Speed Limits: Mobility and Safety Evaluation
Abstract	The effectiveness of variable advisory speed limit (VASL) systems in congested urban work zones was investigated. Except for one article, all previous studies focused on regulatory speed limit systems. This study uses a comprehensive set of performance measures to investigate VASL effectiveness. The empirical analysis showed that VASL were effective in making drivers slow down gradually as they approached the work zone, thus reducing sudden speed changes. Simulation showed that operationally, the use of VASL resulted in: a 40% to 58% decrease in average queue length, a 6% to 13% reduction in throughput, a 20% to 29% decrease in number of stops and a 1.5% to 10% increase in travel time. The use of VASL achieved a decrease in the standard deviation of speeds at the taper and 1-mile upstream of the work zone. The maximum speed differences also decreased up to 10 mph with VASL. The effect of VASL on predicted number of rear end and lane changing conflicts varied based on the proportion of trucks in the traffic stream. The number of conflicts increased due to VASL when the traffic stream consisted of 10% trucks. For 15% trucks however, the number of conflicts with VASL were lower than without VASL. The mixed results of the effects of VASL on operational and safety measures led to the further investigation of the algorithm used for VASL control. A new VASL algorithm was developed which increased work zone throughput by 11.5%, compared to the existing algorithm, and decreased both rear-end and lane changing conflicts significantly.

Authors	Jie Fang, University of Alberta, Canada Md. Hadiuzzaman, University of Alberta Md. Ahsanul Karim, University of Alberta, Canada Ying Luo, University of Alberta, Canada Tony Z. Qiu, University of Alberta, Canada
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Highway Safety Performance
Paper Number	14-1568
Paper Title	Novel Variable Speed Limit Control Strategy with Traffic State Prediction-Based Collision Probability Assessments
Abstract	With the ever-increasing number of vehicles on roadways, traffic safety has become one of the most serious challenges facing transportation engineers. To mitigate traffic safety concerns, a variety of active traffic control measures have been intensively investigated and consequently deployed, such as Variable Speed Limit (VSL). VSL is usually adopted to advise a lower speed limit more appropriate to a congested traffic condition, and to take advantage of the homogenous traffic flow effect. However, in earlier studies, due to the absence of traffic state prediction, the impact of the applied VSL control was not quantitatively analyzed. In this study, a Model Predictive Control (MPC) framework was adopted to predict and assess future traffic states. Taking into consideration the impact of VSL control, a macroscopic traffic flow model was also adopted. The collision probabilities of the predicted traffic states were assessed by a precursor-based collision prediction model to determine the optimized control signal. By this design, the proposed algorithm controller provides a robust method for evidently determining the VSL control plan to optimize safety performance over a traffic network. To evaluate the proposed control algorithm, a field-data-based simulation study was conducted to reproduce a major ring road in Edmonton, Alberta, Canada. The proposed algorithm was used to implement VSL control on the studied 11-kilometer freeway stretch, and then compared with the uncontrolled scenario. The evaluation proved that the proposed VSL control algorithm can effectively reduce the collision probability of a congested traffic network with no significant compromises in mobility.

Authors	Tazeen Fatema, Carleton University, Canada Karim Ismail, Carleton University, Canada Yasser Hassan, Carleton University, Canada
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	811
Session Title	Analytical Models for Safe and Sustainable Transport
Paper Number	14-3236

Paper Title	Validation of Probabilistic Model for Design of Freeway Entrance Speed Change Lanes
Abstract	Traffic operation on entrance speed change lanes (SCL) is more complicated than exit-SCL as vehicles are always interacting during merging from SCL to freeway. An adequate length of SCL provides road users sufficient time for acceleration and searching gap so that they can comfortably merge onto the freeway. This study focuses on analyzing the entrance SCL from a safety point of view within a probabilistic framework. Sixteen entrance limited-type SCLs along Highway 417 were considered to investigate the link between the probabilistic measure, probability of non-compliance (Pnc), and collision frequency. Regression analysis was conducted in order to quantify the effect of geometry of SCL, driver merging behavior along SCL, road users' exposure, and Pnc on collision occurrence. The model containing Pnc outperformed other models, and the inclusion of Pnc in the regression models resulted in significant improvement in model fit. The study provides positive evidence regarding the validity of Pnc as a surrogate measure of safety.

Authors	Gregory M. Fitch, Virginia Tech Transportation Institute Kevin Grove, Virginia Tech Transportation Institute Richard J. Hanowski, Virginia Tech Transportation Institute Miguel A. Perez, Virginia Tech Transportation Institute
Sponsoring Committee	AND10, Vehicle User Characteristics
Session Number	338
Session Title	Naturalistic Driving Data and Driver Behavior
Paper Number	14-1108
Paper Title	Using Naturalistic Driving Data to Investigate Light Vehicle and Commercial Motor Vehicle Driver Compensatory Behavior While Conversing on a Cell Phone
Abstract	Some empirical studies have found driving performance degrades when conversing on a cell phone. In contrast, naturalistic driving studies have not found conversing on a cell phone to be associated with an increased safety-critical event risk. Some naturalistic driving studies have also found commercial motor vehicle drivers to be at a decreased safety-critical event risk when conversing on a hands-free cell phone. Determining why driving performance decrements have not translated into an increased safety-critical event risk is essential for understanding driver distraction. One possible explanation is that drivers compensate for the increased workload of conversing on a cell phone by increasing their safety margins. This study investigated whether such driver adaptation took place in both light vehicle and commercial motor vehicle naturalistic driving datasets. Instances where drivers conversed on a cell phone were selected. Baseline epochs that took place 30 seconds prior to the start of the call were sampled. Drivers' travel speed, headway, inclination to travel in the slowest lane, inclination to change lanes, and lane-keeping performance were compared. Commercial motor vehicle drivers were found to significantly increase their speed by 4 km/h when conversing on a cell phone. Light vehicle drivers were significantly less likely to unintentionally depart their lane when conversing on a hand-held cell phone. Based on the measures examined, drivers do not increase their longitudinal safety margins. However, they do improve their lane keeping performance. Considering that drivers look forward more often when conversing on a cell phone, the increased visual attention to the forward roadway may be the ultimate reason why conversing on a cell phone has not been found to increase safety-critical event risk.

Authors	Nick Foster, Portland State University Christopher M. Monsere, Portland State University Katherine Carlos, Portland State University
Sponsoring Committee	ANF10, Pedestrians
Session Number	731
Session Title	Designing Roadways to Improve Pedestrian Safety
Paper Number	14-2893
Paper Title	Evaluating Driver and Pedestrian Behaviors at Enhanced Multilane Midblock Pedestrian Crossings: Case Study in Portland, Oregon
Abstract	This study examines driver and pedestrian behaviors at two enhanced midblock pedestrian crossings in Portland, Oregon. One crossing is on a five-lane arterial with a posted speed of 35/45 miles-per-hour (MPH) and features six rectangular rapid flash beacon (RRFB) assemblies and a narrow median refuge. The other crossing is on a suburban arterial with four travel lanes and a two-way left-turn lane. The crossing is enhanced with four RRFB assemblies and a median island with a "Z" crossing, or Danish offset, designed to encourage pedestrians to face oncoming traffic before completing the second stage of their crossing. Approximately 62 hours of video have been collected at the two locations. A total of 351

pedestrian crossings are analyzed for driver compliance (yielding) rates, pedestrian activation rates, pedestrian delay, and conflict avoidance maneuvers. The suburban arterial crossing is also evaluated to determine its effectiveness at diverting pedestrians to cross at it instead of away from a crosswalk, as well as pedestrian compliance with the Z-crossing. This study finds that average driver yield rates at both sites are just over 90% when the RRFB is activated, which is consistent with previous studies. RRFB actuation rates range from 83% to over 90%. The results also show that approximately 52% of all crossings at the marked crosswalk at the second location are from diverted pedestrians and that the enhanced crossing captures about 82% of all crossings near the crosswalk. Finally, approximately 52%, of the pedestrians using the crosswalk follow the Z-crossing pattern through the median.

Authors John Anthony Gambatese, Oregon State University
Fan Zhang, Oregon State University
Ali Moghaddam Vahed, Oregon State University
Sponsoring Committee AHB55, Work Zone Traffic Control
Session Number 590
Session Title Vehicle Speeds in Work Zones
Paper Number 14-2454
Paper Title Implementation and Evaluation of Traffic Control Devices on Highway Nighttime Paving Projects
Abstract Highway preservation projects are commonly conducted at night and often require working in close proximity to ongoing traffic. Vehicle speed and speed variability in work zones is inextricably connected to the work zone design and the selected traffic control devices. To provide guidance on how to effectively and efficiently reduce traffic speeds, the Oregon Department of Transportation conducted a research study to investigate the impact of selected traffic control devices on vehicle speed within highway paving project work zones. The research centered around two case studies on two-lane paving projects in Oregon. On each case study, the researchers implemented multiple traffic control devices and evaluated their impact on vehicle speed. The conclusions drawn from the two case studies are different, but they all suggest that a police officer parked on the site was found to effectively reduce traffic speeds and should be used if available and feasible. The research findings also suggest using a combination of temporary reduced speed limit signs, radar speed monitoring display, and PCMS signs on both trailers and rollers will be helpful and should be easy to implement on different projects. Further research is needed to validate the research findings and better identify the advantages of one traffic control device over another.

Authors Timothy Jordan Gates, Wayne State University
Peter Tarmo Savolainen, Wayne State University
Honey-Um Maria, Wayne State University
Sponsoring Committee AHB50, Traffic Control Devices
Session Number 425
Session Title Research on Traffic Control Devices
Paper Number 14-0942
Paper Title Predicting Driver Action At Signalized Intersections Using Nested Logit Models
Abstract The primary objective of this research was to identify factors that influence whether a vehicle will stop or proceed through, either legally or illegally, when approaching a signalized intersection during the yellow indication. To accomplish this objective, naturalistic driver behavioral data were collected at 72 signalized intersection approaches selected from four distinct regions of the United States. Data were obtained for a total of 6,208 vehicles that were approaching a study intersection during the yellow interval. Using these data, a nested logit model was developed to investigate the influence of various factors on the likelihood of a driver approaching during the yellow interval to stop, proceed through legally, or commit red light running. The nested logit approach represents an improvement over prior binary logistic regression modeling by allowing simultaneous estimation of all three potential driver actions. It was determined that red light running was more likely to occur under the following conditions: 1) duration of the yellow interval was equal to or less than 4.5 seconds, 2) subject vehicle was part of a platoon, 3) approach speed limit was less than or equal to 40 mph, 4) subject vehicle was farther from the intersection at the onset of yellow, or 5) subject vehicle approached at a lower rate of speed. The results may be utilized to improve the accuracy of real-time red light running prediction algorithms, including those utilized in conjunction with traffic signal phase extension systems.

Authors	Timothy Jordan Gates, Wayne State University Peter Tarmo Savolainen, Wayne State University Honey-Um Maria, Wayne State University
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	425
Session Title	Research on Traffic Control Devices
Paper Number	14-0943
Paper Title	Impacts of Automated Red-Light-Running Enforcement Cameras on Driver Behavior
Abstract	The primary objectives of this study were to 1) determine the impact of automated red light running enforcement on driver behavior and 2) provide guidance towards the timing of yellow change intervals at locations where red light enforcement cameras exist. To accomplish these objective, naturalistic driver behavior data were covertly collected using high definition video cameras at 82 signalized intersection approaches selected from four different regions of the United States. Ten of these sites included automated red light running enforcement cameras. Data were obtained for a total of 7,306 vehicles that were approaching a study intersection during the yellow interval. The following response variables were investigated: brake response time; deceleration rate; time of entry into the intersection after the onset of red; and driver action, which was categorized as stopped, proceeded through legally, or proceeded through illegally (i.e., red light running). The following conclusions related to the presence of red light enforcement cameras were drawn from the research findings: 1) Drivers react approximately 5 percent (0.05 seconds) more quickly to the yellow indication when stopping at locations where red light cameras are present; 2) red light cameras do not impact deceleration rates; 3) red light cameras increase the likelihood of stopping by 2.4 percent; 4) red light cameras decrease the likelihood of red light running by 19.4 percent; and 5) red light cameras reduce the intersection entry time for red light runners by approximately 43 percent (0.24 seconds). As camera enforcement of red light running had little to no impact on brake response times or deceleration rates, it is not necessary to deviate from baseline values for yellow change interval timing.

Authors	Daba Shabara Gedafa, University of North Dakota Bryan Kaemingk, University of North Dakota Brian Mager, University of North Dakota Jeffrey Pape, University of North Dakota Mark Tupa, University of North Dakota Taryn Bohan, University of North Dakota
Sponsoring Committee	ANF10, Pedestrians
Session Number	731
Session Title	Designing Roadways to Improve Pedestrian Safety
Paper Number	14-1155
Paper Title	Impacts of Alternative Yield Sign Placement on Pedestrian Safety
Abstract	Although pedestrian crashes account for only 1 percent of reported motor vehicle crashes in the United States, they account for 14 percent of fatal crashes. Pedestrians are at a higher risk of fatalities than automobile operators when crashes per traveling distance are considered. Because of the high societal costs of pedestrian crashes, measures designed to reduce their frequency and severity should receive high priority. Additional countermeasures such as crosswalks and signs need to be devised to decrease pedestrian-automobile collisions. The main objectives of the study are to investigate the effects of yield sign yielding for pedestrians and traffic speed and its implication on pedestrian safety. City of Grand Forks and the University of North Dakota have been used as test sections. Yielding for pedestrian and traffic speed without and with the sign have been collected. Two-proportion z-test and an independent t-test have been used to investigate the effect of the sign on yielding for pedestrian and traffic speed, respectively. Placing yield sign at the crosswalk is the most effective way of increasing yielding for pedestrian. Percent drivers not yielding for pedestrian and pedestrian-driver conflict are significantly lower in the presence of the sign. The presence of the sign results in lower average traffic speed. This implies the risk to pedestrian will be less if there is crash. KEY WORDS: yield sign, pedestrian safety, traffic speed, crosswalk, yielding for pedestrian.

Authors	Kelvin Goh, Monash University, Australia Graham Currie, Monash University, Australia Majid Sarvi, Monash University, Australia David Logan, Monash University, Australia

Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	710
Session Title	Truck and Bus Safety
Paper Number	14-1894
Paper Title	Investigating Road Safety Impacts of Bus Priority Using Experimental Microsimulation Modeling
Abstract	The safety implications of implementing bus lanes on road corridors remain unclear given that findings from previous research have been mixed. The authors recent research demonstrated improvements in road safety resulting from bus priority in Melbourne however causal factors for this effect remain to be explored. In this study, an experimental microscopic traffic simulation modelling approach was adopted to explore the road safety effects of implementing bus lanes on a representative road corridor in Melbourne. Models compare traffic 'conflicts' patterns between three traffic configurations – (1) mixed traffic (base case, no priority), (2) kerbside lane reallocated for buses and (3) new kerbside lane added for buses. For each configuration, the safety performance of the road corridor including intersection approaches and bus stop locations were measured using two safety performance indicators – (1) Deceleration Rate to Avoid a Crash (DRAC) and (2) Crash Potential Index (CPI). Overall results showed that kerbside bus lanes reduce conflict occurrences at intersection approaches and bus stop locations regardless of scheme design (2 or 3). Results point to reductions in rear end and side swipe accidents as a major driver of the reduced road accident risk consistent with outcomes in our previous research. Bus priority acts to remove bus movements from traffic flows and provides new and separate road space for kerbside turning traffic at intersections. This acts to reduce side swipe and rear end traffic conflicts thus improving road safety. Implications for policy and future research are suggested.

Authors	Radhameris A. Gomez, University of Massachusetts, Amherst Siby Samuel, University of Massachusetts, Amherst Matthew Ryan Elam Romoser, University of Massachusetts, Amherst Michael A. Knodler, University of Massachusetts, Amherst John Collura, University of Massachusetts, Amherst Donald L. Fisher, University of Massachusetts, Amherst
Sponsoring Committee	ANB50, Traffic Control Devices and ANF10, Pedestrians
Session Number	515
Session Title	Pedestrian Planning, Design, and Safety
Paper Number	14-1834
Paper Title	Mitigation of Pedestrian-Vehicle Conflicts at Stop-Controlled T-Intersections
Abstract	Urban areas house 80% of the population and account for almost two-thirds of all pedestrian fatalities making safe accommodation of pedestrians a key priority (1). Crosswalks at T intersections are a prime example of an intersection geometry in such areas that is challenging both for the driver and pedestrians alike. Previous research validates the advantages of advance yield markings over other more common unsignalized midblock crosswalk treatments. Such markings could also prove effective at unsignalized T intersection crosswalks, especially in those multiple-threat situations where the drivers' view of critical information was obscured by other yielding vehicles. A simulator was used to compare the effectiveness of advanced yield markings and standard crosswalk markings on drivers' behaviors at unsignalized T intersections. Measures were gathered both of scanning behaviors using an eye tracker and stopping/yielding behaviors using the data from the simulator. Crosswalks in the simulated world were located on both the near and far side of the side street (from the participant driver's perspective). A vehicle obstructing the driver's view of pedestrians in the crosswalk was placed either in the left travel lane or the right travel lane. There was a main effect of the treatment (advance yield markings were more safe) and the location of the crosswalk (the far side was more safe). And there was an interaction between the treatment and the location of the obstruction (advance yield markings had an effect on glances only when the obstructing vehicle was in the left travel lane). There are clear implications for practice.

Authors	Yanyong Guo, Southeast University, China Pan Liu, Southeast University, China Lu Bai, Southeast University, China Chengcheng Xu, Southeast University, China Jun Chen, Southeast University, China
Sponsoring Committee	ANF20, Bicycle Transportation

Session Number	526
Session Title	Cyclist Safety and Operations
Paper Number	14-1921
Paper Title	Red-light Running Behaviors of E-scooters and E-bikes at Signalized Intersections in China
Abstract	A comparative analysis was conducted to compare the red-light running behaviors of the riders of e-bikes, e-scooters and bicycles as they were crossing signalized intersections. The crossing behaviors of 5,646 individuals, including the riders of 1,568 e-bikes, 2,612 e-scooters, and 1,466 bicycles were observed. The average red-light running rate for e-bikes, e-scooters and bicycles at the selected sites was found to be 24.9%, 25.0%, and 18.3%, respectively. The red-light running rates for e-bikes and e-scooters are significantly higher than those for bicycles. The difference in the red-light running rates for e-bikes and e-scooters is not statistically significant. A binary logit model was then developed to evaluate how various factors affect the red-light running rates of two-wheeled vehicles at signalized intersections. Comparing the traffic conflicts caused by various red-light running two-wheelers, it was found that bicycles were slightly more likely to be involved in traffic conflicts than e-bikes and e-scooters as they were crossing intersections during a red pedestrian phase. In addition, e-bikes are less likely to be involved in traffic conflicts in the middle stage of a red pedestrian phase than e-scooters and bicycles. Both e-scooters and e-bikes have higher crossing speeds than bicycles. Even though e-scooters have significantly higher speeds than e-bikes as they were crossing intersections during green phases, the difference in the crossing speeds between red-light running e-bikes and e-scooters is not statistically significant.
Authors	Md. Hadiuzzaman, University of Alberta, Canada Jie Fang, University of Alberta, Canada Md. Ahsanul Karim, University of Alberta, Canada Ying Luo, University of Alberta, Canada Tony Z. Qiu, University of Alberta, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-1564
Paper Title	Modeling Driver Compliance with Variable Speed Limits and Quantifying Impacts of Compliance Levels and Control Strategy in Mobility and Safety
Abstract	Variable Speed Limits (VSL) aim to improve freeway mobility and safety by controlling collective behaviors of drivers who are coming from upstream and ramps. Thus, VSL benefits should be positively correlated with VSL compliance level (CL). Surprisingly, a number of heuristic VSL control strategies have shown that VSL with increased CLs can, in fact, increase travel time. However, it is yet to be analyzed whether or not that outcome is due to the control strategy design or the CL. Some recent studies have shown that, regardless of CL, a proactive optimal VSL control provides mobility benefits; however, no evidence was found to indicate which CL is most achievable in practice, nor was a description found for the distribution of speed of a given VSL. The objective of this paper is to quantify the relative contribution that CLs with a proactive optimal VSL control have on improving mobility and safety. In this study, several CL-to-VSL strategies were modeled after real-world driver behavior. To quantify the impact of CLs only, speed distributions were altered with the static speed limit. Then, the benefits were quantified by implementing a proactive optimal VSL control strategy with the CLs. The simulation evaluation showed that both VSL mobility and safety benefits are positively correlated with increasing CLs. Specifically, the travel time, throughput, and collision probability are improved in the range of 5-15%, 6-8%, and 50-60%, respectively. The study findings will help guide transportation agencies in deploying VSL control considering CL, so as to achieve maximum mobility and safety benefits.
Authors	Asso Hamzehei, Queensland University of Technology, Australia Edward Chung, Queensland University of Technology, Australia Mark Miska, Queensland University of Technology, Australia
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-5726
Paper Title	Traffic Safety Risks, Trends, and Pattern Analysis on Motorways
Abstract	Crashes that occur on motorways contribute to a significant proportion (40-50%) of non-recurrent motorway congestions. Hence, reducing the frequency of crashes assist in

addressing congestion issues (Meyer, 2008). Analysing traffic conditions and discovering risky traffic trends and patterns are essential basics in crash likelihood estimations studies and still require more attention and investigation. In this paper we will show, through data mining techniques, that there is a relationship between pre-crash traffic flow patterns and crash occurrence on motorways, compare them with normal traffic trends, and that this knowledge has the potentiality to improve the accuracy of existing crash likelihood estimation models, and opens the path for new development approaches. The data for the analysis was extracted from records collected between 2007 and 2009 on the Shibuya and Shinjuku lines of the Tokyo Metropolitan Expressway in Japan. The dataset includes a total of 824 rear-end and sideswipe crashes that have been matched with crashes corresponding traffic flow data using an incident detection algorithm. Traffic trends (traffic speed time series) revealed that crashes can be clustered with regards to the dominant traffic patterns prior to the crash occurrence. K-Means clustering algorithm applied to determine dominant pre-crash traffic patterns. In the first phase of this research, traffic regimes identified by analysing crashes and normal traffic situations using half an hour speed in upstream locations of crashes. Then, the second phase investigated the different combination of speed risk indicators to distinguish crashes from normal traffic situations more precisely. Five major trends have been found in the first phase of this paper for both high risk and normal conditions. The study discovered traffic regimes had differences in the speed trends. Moreover, the second phase explains that spatiotemporal difference of speed is a better risk indicator among different combinations of speed related risk indicators. Based on these findings, crash likelihood estimation models can be fine-tuned to increase accuracy of estimations and minimize false alarms.

Authors	Hillary N. Isebrands, Federal Highway Administration Shauna Hallmark, Iowa State University Neal R. Hawkins, Iowa State University
Sponsoring Committee	ANB75, Roundabouts
Session Number	786
Session Title	Roundabout Perception and Reality: Speed, Pedestrians, Capacity
Paper Number	14-5582
Paper Title	Approach Speed Effects at Rural High-Speed Intersections: Roundabouts Versus Two-Way Stop Control
Abstract	Speed can increase the risk injury producing crashes, especially at intersections where vehicles may be approaching an intersection and entering an intersection with high speed differentials. It is known that roundabouts force all drivers to reduce their speed in the intersection; however, no advanced approach speed data was available for roundabouts with high speed approaches to verify this phenomenon. This research performed a comparative evaluation of the difference in the average approach speeds between rural roundabouts and rural two-way stop control intersections and between rural roundabouts with and without rumble strips on the intersection approaches. Approach speed data proved that drivers are able to slow down in advance of roundabouts on rural roadways and the mean speeds at 100 ft from the yield line were 2.5 mph lower than mean speeds at 100 ft from the stop bar at stop controlled approaches. Additionally, a comparison between roundabout approaches with and without rumble strips showed mean speeds 4.3 mph and 3.3 mph lower at 100 ft and 250 ft from the yield line, respectively, for the approaches with rumble strips; however, the variation in speeds increased with the introduction of rumble strips.

Authors	Jungwook Jun, Virginia Department of Transportation Randall Guensler, Georgia Institute of Technology Jennifer Harper Ogle, Clemson University
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-4232
Paper Title	Potential GPS-Observed Driving Behavior Exposure Metrics for Crash Risk Analysis
Abstract	Using second-by-second naturalistic data collected by a large fleet of GPS instrumented vehicles, a relationship among longitudinally-observed driving behavior and exposure metrics (mileage, driving duration, speeding, hard acceleration or deceleration, cruise speed duration, unfamiliar roadway exposure, left/right turn exposure, and crash location exposure) and numbers of crash involvements was investigated. With the initially proposed 413 driving behavior exposure metrics, this study identified 22 driving behavior exposure

metrics that demonstrated significant difference between the crash-involved and the crash-not-involved drivers after the statistical analyses. Further, accompanied by the 22 driving behavior exposure metrics, the study determined five most contributing metrics in predicting the potential crash involvement status of individuals as the following: mileage in rural area during the afternoon, frequency of over-speed activity (>= 15mph) per mile on arterials during the morning, frequency of hard deceleration (>= 6mph/s) per mile on local streets during the night, frequency of hard deceleration (>= 8mph/s) per mile on freeways during the morning, and frequency of hard deceleration (>= 8mph/s) per mile on freeways during the afternoon. Such GPS-observed driving behavior exposure metrics supported existing safety campaigns such as anti-aggressive driving and speed enforcement to reduce the risk and the number of future crashes. When combined with the automobile insurance premium structure, these driving behavior and exposure metrics could be used to help drivers rectify their driving habits and patterns through proper education and monitoring programs. Immediate implantation of such driving metrics as part of safety measures is arduous due to requirement of sophisticated and expensive data collection systems. However, the recent advancement in mobile telecommunication technology would provide opportunities to monitor individual driving activities for a long-time period.

Authors	Ioannis Kaparias, City University London, United Kingdom Michael G.H. Bell, University of Sydney, Australia Thomas Biagioli, Imperial College London, United Kingdom Liban Bellezza, City University London, United Kingdom Bill Mount, Imperial College London, United Kingdom
Sponsoring Committee	AHB50, Traffic Control Devices, AND10, Vehicle User Characteristics, and AND40, Visibility
Session Number	423
Session Title	Methods for Field Assessment and Evaluation of Driving Behavior and Roadway Safety Systems
Paper Number	14-2751
Paper Title	Behavioural analysis of vehicle-pedestrian interactions: The case of street designs with elements of shared space
Abstract	This paper describes the development and implementation of qualitative behavioural criteria in order to analyse the conduct of pedestrians and vehicles when they are required to interact with each other, with particular interest to street designs with elements of shared space. The new behavioural analysis technique is developed by identifying the fundamental principles that underpin existing traffic analyses, such as traffic conflicts techniques, and adapting those to a qualitative framework that describes the mindset and rationale of road users. The technique is then applied to a case study in London, using video data from periods before and after the redevelopment of the Exhibition Road site from a conventional dual carriageway to a modern design with some elements of shared space. With the main goals being to assess the pedestrians' confidence and the vehicles' tolerance/patience when forced to interact with each other, behavioural trends are related to instantaneous characteristics of the vehicle flow (vehicle approach speed and traffic density). The data produced are used to develop qualitative behavioural relationships for pedestrian-vehicle interactions, as well as location-specific conclusions for the Exhibition Road site.

Authors	Ali Kassim, Carleton University, Canada Karim Ismail, Carleton University, Canada Yasser Hassan, Carleton University, Canada
Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	526
Session Title	Cyclist Safety and Operations
Paper Number	14-2095
Paper Title	Automated Measuring of Cyclist and Motor Vehicle Postencroachment Time at Signalized Intersections
Abstract	Conflicts between motor vehicle and cyclists at a signalized intersection were characterized in this study using an objective conflict indicator; Post- Encroachment Time (PET). Traffic video data was collected for a total of 84 hours over nine days at two signalized intersections in the Downtown area of Ottawa. PET was calculated using three different measurement methods, [i] video timer measurement (MVTM) method, [ii] frame count measurement (MFCM) method and [iii] automated measurement (AM) method, for two types of conflicts, right-turn and left-turn. The movements "right, through and left" of a total 2736 cyclists have been observed. Cyclist stream interacted with a total of 4103 right-

turn vehicles and 7701 left-turn vehicles. A total of 384 conflict events for PET (0, 3] seconds between cyclists and vehicles were analyzed in this study. An automated video analysis technique was developed to measure the PET between cyclists and motor vehicles. The results of the conflict analysis showed that the average absolute error of PET between the MFCM and AM methods was 0.12 second and the standard deviation was 0.15 second. The evaluation results showed that there was a very good agreement in the PET classification of individual conflicts between the MFCM and AM methods. The classification was conducted by counting events with PET under conflict severity levels of 3.0, 2.0 and 1.0 seconds. The evaluation result showed that the coefficient of determination between the AM and MFCM methods was found to be 0.938. The automated video analysis technique has a promising practical benefits including saving time and staff resource while providing reliable measurements.

Authors Zhibin Li, Southeast University, China
Pan Liu, Southeast University, China
Ye Li, Southeast University, China
Chengcheng Xu, Southeast University
Hao Yu, Southeast University, China
Yuanyuan Zhang, University of California, Berkeley

Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation
Session Number 562
Session Title Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number 14-3515
Paper Title Development of Variable Speed Limit Strategy Based on Car-Following Behaviors for Improving Freeway Safety Under Severe Weather

Abstract Severe weather reduces sight distance and increases stopping distance of traveling vehicles. Traffic collisions are likely to occur when vehicles encounter traffic congestions on freeways under severe weathers. The primary objective of this study is to develop a control strategy of variable speed limit (VSL) to improve freeway safety in different types of weather conditions. The control strategy aims to reduce vehicle speeds gradually prior to congestions. A car-following model was used to simulate the behaviors of drivers in different visibility and road adhesion conditions. The time-to-collision was calculated to evaluate the collision potentials on freeway mainlines. Five typical severe weathers were tested. The simulation results showed that the VSL control strategy proposed in this study effectively reduced collision potentials under various types of severe weathers. The collision potential was reduced by 53.98% in heavy fog weather to 91.69% in heavy rain weather. The VSL strategy was compared to a previous VSL algorithm. The results showed that the strategy in this study outperformed the previous one in reducing collision potentials in most of cases.

Authors Jun Liu, University of Tennessee, Knoxville
Bryan Bartnik, University of Tennessee, Knoxville
Stephen H. Richards, University of Tennessee, Knoxville
Asad J. Khattak, University of Tennessee, Knoxville

Sponsoring Committee AHB60, Highway/Rail Grade Crossings
Session Number 442
Session Title Highway-Rail Grade Crossings: Human Factors Research and Analysis
Paper Number 14-4413
Paper Title How are Driver Characteristics related to Safety at Railroad-Crossings? The case of Passive Railroad Grade Crossings

Abstract Injury and fatality rates at highway-rail grade crossings are often related to drivers' characteristics and contextual factors. This study focuses on analyzing associations of driver characteristics (such as age, gender, education level, driver training) with safe and unsafe driving behaviors (mainly speeds) at rural highway-rail grade crossings. The study conducts a series of experiments on a high-fidelity driving simulator at the University of Tennessee, focusing on the role of passively-controlled crossings that do not require drivers to stop or slow down under most circumstances. Based on rigorous analysis of data collected from 64 individuals, the results reveal that older drivers (> 65 years) have slower speeds compared with younger drivers when approaching a rail-road crossing. Drivers' training backgrounds and education levels have limited associations. In addition, drivers' knowledge and personal experience with crossings is also associated with their behavior at highway-rail grade crossings. This study also explores the potential correlations between drivers' personal experience with crossings and their driving performance while crossing highway-rail

crossings. Drivers who passed highway-rail crossings frequently can get used to the crossing and not slow down. The implications of the findings are discussed in the paper.

Authors	Guangquan Lu, Beihang University, China Yunpeng Wang, Beihang University, China Xinkai Wu, California State Polytechnic University, Pomona Henry X. Liu, University of Minnesota, Twin Cities
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-5613
Paper Title	Analysis of Yellow-Light Running at Signalized Intersections Using High-Resolution Traffic Data
Abstract	Many accidents occurring at signalized intersections are closely related to drivers' decision of running through intersection during yellow light, i.e., yellow-light running (YLR). Therefore it is important to understand of the relationships between YLR and the factors which contribute to drivers' decision of YLR. This requires collecting a large amount of YLR cases. However, existing data collection method, which mainly relies on video cameras, has difficulties to collect a large amount of YLR data. In this research, we propose a method to study drivers' YLR behaviors using high-resolution event-based data from signal control systems. We use 8 months' high-resolution data collected by two stop-bar detectors at an intersection located in Minnesota and identified over 30,000 YLR cases. To identify the possible reasons for drivers' decision of YLR, this research further categorized the YLR cases into four types: "in should-go zone", "in should-stop zone", "in dilemma zone", and "in option zone" according to driver's location when signal turns to yellow. Statistical analysis indicates there were about 10% of YLR drivers that cannot run through intersection before traffic light turns to red. Furthermore, based on a strong correlation between hourly traffic volume and number of YLR events, this research developed a regression model that can be used to predict the number of YLR events based on hourly flow rate.

Authors	Ying Ni, Tongji University, China Menglong Wang, Tongji University, China Keping Li, Tongji University, China
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	425
Session Title	Research on Traffic Control Devices
Paper Number	14-1433
Paper Title	Impacts of New Chinese Regulation of Yellow Signal on Driving Behavior and Rear-End Collision Potential
Abstract	A new regulation of solid yellow has been implemented at the beginning of this year in China, saying that drivers should stop when they are approaching yellow light. Yellow violation has been punished for the first week, but then it has been abolished since some safety problems have aroused during the initial periods of its implementation, and the public discussed about the necessity of installing green signal countdown devices (GSCD) to support people to take proper actions. The paper aims to find out how the new regulation impacts driving behavior, and explore whether GSCD devices are helpful to improve traffic safety under the new situation. Based on field observation and data collection at four intersections (two of them are GSCD intersections) before and after the regulations implementation, a comparison of driving behavior including driver type distribution (namely aggressive, normal and conservative drivers), speed distribution, car following behavior has been carried out; Models of drivers stop/go decision and rear-end collision probability has been developed, based on which the distribution of indecision zones and rear-end collision potential has been estimated by using Monte Carlo simulation. The comparison results showed that: (1) the new regulation helps to restrain aggressive driving behavior effectively, and meanwhile it encourages conservative behavior. It helps to reduce approaching speeds and speeding percentages significantly, larger car following headways are more likely to be accepted; (2) the new regulation can significantly shift indecision zones towards the stop line resulting in more rear-end collisions occurring near stop line while much fewer collisions at upstream of intersection; (3) in most cases GSCD devices result in higher rear-end collision potential, especially for vehicles in indecision zones. Based on the above findings, we recommend that education should be given to drivers in order to avoid too conservative behaviors; GSCD devices are not recommended to install since there they have negative effects on traffic safety in terms of increasing rear-end collision potential.

Authors	Anurag Pande, California Polytechnic State University, San Luis Obispo James Loy, California State Polytechnic University, San Luis Obispo Vinayak V. Dixit, University of New South Wales, Australia Katherine Spansel, Louisiana State University Brian Wolshon, Louisiana State University Joshua Kent, Louisiana Department of Transportation
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-5291
Paper Title	Exploration of Naturalistic Driving Data for Identifying High Crash Risk Highway Locations
Abstract	This paper describes a project that was undertaken using naturalistic driving data collected via Global Positioning System (GPS) devices to examine the relationship between long-term crash frequency and repeated occurrences of high magnitude jerks while decelerating in the driving data. The motivation to look for correlations between abrupt/abnormal driving maneuvers and long-term crash frequency was to demonstrate a proof-of-concept for proactive safety assessments of crash prone locations. Linear referencing in ArcMap was used to link the GPS data with roadway characteristic data from a roadway base map. The linear referencing methodology was the key to relate the GPS driving data with the freeway corridor of interest, i.e., US 101 northbound (NB) and southbound (SB) in San Luis Obispo California. The process used to merge GPS data with quarter-mile freeway segments for traditional crash frequency analysis is also discussed in the paper. Negative binomial regression analyses showed that proportion of high magnitude jerks while decelerating on freeway segments (from the driving data) was significantly related with the long-term crash frequency of those segments. Applying the same model, average daily traffic (ADT), roadway curvature and presence of an auxiliary lane were found to be insignificant. The results from this exploration are promising since the data used to derive the variable(s) used in the analysis can be collected using most off-the-shelf GPS devices, including many smartphones. Keywords: Naturalistic driving data, crash frequency, negative binomial model, traffic safety.

Authors	Yi Qi, Texas Southern University Qun Zhao, Texas Southern University
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	425
Session Title	Research on Traffic Control Devices
Paper Number	14-3914
Paper Title	Safety Impacts of Signalized Lane Merge Control at Highway Work Zones
Abstract	Lane closures due to highway work zones present many challenges to the goal of ensuring smooth traffic operations and a safe environment for drivers and workers. Late merge behavior at the work zone closure is a dangerous behavior that impacts the traffic conflicts upstream of work zone closures. The objective of this research is to analyze the safety impacts of using a signalized lane control strategy at the work zone merge points. To achieve the objective of this research, a field study was conducted at a highway work zone to collect traffic and driver behavior data, and a two-stage, simulation-based approach was used to analyze the safety impacts of implementing a signalized lane merge control strategy at the studied work zone. At the first stage, micro-simulation models were developed and calibrated based on field data to generate vehicle trajectories. At the second stage, FHWA's Surrogate Safety Assessment Model (SSAM) was employed to identify potential conflicts under different traffic conditions. The research concludes that a proposed signal control device could significantly reduce lane-change conflicts at work zone merge points. In addition, recommendations on the signal cycle length and timing splits are provided.

Authors	Fengxiang Qiao, Texas Southern University Jing Jia, Texas Southern University Lei Yu, Texas Southern University Dong Zhai, GeoFields, Inc
Sponsoring Committee	AHB55, Work Zone Traffic Control
Session Number	253
Session Title	Work Zone Traffic Control for Safety and Mobility
Paper Number	14-1782
Paper Title	Radio Frequency Identification-Based Drivers' Smart Assistance System to Enhance Safety and Reduce Emissions in Work Zone

Abstract The work zone is an area of roadway with highway construction, maintenance, or utility-work activities. According to the National Highway Traffic Safety Administration, many traffic accidents and fatalities happened in work zone areas. A lot of traditional safety countermeasures have been utilized in work zone areas including installing special signs and barriers, and posting suitable speed limits. However, these have not fully solved the problems. Radio Frequency Identification (RFID) is a globally accepted technology, which has a great success in business management for decades, which can be employed as an advisory device communicating vehicles with infrastructures in work zone areas. The purpose of this paper is to develop a RFID based Drivers Smart Assistance System (DSAS) to improve the traffic safety and air quality in work zone. The RFID devices would provide the opportunity to communicate between vehicles and roadside in real-time, which is then compensated with GPS and other sensors for dynamic traffic management. With such assistant system, suitable verbal and image warning messages will be provided to drivers when approaching work zones. Real road tests in Houston area by twenty drivers were conducted and the impacts on vehicle speed, safety and vehicle emissions are examined. Statistical analyses results from tests show that the DSAS will help drivers to take earlier actions to decelerate and reduce speeds. Besides, this system can also help to reduce most types of vehicle emissions, and receives good evaluations from all test subjects. It is recommended further testing and improving this promising system in even broader tests.

Authors Riccardo Rossi, University of Padua, Italy
Massimiliano Gastaldi, University of Padua, Italy
Gregorio Gecchele, University of Padua, Italy
Francesco Biondi, University of Padua, Italy
Claudio Mulatti, University of Padua, Italy

Sponsoring Committee AND10, Vehicle User Characteristics
Session Number 441
Session Title Driving Through Curves and Work Zones and Past Roadside Vegetation
Paper Number 14-3662
Paper Title Traffic-Calming Measures Affecting Perceived Speed in Approaching Bends with On-Field Validated Virtual Environment

Abstract With the aim of reducing the number of road traffic deaths around the world, the United Nations General Assembly has proclaimed the years 2011-2020 as the Decade of Action for Road Safety. Excessive speed is one of the main problems to be overcome. The aim of this study is to test the effectiveness of traffic-calming measures in reducing drivers' speed along a road with a dangerous bend in an inland area near Venice, Italy. Both the driving simulator of the Transportation Laboratory of the University of Padova and the simulated scenario were first validated by reproducing the study site environment. Once the scenario had been validated, a driving simulator experiment was carried out to analyse changes in speed profiles due to various countermeasures: evenly spaced guide posts, tall guide posts, narrowing guide posts, and dragon's teeth markings. Both tall and narrowing guide posts served to reduce drivers' speed by up to 2.7 km/h. Interestingly, unlike tall guide posts, which did not produce any detrimental effect on drivers' behavior, narrowing guide posts led drivers occupy more variable positions within the lane. In view of this at-risk behavior, the convenience of using such measures to produce an apparent narrowing of the lane on real roads is discussed. In conclusion, the usefulness of this study is twofold. It first rules in favor of using driving simulators as reliable research tools to reproduce drivers' real behavior; second, it provides effective, low-cost measures to counteract excessive speed on dangerous road sections.

Authors Taha Saleem, Ryerson University, Canada
Bhagwant Persaud, Ryerson University, Canada
Amer Shalaby, University of Toronto, Canada
Alexander Ariza, University of Toronto, Canada

Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation
Session Number 562
Session Title Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number 14-5099
Paper Title Can Microsimulation Be Used to Estimate Intersection Safety? Case Studies Using VISSIM and Paramics

Abstract A safety prediction model is designed to estimate the safety of a road entity and, in most cases, these models link traffic volumes to crashes. A major problem with such models is that crashes are rare events and that crash statistics do not take into account many factors

that may have contributed to the crashes. The use of traffic conflicts to measure safety can overcome these problems since conflicts occur more frequently than crashes and can either be easily measured in the field, or estimated using microsimulation models. For the purpose of this paper, crash prediction models are developed from simulated peak hour conflicts for a group of urban 4-legged signalized intersections in Toronto, Canada, and their predictive capabilities are evaluated. Two microsimulation packages, VISSIM and Paramics, are used as case studies. To further demonstrate the versatility of the approach, VISSIM is used with pre-calibrated parameter values while a substantial effort is devoted to calibrating Paramics parameters using the crash data. To demonstrate the predictive capability of the crash-conflict models, specifically to test whether the models can capture the effects of geometric and operational variables, the effects of a hypothetical left turn treatment on crashes and conflicts are explored and compared to results of an empirical Bayes study that evaluated actual treatments in the same city. For this objective, the predictive ability of the models for intersections in various AADT ranges and with various combinations of left and right turn lanes is also assessed. The overall results indicate that the use of simulated conflicts is a viable and promising approach for intersection safety estimation.

Authors Nicolas Saunier, Polytechnique Montreal, Canada
Mohamed Gomaa Mohamed, Polytechnique Montreal, Canada
Sponsoring Committee ANB20, Safety Data, Analysis and Evaluation
Session Number 562
Session Title Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number 14-2380
Paper Title Clustering Surrogate Safety Indicators to Understand Collision Processes
Abstract As time series are collected through more and more pervasive devices carried by users and vehicles, new tools are necessary to understand and mine the large amounts of data being thus generated. This work proposes a new similarity measure for time series that is applied to surrogate measures of safety and other indicators characterizing road user interactions. The new similarity measured based on the aligned longest common sub-sequence is paired with a custom clustering algorithm that identifies prototypes for each cluster of indicators. The methods is applied to five indicators, including time to collision and probability of collision, for a large real world dataset of traffic videos of collisions and conflicts. The results confirm the general assumption of surrogate methods for safety analysis that some interactions without a collision have very similar processes to collisions. It also highlights the danger of using other interactions without a collision that seem to share no similarities with collisions.

Authors Usama Elrawy Shahdah, University of Waterloo, Canada
Frank Saccomanno, University of Waterloo, Canada
Bhagwant Persaud, Ryerson University, Canada
Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Highway Safety Performance
Paper Number 14-4289
Paper Title Developing Crash-Conflict Model for Safety Performance Analysis and Estimation of Crash Modification Factors for Urban Signalized Intersections
Abstract Surrogate safety measures based on high risk vehicle interactions and traffic conflicts have been used to provide a more causal perspective on lack of safety at a given location for different road and traffic conditions. The traffic conflict approach, however, has been criticized for lacking a formal link to observational crashes, i.e., to actual safety performance, which can be viewed as being the only verification of transportation system failure from a safety perspective. Hence, a link to observed crashes provides an observational basis for the use of simulated traffic conflicts to identify sites with potential safety problems and for suggesting and evaluating cost-effective treatments. This paper presents a statistical relationship between observed crashes and simulated traffic conflicts for a range of conflict thresholds and simulation runs. Conflicts were simulated for a sample of signalized intersections from Toronto using a VISSIM microscopic traffic simulation platform. The effect of conflict threshold and number of simulation runs in applying this relationship for estimating countermeasure crash modification factors (CMFs) is discussed. The results support the view that CMFs can be estimated more reliably when an appropriate number of simulation runs and conflict thresholds are used in the calibration of the crash-conflict relationship.

Authors	Jaehyun So, University of Virginia Byungkyu (Brian) Park, University of Virginia Sage M. Wolfe, Ohio State University George Dedes, DGNSS Solutions, LLC
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-3077
Paper Title	Development and Validation of Vehicle Dynamics-Integrated Traffic Safety Simulation Environment for Enhanced Surrogate Safety Measures
Abstract	A vehicle dynamics model (i.e., CarSim) was integrated with a microscopic traffic simulation model (i.e., VISSIM) for a surrogate safety assessment. This idea was initiated from the fact that the microscopic traffic simulation model generates various traffic situations and the vehicle dynamics model has an extensive capability of modeling the vehicle dynamics including pitch, yaw, and roll as well as generating realistic vehicle trajectories. In addition, a driver aggressiveness model, which was derived from the Next Generation Simulation (NGSIM) project lane change vehicle trajectories, was incorporated into the lane change vehicles in VISSIM. The resulting VISSIM vehicle trajectories were processed through CarSim to account for the vehicle dynamics and the traffic conflicts were identified through the Surrogate Safety Assessment Model (SSAM). The VISSIM-CarSim integrated simulation environment resulted in 9.5 % fewer traffic conflicts as compared with the VISSIM only approach. The results of the two conflict estimation approaches, that is, one from the proposed VISSIM-CarSim integrated approach and the other from the VISSIM only approach, were analyzed to estimate their correlation with the actual traffic crashes. These correlations were then used to assess and compare the effectiveness of these two approaches for assessing traffic safety. This analysis showed that the traffic conflicts obtained from the proposed approach exhibited a stronger correlation (i.e., 0.72 correlation coefficient) with traffic crashes than the existing approach did (i.e., 0.61 correlation coefficient). Traffic conflicts computed for both approaches showed statistically significant relationships with the actual traffic crashes. In addition, a cross-validation test on the confidence intervals of the correlation coefficients showed that the correlation coefficients have very tight confidence intervals (i.e., 0.02 for both cases). This indicated that while traditional traffic conflicts can be used as a traffic safety estimator, the newly developed vehicle dynamics model-integrated traffic safety simulation environment is a superior and valid alternative for assessing the surrogate safety.

Authors	Praprut Songchitruksa, Texas A&M Transportation Institute Liteng Zha, Texas A&M Transportation Institute
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	224
Session Title	Safety Data, Analysis, and Evaluation
Paper Number	14-3544
Paper Title	Advancing Safety Performance Monitoring at Signalized Intersections Using Connected Vehicle Technology
Abstract	Crash-based safety evaluation is often hampered by randomness, lack of timeliness, and rarity of crash occurrences. This is particularly the case for technology-driven safety improvement projects that are frequently updated or replaced by newer ones before it is possible to gather adequate crash data for a reliable and defensible before-after evaluation. Surrogate safety data are commonly used as an alternative to crash data; however, its current practice is still resource intensive and prone to human errors. The advent of connected vehicle technology allows vehicles to communicate with each other as well as infrastructure wirelessly. Through this platform, vehicle movements and signal status at the facilities can be automatically and continually monitored in real time. This study explores the viability of long-term monitoring of connected vehicle data for safety performance evaluation. This paper proposes a safety monitoring application that utilizes connected vehicle data to detect potential safety indicators at signalized intersections. As limited saturation of on-board equipment (OBEs) is expected in the near-term evolution, the development focuses on a roadside equipment (RSE) application that can process data elements from OBEs via vehicle-to-infrastructure (V2I) communications using standard message sets. A microscopic simulation was designed to evaluate the effectiveness of the proposed safety indicators in detecting degrading safety performance. A signalized intersection test bed was created in VISSIM while the wireless communications capability and the application were implemented using C2X API. The evaluation results indicated that

the application can effectively detect changes in safety performance at full market penetration. Future research is needed to quantify the combination of penetration rates and monitoring periods that can yield effective detection of changes in safety performance at intersections with varying operating characteristics.

Authors	Paul St-Aubin, Ecole Polytechnique de Montreal, Canada Nicolas Saunier, Polytechnique Montreal, Canada Luis Fernando Miranda-Moreno, McGill University, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-5363
Paper Title	Road User Collision Prediction Using Motion Patterns Applied to Surrogate Safety Analysis
Abstract	Surrogate safety analysis is the process of diagnosing road safety indirectly from measures of ordinary (non-collision) road user behaviour, such as absolute speed and time-to-collision. While absolute speed has enjoyed much popularity in the literature, other measures such as time-to-collision are currently under developed. Before conflict measures such as time-to-collision can be adopted, several challenges need to be overcome, notably the problem of accurately modeling collision courses and collision probability from normal road user behaviour. This paper describes and explores the feasibility of implementing discretized motion pattern maps for the purpose of predicting potential collisions between road users and their measures based on an empirical naturalistic behaviour model calibrated from site-specific data for use in surrogate safety analysis. The methodology is applied to a pre-existing framework which extracts road user trajectory data from video data of a traffic scene, and then predicts and estimates potential collisions. To this end, this paper examines the motion pattern model discretization process, the probabilistic framework, the resulting indicators, and then compares the motion prediction methodology with that of the classical constant velocity motion prediction methodology. The methodology is explored using road user behaviour inside the weaving zone of a roundabout to illustrate the flawed use of constant velocity motion prediction.

Authors	Jian Sun, Tongji University, China Jie Sun, Tongji University, China Peng Chen, Nagoya University, Japan
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-3348
Paper Title	Using Support Vector Machine Models for Real-Time Crash Risk Prediction on Urban Expressways
Abstract	This paper adopted a novel methodology¡ªsupport vector machine (SVM) with two penalty parameters for the evaluation of real-time crash risk on urban expressway segments using the dual-loop detector data. The purpose of this study is to develop a model that can identify traffic conditions prone to crashes effectively and support implementation of proactive traffic safety management. Based on the crash data and the corresponding detector data collected on expressways of Shanghai, different combinations of dual-loop detector data and time segments before crashes were used to develop the optimal crash risk estimation model by SVM. Then, the transferability of SVM model was assessed by examining whether the model developed on one expressway is applicable to other similar ones. In addition, the prediction results and transferability of SVM model were compared with those given by other frequently used classification algorithms, including Logistic Regression, Bayesian Networks, Native Bayes classifier, K-Nearest Neighbor, and Back Propagation Neural Network. The results showed that SVM model is more suitable to the prediction of real-time crash risk with small-scale data than other algorithms with the crash classification accuracy reaching 80% at best. A comparison to the similar studies by other researchers also implied that the proposed model achieved better predication accuracy.

Authors	Joshua Swake, Oregon State University David S. Hurwitz, Oregon State University Justin Neill, Oregon State University John Anthony Gambatese, Oregon State University
Sponsoring Committee	AND10, Vehicle User Characteristics
Session Number	441

Session Title	Driving Through Curves and Work Zones and Past Roadside Vegetation
Paper Number	14-2225
Paper Title	Influence of Mobile Work Zone Barriers in Maintenance Work Zones on Driver Behavior: Driving Simulator Study
Abstract	Highway construction projects often require temporary changes in roadway characteristics, such as the number of operational lanes, lane path, lane width, shoulder width, and posted speed limit. These modifications which are often temporary in nature have the potential to impact driving performance. Many research efforts have focused on developing standards to ensure the safety of drivers and workers in work zones, however comparatively little research has been conducted to better understand the influence of mobile work zone barriers (MWB), a relatively new type of positive barrier designed to protect workers in the activity area of a work zone, on driver behavior. The OSU Driving Simulator was used to evaluate the influence of an MWB on driver behavior in single left lane and right lane drop maintenance work zones on 4-lane, 2-way divided highways. Thirty six drivers traversed 144 work zones. Measures of vehicle trajectory, lateral position and glance patterns were recorded and examined. No statistical differences were observed in the glance patterns of drivers between work zones with and without the MWB, suggestive statistical differences were identified between average speeds in the taper and activity area of right lane closure work zones with speeds slightly slower in the presence of the MWB, and an eight inch shift to the right was observed in the lateral position of vehicles in the activity area of left lane drop work zones in the presence of the MWB. Results suggest that no critical hazards are introduced to drivers from the application of MWBs in maintenance work zones.

Authors	Nicholas Tymvios, University of North Carolina, Charlotte John Anthony Gambatese, Oregon State University
Sponsoring Committee	AHB55, Work Zone Traffic Control
Session Number	590
Session Title	Vehicle Speeds in Work Zones
Paper Number	14-4616
Paper Title	Comparison of Vehicle Speeds Adjacent to Maintenance Work Zones With and Without a Mobile Barrier
Abstract	Highway maintenance and construction activities are oftentimes performed in a travel lane, median, or shoulder adjacent to vehicles traveling at relatively high speeds and in close proximity to the workers. Work zone traffic control efforts include safety measures for the workers that typically include multiple traffic control devices. However, worker and motorist safety continues to be a concern. Current traffic control capabilities for short duration work zones can be improved in order to increase the protection of workers and reduce the effect of the maintenance activities on the traveling public. A recent advancement in work zone safety is a mobile barrier system that consists of a motorized tractor/trailer combination and provides complete isolation of the work area. This paper presents research conducted to investigate the impacts of a mobile barrier on vehicles traveling adjacent to the mobile barrier and maintenance work zones. The study findings show that vehicle speeds are higher with the mobile barrier present than without the mobile barrier, indicating greater mobility as a result of faster travel times through the work zone. The presence of a mobile barrier resulted in lower speed reduction from the beginning to the end of the work zone. This positive impact on vehicle movement through the work zone complements the increased worker safety provided by the mobile barrier.

Authors	Ronald G. Van Houten, Western Michigan University Miles Bennett, Western Michigan University
Sponsoring Committee	ANF10, Pedestrians
Session Number	731
Session Title	Designing Roadways to Improve Pedestrian Safety
Paper Number	14-0222
Paper Title	Comparison of Gateway In-Street Sign Treatment with Other Driver Prompts to Increase Yielding to Pedestrians at Crosswalks
Abstract	An important goal to reduce the number of collisions between motorists and pedestrians is to increase motorists yielding right-of-way to pedestrians in crosswalks. A Gateway installation of in-street signs (one in-street sign installed between the two travel lanes in each direction, and one on both edges of the roadway in each direction) was evaluated on multilane roads. The first experiment compared the efficacy of adding multiple in-street signs used in a gateway configuration with a single sign between the two travel lanes in each direction. The second experiment compared the in-street sign gateway treatment with a

more expensive Pedestrian Hybrid Beacon. The third experiment compared the in-street sign gateway with the more expensive Rectangular Rapid Flashing Beacon (RRFB), The results demonstrated that the Gateway in-street sign treatment produced very high levels of drivers yielding behavior, and that the Gateway treatment was as effective as the two more expensive treatments.

Authors	Luís Vasconcelos, Polytechnic Institute of Viseu Luís Filipe Cavaco Andrade Jesus Neto, University of Coimbra, Portugal Álvaro Seco, University of Coimbra, Portugal Ana Bastos Silva, University of Coimbra, Portugal
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-0229
Paper Title	Validation of Surrogate Safety Analysis Module Technique for Assessment of Intersection Safety
Abstract	The Surrogate Safety Analysis Module (SSAM) is a software application that reads trajectories files generated by microscopic simulation programs and calculates surrogate measures of safety. This approach eliminates the subjectivity associated with the conventional conflict analysis technique and allows assessing the safety of a facility under a controlled environment before the occurrence of accidents. The specific goal of this research is to validate SSAM as a tool for accident prediction in urban intersections. Two different methods are used: the first one compares the simulated number of conflicts using SSAM and the predicted number of injury accidents using analytic models in three reference intersections layouts (4-leg intersection, 4-leg staggered intersection and single-lane roundabout); in the second part, SSAM results are put against conflicts observed on site in four real intersections, two priority ones and two roundabouts. The results allow concluding that despite some limitation related to the nature of current traffic microsimulation models, SSAM analysis is a very promising approach to access the safety of new facilities or innovative layouts.

Authors	Chen Wang, Shanghai Jiaotong University, China Nikiforos Stamatiadis, University of Kentucky
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-0777
Paper Title	Evaluation of Aggregate Conflict Propensity Metric Through Traffic Simulations
Abstract	The development of surrogate safety measures is essential due to the problems of availability and quality of historical crash data. The Aggregate Conflict Propensity Metric (ACPM) is a surrogate metric recently proposed and it is based on conflict studies and traffic simulations. ACPM is expected to be capable of assessing the relative safety levels of traffic facilities and/or treatments in order to help traffic engineers to select appropriate treatments based on traffic safety estimates. This paper presents three experimental tests conducted to evaluate the reliability of ACPM. In each test, ACPM is compared to a traditional conflict indicator in terms of identifying and ranking safety of traffic conditions under various traffic volumes based on traffic simulations. ACPM shows its strength and reliability in all three tests, as it provides results highly consistent with the Highway Safety Manual. The experimental tests indicate that ACPM is a promising surrogate safety measure that can appropriately identify relative safety among traffic treatments and/or facilities and provide traffic engineers with useful information on potential safety impact.

Authors	Chen Wang, Shanghai Jiaotong University, China Nikiforos Stamatiadis, University of Kentucky
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-1308
Paper Title	Derivation of New Surrogate Measure of Crash Severity
Abstract	This paper proposes a new surrogate measure named Aggregated Severe Crash Metric (ASCM) based on conflict studies and traffic simulations, in order to allow for relative comparisons and safety evaluations among intersection designs in terms of crash severity. A procedure is developed to determine the injury probability of a simulated traffic conflict, by

randomly assigning drivers and vehicles into this particular conflict and repeating this process for multiple times. An experimental validation effort was conducted by simulating twelve intersections through the simulation package of VISSIM. The Surrogate Safety Assessment Model (SSAM) is utilized to extract useful conflict data as the entry into the model for estimating the ASCM. The Spearman rank tests indicate that ASCM is able to identify the relative safety among traffic facilities in terms of crash severity. Notably, ASCM outperforms the Highway Safety Manual (HSM) procedures in rank tests. Preliminary efforts to correlate ASCM to crashes and to use it as a crash predictor indicate that regression models are well fitted for ASCM and predicted real severe (i.e. fatal and injury) crash frequency, suggesting its potential to be directly linked to actual severe crash frequency.

Authors Yao Wu, Southeast University, China
Jian Lu, Southeast University, China
Yanyong Guo, Southeast University, China

Sponsoring Committee ANF20, Bicycle Transportation
Session Number 526
Session Title Cyclist Safety and Operations
Paper Number 14-4258
Paper Title Analysis of the Red-light Running Frequency of Cyclists at Signalized Intersection in China

Abstract Red-light running behaviors of bicycles at signalized intersection lead to a large number of traffic conflicts and high collision potentials. The primary objective of this study is to analysis the red-light running frequency of cyclists at signalized intersections. Using data collected at twenty five approaches at seventeen signalized intersections, the underlying distributions of the red-light running frequency of bicycles were examined. It was found that the frequency of red-light running generally followed a negative binominal distribution. The negative binomial (NB) model was developed to relate the bicycles' red-light running frequency to various explanatory variables. The validation results showed that the prediction performance of the NB regression model was satisfactory. For a comparison purpose, the Poisson regression model was also developed. The prediction performance of the two models was compared. It was found that the NB regression model produced better prediction performance than did the Poisson regression model. The model estimates show that the red-light running of cyclists are significantly influenced by bicycle flow, conflict traffic flow, pedestrian signal type, vehicle speed, and e-bike rate. The research results can help transportation professionals to predict the expected numbers of the red-light running of bicycles; and develop effective guidelines or policies to reduce red-light running frequency of bicycles at signalized intersections.

Authors Xinkai Wu, California State Polytechnic University, Pomona
Natanael Vall, California State Polytechnic University, Pomona
Henry X. Liu, University of Minnesota, Twin Cities
Xudong Jia, California State Polytechnic University, Pomona

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Transportation Safety Management
Paper Number 14-4266
Paper Title Intersection Safety Evaluation Using High-Resolution Traffic Signal Data

Abstract This research proposes a comprehensive intersection safety evaluation system, which is able to quantify the safety performance of signalized intersections and identify the emerging and impending hazardous situations using high-resolution traffic signal data collected from existing loop detection system. Such system is much needed for the implementation of a real-time intersection collision avoidance system. Also, the intersection safety information collected from a network-wide system can be used to rank the safety severity for all intersections in the network, therefore helps agencies identify the intersections which need most improvement. In detail, the system fulfills the following two major functions: 1) Estimate potential traffic conflicts based on real traffic conditions. This function will focus on estimating both rear-end and crossing (i.e. right-angle) traffic conflicts; and 2) Predict red-light violations. This function is to identify possible red-light violations, which is a major factor that leads to traffic conflicts. The overall intersection safety can be evaluated based on a combination of the potential traffic conflicts and red-light-running cases. The proposed system has been applied to a corridor with 3 intersections located at Minneapolis, MN. This research is expected to contribute significantly to the improvement of intersection safety.

Authors	Chengcheng Xu, Southeast University, China Pan Liu, Southeast University, China Wei Wang, Southeast University,China Zhibin Li, Southeast University, China Rui Guo, University of South Florida, Tampa
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-3844
Paper Title	Improving the Spatial and Temporal Transferability of Real-Time Crash Risk Prediction Models Using Bayesian Updating Approach
Abstract	The primary objective of this study is to investigate the feasibility of using the Bayesian updating approach to improve the spatial and temporal transferability of the real-time crash risk prediction models. Three different data samples were collected in this study, including a data sample collected from the I-880N freeway in 2002, a data sample collected from the I-880N freeway in 2009, and a data sample collected from the I-5N freeway in 2009. The preliminary analysis showed that the crash risk prediction models developed for the three data samples were different from each other. The model parameters for traffic flow variables did not remain stable over time or space. The spatial and temporal evaluation results showed that the crash risk prediction models could not be directly transferred across time and space. It was found that the models developed for I-880N in 2002 and I-5N in 2009 could not accurately predict the crash likelihood on the I-880N data sample in 2009. The Bayesian updating approach was applied to improve the spatial and temporal transferability of the real-time crash risk prediction models. The authors also estimated the effects of the size of the updating data sample on the model transferability. The updating results showed that the Bayesian updating approach was effective in improving both the spatial and temporal transferability of the crash risk prediction models with low data requirements. The predictive performance of the transferred model updated by the Bayesian updating approach was better than that of the transferred model without being updated even when the updating data sample was very small. The predictive performance of the transferred model increased as the sample size of the updating data was increased. It was also found that, when limited new data on a freeway were available, updating an existing crash risk prediction model for the freeway was a better approach than developing a new model using the limited data.

Authors	Chengcheng Xu, Southeast University, China Wei Wang, Southeast University, China Pan Liu, Southeast University, China Rui Guo, University of South Florida, Tampa Zhibin Li, Southeast University, China Fangwei Zhang, Southeast University, China
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	562
Session Title	Alternative Safety Performance Indicators: Advancing the Frontier
Paper Number	14-4038
Paper Title	Real-Time Freeway Crash Risk Assessment Using Structural Equation Modeling and Segmentation Analysis Approach
Abstract	The study presented in this paper aims to propose a new analysis procedure for the real-time crash risk assessment using the structural equation modeling (SEM) and segmentation analysis. The SEM can handle with a large number of correlated traffic flow variables in the crash risk prediction model, and produce more precise estimates of the effects of the traffic flow variables on crash risks. The segmentation analysis can help identify distinct traffic states and develop specific strategies for reducing the crash risks in each traffic state. To achieve the research objective, the traffic, crash and geometric data were obtained from the I-880N freeway in the United States in 2008 and 2009. The factor analysis was first used to detect initial relationships between latent traffic variables and the observed traffic flow variables, which were used to develop the measurement equations in SEM. The estimation results showed that the SEM could effectively transform the large number of correlated traffic flow variables into four latent traffic variables. In the estimated SEM, in addition to the direct effects on crash risks found in previous studies, the traffic flow variables were also found to have indirect effects on crash risks through influencing other traffic flow variables. The predictive performance of the SEM was also tested. Compared with the logistic regression model, the SEM approach can increase the crash prediction accuracy by an

average of 7.6%. The K-means clustering analysis was further conducted to classify freeway flow into 8 different traffic states based on the four latent traffic variables extracted by the SEM. The major traffic flow variables contributing to crash risks were found to be different across the various traffic states. The possible control strategies for each traffic state were discussed to reduce the crash risks on freeways.

Authors Rongjie Yu, Tongji University
Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Transportation Safety Management
Paper Number 14-0539
Paper Title Optimal Variable Speed Limit System to Ameliorate Traffic Safety Risk
Abstract Active Traffic Management (ATM) systems have been emerging in recent years in the US and Europe; they provide control strategies to improve traffic flow and reduce congestion on freeways. This study investigates the feasibility of utilizing a Variable Speed Limits (VSL) system, one key part of ATM, to improve traffic safety on freeways. A proactive traffic safety improvement VSL control algorithm is proposed. First, an extension of the METANET traffic flow model is employed to analyze VSL's impact on traffic flow. Then, a real-time crash risk evaluation model is estimated for the purpose of quantifying crash risk. Finally, optimal VSL control strategies are achieved by employing an optimization technique to minimize the total crash risk along the VSL implemented corridor. Constraints are set up to limit the increase of average travel time and the differences of the posted speed limits temporarily and spatially. This novel VSL control algorithm can proactively reduce crash risk and therefore improve traffic safety. The proposed VSL control algorithm is implemented and tested for a mountainous freeway bottleneck area through the micro-simulation software VISSIM. Safety impacts of VSL are quantified as crash risk improvements and speed homogeneity improvements. Moreover, three different driver compliance levels are modeled to monitor the sensitivity of driver compliance effects on VSL's safety benefits. Conclusions demonstrated that the proposed VSL system would improve traffic safety by decreasing crash risk and enhancing speed homogeneity. Future implementation suggestions of the VSL control strategies and related research are also discussed.

Authors Mohamed H. Zaki, University of British Columbia, Canada
Tarek Sayed, University of British Columbia, Canada
Khaled Shaaban, Qatar University
Sponsoring Committee AND30, Simulation and Measurement of Vehicle and Operator Performance
Session Number 454
Session Title Simulation and Measurement of Driver Performance
Paper Number 14-0605
Paper Title Using Drivers' Jerk Profiles in Computer Vision-Based Traffic Safety Evaluations
Abstract Traffic conflicts have been advocated as surrogate safety measures for traffic collisions. A traffic conflict is composed of chained events in which at least one of the involved road-users usually performs some sort of evasive actions avoiding collision. It is conceivable to assume that the analysis of evasive manoeuvers can provide relevant information about traffic safety. The evasive action usually involves powerful braking which lead to sudden negative acceleration changes (deceleration). The temporal dynamics (variation over time) of the acceleration of a vehicle is represented by the jerk profile. More formally, jerk is the derivative of the acceleration. In case of evasive action by braking, the jerk profile is characterized by strong negative values. This paper examines two issues in the quest to better understand the benefits of evasive action analysis. The first issue is whether jerk profiles can be used to identify critical traffic events (conflicts). The second issue addresses the validity of an assumption made in earlier studies concerning the inadequacy of using the deceleration profile as standalone measure for conflict identifications. In this work, traffic data collection was performed using automated video analysis. Computer vision analysis was applied on the recorded videos to extract trajectory dynamic data (speed, acceleration and jerks) as well as possible interactions among road-users. The analysis was applied on two data sets with distinct traffic patterns. The study revealed a significant difference between the jerk behavior of the group of drivers involved in conflicting and normal traffic situations. It also showed instances where automated jerk evaluation was successful in finding conflicts undetected by conventional conflicts indicators. This demonstrates that evasive actions represented through the jerk behavior can provide valuable information in detecting drivers involved in conflicting situations. The same cannot be demonstrated for

the road-users' deceleration behavior. There is no statistically significant difference between the acceleration measures for road-users involved in conflicting and normal events. This supports earlier studies on the shortcoming of using deceleration data for conflict identification. This work demonstrates that benefits of using of computer vision techniques to automate traffic conflict analysis and to calculate measures such as jerk which cannot be calculated using manual observation methods. It also gives insight in the nature of evasive actions performed by drivers in safety critical situations.

8 Applications of the Highway Safety Manual

The calibration of the Highway Safety Manual, including the evaluation of the challenges and the practical solutions to address these challenges, is the focus of six papers (Brown et al., 14-2587; Dixon et al., 14-5386; Dell'Acqua et al., 14-0135; La Torre et al., 14-1118; Qin et al., 14-1053; Trieu et al., 14-1024). Moreover, a method to estimate and/or update SPF parameters combining the information available from limited data with the SPF parameters values reported in the Highway Safety Manual is presented (Heydari et al., 14-1519).

From an application point of view, the papers addressed:

- Roundabouts in Oregon (Dixon et al., 14-5386);
- Two-lane, two-way undivided urban arterials (Trieu et al., 14-1024);
- Rural local roads in South Dakota (Qin et al., 14-1053);
- Two-lane rural highways in Italy (Dell'Acqua et al., 14-0135);
- Motorways in Italy (La Torre et al., 14-1118);
- Freeway segments in Missoury (Brown et al., 14-2587).

Authors	Henry Brown, University of Missouri, Columbia Carlos Sun, University of Missouri, Columbia Praveen Edara, University of Missouri
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Highway Safety Performance
Paper Number	14-2587
Paper Title	Nuts and Bolts of Statewide Highway Safety Manual Calibration
Abstract	The new Highway Safety Manual (HSM) contains safety prediction models and modification factors that need to be calibrated to local conditions. This calibration process requires detailed data such as crash frequencies, traffic volumes, geometrics and land-use. The HSM does not document in detail techniques for gathering such data since data systems vary significantly across states. The calibration process also requires certain decisions such as the sampling approach, the determination of the minimum segment length, the treatment of left-turn phasing and the inclusion or exclusion of speed-change lane adjacent crashes. This paper highlights some challenges and practical solutions from the statewide HSM calibration in Missouri, including lessons learned from other states such as Kansas, Illinois and New Hampshire. The models calibrated include 8 segment and 8 intersection facility types and include 3 freeway segment models that will be part of the next edition of HSM. The random sampling technique applied ensured geographic representation across the state. The data processing techniques included examining videologs for roadside features, estimating horizontal curve parameters using CAD, reviewing street view photographs to verify inventories and configuration, and measuring median widths using aerial photographs. Some of the challenges encountered during the calibration included data availability, finding a sufficient sample size for certain facility types, maintaining a balance between segment homogeneity and minimum segment length, and excluding inconsistent crash data. This paper is written to further the safety community's efforts in promoting the application and use of the HSM by discussing some nuts and bolts calibration issues.

Authors	Gianluca Dell'Acqua, University of Naples Federico II, Italy Francesca Russo, University of Naples Federico II, Italy Mariarosaria Busiello, University of Naples Federico II, Italy Salvatore Antonio Biancardo, University of Naples Federico II, Italy
Sponsoring Committee	AFB30, Low-Volume Roads
Session Number	782
Session Title	Safety and Human Factors
Paper Number	14-0135
Paper Title	Highway Safety Manual Transferability to Italian Low-Volume Roads
Abstract	For decades, crashes have been studied as discrete events focusing on the circumstances of the crash. This type of analysis has been used to identify the characteristics of roadway features associated with higher crash experience, but other factors, such as traffic volumes, driver characteristics, land use, and environmental conditions are also needed to explain or describe crash events. The Highway Safety Manual (HSM) provides a predictive method to estimate the expected average crash frequency of a site in given geometric and geographic conditions over a specific period for a specific annual average daily traffic (AADT). The study presented here investigates whether the modeling results closely match the crash records. The HSM algorithms were used to assess transferability as a whole. The results obtained suggest that implementing the HSM techniques should foster the development of local Safety Performance Functions (SPFs) and accident modification factors (AMFs). The calibration preserves the original HSM model form and the relationship between independent variables and crashes. To adjust the base predicted crash frequency to meet the current conditions, the AMFs calculation for lane width, horizontal curve and vertical grade were made. Crash types (head-on/side collisions, single-vehicle crashes, rear-end collisions) were investigated based on the vertical grade and the curvature indicator. The estimated model provides planners and designers with a tool better able to target and select countermeasures to address these specific aspects, resulting in improved project selection and improved safety.

Authors	Karen K. Dixon, Texas A&M Transportation Institute Jianfei Zheng, Oregon State University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Highway Safety Performance
Paper Number	14-5836

Paper Title	Safety Performance for Roundabout Applications in Oregon
Abstract	This paper documents a research effort to quantify the safety performance of roundabouts in the State of Oregon. The primary goal of this effort was to provide the Oregon Department of Transportation with safety performance functions that can be used to evaluate the safety performance of single-lane, four-leg roundabouts. These safety metrics generally conform to the statistical models and methodologies outlined in the Highway Safety Manual (HSM) published by the American Association of State Highway and Transportation Officials. Included in the paper is a graphic that contrasts the roundabout crash model to values predicted using the HSM STOP controlled and signalized intersections for rural two-lane highways.

Authors	Shahram Heydari, University of Waterloo, Canada Luis Fernando Miranda-Moreno, McGill University, Canada Dominique Lord, Texas A&M University Liping Fu, University of Waterloo, Canada
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	368
Session Title	Highway Safety Performance
Paper Number	14-1519
Paper Title	Bayesian Methodology Incorporating Highway Safety Manual for Fitting and Updating Safety Performance Functions
Abstract	In road safety studies, one often must cope with limited data conditions in the decision making process. In these circumstances, the maximum likelihood estimation which relies on asymptotic theory is not efficient. Besides, it has been reported in the literature that (a) Bayesian estimates might be significantly biased on account of using non-informative prior distributions and (b) the calibration of limited data is plausible when existing evidence in the form of proper priors is introduced into analyses. However, the road safety literature lacks a methodological approach to overcome the aforementioned problem. We present a method to estimate and/or update safety performance function (SPF) parameters combining the information available from limited data with the SPF parameters values reported in the Highway Safety Manual (AASHTO, 2010). This method contributes to unification of the SPF parameters updating process. The proposed technique is validated by conducting a sensitivity analysis through an extensive simulation study with 15 different models (with various prior combinations), which in turn contributes to our understanding of the comparative aspects of a large number of prior distributions. The results evince the accuracy of the developed methodology. Therefore, the suggested approach offers considerable promise as a methodological tool to estimate and/or update baseline SPFs under limited data conditions.

Authors	Francesca La Torre, University of Florence, Italy Lorenzo Domenichini, University of Florence, Italy Francesco Corsi, University of Florence, Italy Francesco Fanfani, University of Florence, Italy
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	788
Session Title	Highway Safety Performance
Paper Number	14-1118
Paper Title	Transferability of New Highway Safety Manual Freeway Model to Italian Motorway Network
Abstract	The currently available release of the AASHTO Highway Safety Manual does not include a model referred to freeways and interchanges. For this aim the NCHRP Project No. 17-45 “Safety Prediction Methodology And Analysis Tool For Freeways And Interchanges” has recently developed specific Crash Prediction Models (CPMs) for this type of infrastructures. A key issue to make HSM a standard for road owners and managers world-wide is the transferability of the prediction models to different networks. An extensive study has been conducted on the primary Italian motorway network in order to evaluate the potential issues that occur applying of this methodology to a network characterized by different environment, road characteristics, driver behavior and crash reporting systems, as compared to the ones where the HSM models have originally been developed. The freeway network considered in this study, almost 3000 km long, has been represented by 56 freeway sections characterized by an average length of about 12.5 km, covering 700 km of freeway distributed along all the country. Four different calibration factors were obtained for freeway segments depending on crash severity and type, and two calibration factors were obtained for speed-change lanes depending on crash severity. The results show a good transferability of the analyzed models to the Italian network and especially the freeway models for fatal and injury crashes. Some improvements could be made considering variable calibration factors within the datasets or

Crash Modification Factors local calibrations. The need for an improved localization of the crash data on the Italian road network has also been highlighted, mainly for speed-change lanes.

Authors Xiao Qin, South Dakota State University
Chen Zhi, South Dakota State University
Kim Vachal, North Dakota State University

Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Highway Safety Performance
Paper Number 14-1053
Paper Title Calibration of Highway Safety Manual Predictive Methods for Rural Local Roads

Abstract Establishing performance-based safety goals and objectives becomes more attainable with the Highway Safety Manual (HSM). However, the safety performance functions (SPFs) in the HSM may not be accurate as they are not calibrated to local conditions. In addition, each SPF and crash modification factor (CMF) assumes a set of base site conditions which may not be realistic for local roadways. Although calibration procedures are available in HSM Part C Appendix A, they should be refined or modified to accommodate local data availability and roadway, traffic, and crash characteristics. It is also necessary to determine a set of base conditions applicable to local highways. This paper presents the application of the HSM for rural local two-lane two-way highway segments in South Dakota (SD). The calibration was based on three-year (2009-2011) crash data from 657 roadway segments constituting more than 750 miles of roadways. The calibration process includes establishing new base conditions, developing SPFs, converting CMFs to base conditions as well as substituting default values with state-specific values. Five models have been developed and compared based on statistical goodness-of-fit and calibration factors. Results show that the jurisdiction-specific crash type distribution for CMFs can be drastically different from what is presented in the HSM. The HSM method without modification underestimates SD crashes by 35 percent. The method based on SPFs developed from a full model has the best performance. This study provides important guidance and empirical results regarding how to calibrate HSM models.

Authors Vanvi Trieu, Villanova University
Seri Park, Villanova University
John McFadden, Federal Highway Administration

Sponsoring Committee ANB25, Highway Safety Performance
Session Number 368
Session Title Highway Safety Performance
Paper Number 14-1024
Paper Title Sensitivity Analysis of Highway Safety Manual Calibration Factors Using Monte Carlo Simulation

Abstract The Highway Safety Manual (HSM) is a comprehensive traffic safety tool that allows administrators, planners, engineers, and other agency representatives to make more informed decisions regarding their highway safety improvement programs. Part C of the HSM contains predictive models to quantify the safety of roadways and intersections that require significant data inputs. Since these models were developed with data from specific states, the HSM recommends the use of a calibration factor to account for local conditions when applied elsewhere. The calibration process utilizes a set of sites and criteria for calculating the calibration factor. Therefore, the accuracy and precision of these models are greatly dependent on the calibration process that develops the factor. This paper evaluates the HSM calibration criteria's guidance in the context of two-lane, two-way undivided urban arterial roadways and examines a method to further improve the accuracy and precision of the calibration factors. A sensitivity analysis using different size calibration sets is performed through Monte-Carlo simulation to re-sample sites. Results indicate that the current HSM criteria of 30 to 50 sites is insufficient for evaluating locations with a large number of sites and the minimum threshold of observed crashes per year should be reconsidered. The traffic volume analysis reveals a strong correlation between the traffic distribution of all sites in a jurisdiction in comparison to selected sites. This relationship is directly linked to deriving high quality calibration factors. The calibration factor ratio formula in Part C, Appendix A of the HSM is also validated through a different site allocation strategy. The findings provided prompt for possible future research to enhance the HSM calibration process.

---

9 Transportation Safety Management

Twenty papers evaluated different issues of transportation safety management.

Authors	Rune Elvik, Institute of Transport Economics, Norway
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-0297
Paper Title	Cost-Benefit Analysis of Incentive Systems Rewarding Compliance with Speed Limits
Abstract	The paper presents a cost-benefit analysis of schemes rewarding drivers for not speeding by paying them for not doing so. The analysis is based on the findings of trials that have evaluated the effects of rewarding drivers for not speeding. The effects found in these trials vary considerably. Effects were found to be related to the size of the reward according to a logarithmic function. This means that increasing the reward increases its effect, but at a rapidly declining rate. For the purpose of cost-benefit analysis, three levels of the reward were defined: 20 Euros per year, 300 Euros per year and 1200 Euros per year (corresponds to, respectively, 26, 396 and 1586 US dollars at June 2013 exchange rate). Based on the trials reported, it was estimated that these rewards would reduce the rate of speeding by 20 percent, 70 percent and 95 percent, respectively. To monitor compliance, each car would be equipped with a simple monitoring device. This device would not interfere with driver speed choice, merely record speeding. It was assumed that drivers would join a reward system voluntarily. Three groups of drivers were defined: one group, making up 50 percent of drivers with an annual per driver accident rate 20 percent below the average for all drivers; a second group, 40 percent of drivers, with a per driver accident rate 10 percent below the average, and a third group, 10 percent of drivers, with a per driver accident rate 140 percent above average (i.e. a relative accident rate of 2.4). Propitious selection was assumed; i.e. the safest drivers would be the first to join the program, the least safe drivers would be the last. Official Norwegian monetary valuations of the prevention of traffic fatalities and injuries were applied. The prevention of a fatality was valued at 3.46 million Euros (2009-prices; equivalent to 4.8 million US dollars in 2009). Benefits were found to be smaller than costs for all versions of the reward system and all groups of drivers, except high-risk drivers in the system offering a 20 Euro annual reward for not speeding. Considering the fact that rewards have been found to be effective in the trials that have been reported, this finding must be regarded as surprising. If the reward is treated as a monetary transfer, not as a cost of the program, benefits clearly exceed costs in most versions of the program. It was, however, regarded as more appropriate to treat the rewards as a cost of the program, since it will not have an effect unless the rewards are actually paid.

Authors	Douglas W. Harwood, MRIGlobal Reginald R. Souleyrette, University of Kentucky Michael A. Fields, Kentucky Transportation Center Eric R Green, Kentucky Transportation Center
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-1738
Paper Title	Comparison of Countermeasure Selection Methods for Use in Road Safety Management
Abstract	This paper compares three methods for selecting highway-infrastructure countermeasures to reduce crash frequency and severity. The three methods compared are the usRAP Tools software, the FHWA systemic safety tool, and road safety audits. These methods are less dependent on the availability site-specific crash data than traditional methods based on identification of high-crash locations. Each of the methods is applied to the same network of selected county roads in Kentucky. The paper shows that the usRAP Tools software provides the most robust and quantitative of the methods and produces a recommended safer roads investment program for the county road network based on benefit-cost analysis. The FHWA systemic safety tool requires less roadway data than the usRAP Tools software and provides great flexibility for users to adapt to specific roadway networks and specific data availability situations. However, this flexibility carries with it the risk that users may not fully appreciate the importance of considering and weighting all relevant factors. Road safety audits are effective at identifying safety-related features that are missing or in poor condition, but have the potential to miss the opportunity to make cost-effective improvements to existing infrastructure that is in good condition, but may not fully serve traffic demands.

Authors	Giannis Adamos, University of Thessaly, Greece Eftihia G. Nathanail, University of Thessaly, Greece Paraskevi Kapetanopoulou, Aristotle University of Thessaloniki, Greece
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-3774
Paper Title	Cluster Modeling of Driving Behavior Under Fatigue
Abstract	Road safety campaigns may contribute to the reduction of the number of people killed on the roads as they are considered to be one of the measures used to influence road user behavior to follow the driving regulations and safeguard safety on the road network. The present paper aims at developing prediction models for the assessment of the impact of a fatigue road safety communication campaign on driving behavior, based on the “Health Belief Model”. The above behavioral model takes into account the behavior, and the objectives of the campaign, as defined in the measurement variables of the evaluation, which are composed of self-reported data, collected through a face-to-face questionnaire survey that was conducted before, during and after the campaign implementation. Linear regression analyses were used to define the causal relations between the dependent variables, intention and behavior, and other constructs. Results showed that the models developed for predicting drivers¢ intention to stop and rest when they get tired and drivers¢ behavior towards stopping and resting when they get tired, vary significantly depending on the characteristics of the sample tested, i.e. non-professional drivers versus professional drivers, younger versus older drivers, etc. Also, it was observed that behavioral beliefs and risk comprehension are weak for the predictability of intentions and behavior, however, the inclusion of past behavior increases the predictability of the models predicting intentions and the inclusion of past behavior and intentions (as observed also in similar studies) increases the predictability of the models predicting behavior.

Authors	Alena Vyskocilova, Traffic Research Centre, Czech Republic Ondrej Gogolin, Traffic Research Centre, Czech Republic Ondøej Valach, Traffic Research Centre, Czech Republic
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-0867
Paper Title	New Approach for Evaluation of Socioeconomic Losses Caused by Traffic
Abstract	Transport and its consequences are evaluated from different points of view of safety, road, vehicle and human factor. However, it is very important to assess the transport impacts also from the economic viewpoint. Incurred considerable socio-economic losses impact upon the government and society. Under conditions of the Czech Republic, the methodical procedure of loss calculation of traffic accident rate was used but it was not up-to-date and did not include important cost items, which are inserted into the calculation. Therefore mentioned values were out-of-date and underestimated. The article is aimed at the description of new approach to evaluation of socio-economic losses caused by traffic accidents on land roads under conditions of the Czech Republic. New methodology of loss calculation is defined and stress is laid on current changes, by virtue of which the amount of losses will be put more exactly. Further, problems of determination of compensation for damage established by the courts are mentioned and individual amounts of compensation according to injury consequences and severity of traffic violations are provided. In the final part, the concrete and explanatory example of the calculation and evaluation of losses, final summary and recommendations are mentioned. It is important to place emphasis on evaluation of losses caused by traffic accidents and to reckon them on a yearly basis. Loss amounts provide source information for traffic-engineering analyses and models, aimed at the calculation of effectiveness of measures. Implemented effective traffic-safety precautions will accordingly result not only in reduction and severity of traffic accidents but also considerable saving and efficient spending of financial resources.

Authors	Nam Nguyen, University of Minnesota Lee W. Munnich, University of Minnesota Frank Douma, University of Minnesota
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-3917
Paper Title	Closing the Gap in Rural and Urban Road Deaths
Abstract	Despite the decline in overall motor vehicle fatalities in the U.S., the difference between urban and

rural fatality rates has stayed relatively consistent. Examination of data from the Fatality Analysis Reporting System from 1994 to 2011 shows varying degrees of reductions in fatalities related to the four main causes of rural crashes (behavior, roadway environment, vehicle design, and emergency services); however in all cases, the rural fatality rates are consistently twice the magnitude of urban values. The fatality rate in 2011 for rural areas is still higher than the overall fatality rate in 1994. Future efforts to reduce traffic fatalities should focus on reducing the rural-urban fatality gap. Closing the disparity will require strategies that include adopting proven legislation-based safety improvement measures (LSIMs); state leadership and allocation of resources to the local level; local level interest and involvement; innovative integration of all 4 E's (engineering, enforcement, education, emergency response) of traffic safety; and collaborative inter-agency and public-private participation.

Authors Sabyasachee Mishra, University of Memphis
Sushant Sharma, Texas A&M Transportation Institute
Mihalis M. Golias, University of Memphis
Stephen Boyles, University of Texas, Austin

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Transportation Safety Management
Paper Number 14-4215
Paper Title Economic Competitiveness and Equity-Based Safety Improvement Allocation Model for Urban Intersections

Abstract Economic competitiveness and equity can be two competing objectives while allocating funds for implementation of safety alternatives on urban intersections. One of the critical phase of current safety management process (hazard elimination program) undertaken by most states is resource allocation among identified crash locations. Literature underlines the importance of this phase and lack of sophisticated tools available to state planning agencies for evaluating federal and state policies. The study overcomes this limitation by proposing an optimization based resource allocation model that maximizes safety benefits, subjected to budget and policy constraints. The proposed model incorporates economic competitiveness in the allocation and distributes improvements to urban intersections such that maximum economical benefits are obtained from crash savings. However, results show that while economic competitiveness leads to optimal benefits, resource allocation is inequitable. Hence equity based models are developed by adding two policy options: equity in opportunity and equity in outcome. The resource allocation model is solved using sequential quadratic programming. The model is applied to crash prone intersections in four counties of southeast Michigan. The proposed model is generic and scalable, with flexibilty in including policy options often considered by state and local agencies.

Authors Mohamed Eisa Sarhan, Ain Shams University, Egypt

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 426
Session Title Transportation Safety Management
Paper Number 14-4395
Paper Title Integrated Action Plan to Improve Traffic Safety on Mafraq-Ghweiyfat Road in Abu Dhabi, United Arab Emirates

Abstract In year 2011, Abu Dhabi Police in collaboration with road and traffic authorities in Abu Dhabi, United Arab Emirates, has adopted an integrated plan to reduce the increasing number of collisions on one of the major roads in Abu Dhabi Emirate; namely Mafraq- Ghweiyfat Road. The road has a speed limit of 120 km/h and extends for 325 km connecting Abu Dhabi City in the East to the West side of the emirate. Due to the high collision rates and fatalities on this road, an integrated action plan was implemented in year 2011 to improve traffic safety. The plan included different working directions such as the traffic enforcement, engineering, traffic education/awareness, and emergency services (i.e., 4Es plan). Examples of actions taken in this regard include the increase of the number of fixed and portable speed radars, the increase of the face-to-face traffic enforcement, changes of the enforcement speed limit, and changes in the road geometry and U-turns' design. The paper presents a safety assessment before and after the execution of the action plan. Severe collisions for 6 years from 2007 to 2012 were used for this purpose. The results indicated an overall reduction of both the number of collisions and fatalities/injuries. A comparison with other major roads in the emirate has also shown a superior safety improvement due to the taken actions.

Authors Yi Liu, Illinois Institute of Technology
Arash M. Roshandeh, Illinois Institute of Technology
Zongzhi Li, Illinois Institute of Technology
Konstantinos Kepaptsoglou, National Technical University of Athens, Greece

	Harshingar Patel, Illinois Institute of Technology Xi Lu, Illinois Institute of Technology
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-4574
Paper Title	Heuristic Approach for Optimizing Emergency Medical Services in Road Safety Within Large Urban Networks
Abstract	This paper introduces a double standards model (DSM), along with a genetic algorithm (GA), for assigning emergency medical service (EMS) fleet from vehicle locations to intersection vehicle crash sites such that crash demand sites could be covered in accordance with two service coverage standards. Specifically, all demand sites are required to receive single coverage according to the secondary coverage standard and at least a portion (á) of demand sites need to maintain single coverage as per the primary coverage standard. The proposed model is applied for top two hundred intersections in city of Chicago selected using intersection crash records for 2004-2010 according to crash frequency-based and severity-based scenarios. The top two hundred intersections are split into high and low severity sites for model application. Using the EMS vehicle fleet size currently maintained by the Chicago Fire Department as 15 basic life support (BLS) and 60 advanced life support (ALS) ambulances, almost 100 percent of double vehicle coverage can be achieved. Extended model application is conducted by keeping 15 BLS ambulances unchanged and reducing the 60 ALS ambulances by 50 percent to 30. Results show that nearly 90 percent of double coverage according to the primary standard can still be reached.

Authors	Mariniel Flores, University of Saskatchewan, Canada Peter Y. Park, University of Saskatchewan, Canada Angela Gardiner, City of Saskatoon, Canada Justine Nyen, City of Saskatoon, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-2990
Paper Title	Development of Traffic Safety Action Plan for Small Municipality: Case Study for City of Saskatoon, Canada
Abstract	Many jurisdictions have developed a high-level traffic safety policy document, such as the American “Strategic Highway Safety Plan” (SHSP) or the Canadian “Traffic Safety Action Plan” (TSAP). A SHSP and TSAP are both a scientific, data-driven, four to five year comprehensive safety document that is designed to identify a jurisdiction’s areas of safety concern known as “emphasis areas” and establish target safety goals (i.e., collision reduction goal(s)) for each chosen emphasis area. However, a TSAP includes additional information, such as network screening results, and general safety strategies/programs for each chosen emphasis area. This study discusses the development of a TSAP for a small municipality through a case study for the City of Saskatoon. Many studies investigated selection of emphasis areas and target safety goals for the development of a SHSP, However, there is very few or limited studies that have discussed the approaches specifically for the development of a TSAP for a small municipality. This study used the most recent ten years (2001-2010) of collision data in the City of Saskatoon, Saskatchewan. The study provides knowledge for those who wish to develop a TSAP by describing the process and highlighting the challenges in developing a TSAP for a small municipality.

Authors	Kirolos M. Haleem, Florida International University Albert Gan, Florida International University Priyanka Alluri, Florida International University Dibakar Saha, Florida International University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	426
Session Title	Transportation Safety Management
Paper Number	14-3440
Paper Title	Identification of Safety Practices, Issues, and Needs of Local Transportation and Law Enforcement Agencies
Abtract	As part of the effort to implement the Strategic Highway Safety Plan (SHSP), state Departments of Transportation (DOTs) are increasingly looking to reach out to local and law enforcement agencies. This paper summarizes the results from a study by the Florida Department of Transportation (FDOT) to identify the existing safety practices, issues, and needs of local transportation agencies and law enforcement offices in Florida. As part of the study, two comprehensive online surveys were

developed targeting local transportation agencies and law enforcement agencies. The survey questions targeting local transportation agencies included 39 questions that focused on several areas of interest, such as: standardization of crash analysis methods and tools, high crash locations, training needs, and working with FDOT. Of special emphasis among the areas is standardization of crash analysis, which targets agencies' feedback on adoption of the Highway Safety Manual (HSM), deployment of SafetyAnalyst, and use of a standard geographic information systems (GIS) spatial tool. For law enforcement agencies, the survey included 25 questions covering topics on selection of enforcement locations, traffic violations and safety campaigns, use of crash reports, and working with transportation agencies. This paper only includes results from select questions from both surveys that are likely to be of general interest to the readers. The surveys developed in this study could be adapted by other state DOTs interested in conducting similar studies to identify their local agency practices and needs to assist in their SHSP implementation.

Authors Linda Rothman, Hospital for Sick Children, Canada
Colin Macarthur, Hospital for Sick Children, Canada
Teresa To, Hospital for Sick Children, Canada
Ron Buliung, University of Toronto, Canada
Andrew Howard, Hospital for Sick Children, Canada

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 567
Session Title Transportation Safety Management
Paper Number 14-1631
Paper Title Motor Vehicle-Pedestrian Collisions and Walking to School in the City of Toronto: Exploration of Role of the Built Environment

Abstract Initiatives to increase active school transportation are popular. However, increased walking to school could also potentially increase collision risk. The built environment is related to both pedestrian collision risk, and walking to school. We examined the influence of the built environment on walking to school and child pedestrian collisions in Toronto, Canada. Police-reported pedestrian collision data from 2002-2011 for children ages 4-12 and walking rates and built environment data from field surveys and municipal sources were mapped onto school attendance boundaries. Collision rates were calculated using 2006 census populations and modelled using negative binomial regression. There were 481 collisions with a mean collision rate of 7.4/10, 000 children per year. While walking to school and collision rates were correlated, with a 13% increase in collision rate with every 10% increase in walking, the relationship was not statistically significant adjusting for population density and roadway design variables including; multi-family dwelling density, traffic light, traffic calming and one way street density, school crossing guard presence and school socioeconomic status. Pedestrian collisions are more strongly associated with built environment features than with walking rates. Road design features were related to higher collision rates and warrant further examination for their safety effects for children. The most effective way to avoid child pedestrian collisions is to design or use school routes that minimize road crossings.

Authors Kristian Larsen, University of Toronto, Canada
Ron Buliung, University of Toronto, Canada
Guy Faulkner, University of Toronto, Canada

Sponsoring Committee ANB10, Transportation Safety Management
Session Number 567
Session Title Transportation Safety Management
Paper Number 14-1763
Paper Title Physical Activity and School Travel: Assessing How Traffic Safety and the Built Environment Relate to Physical Activity Levels Before and After School

Abstract The most common form of physical activity for people of all ages is walking, thus the use of active travel modes, such as walking or cycling for school trips, can increase daily physical activity levels. The purpose of this paper is to examine how traffic safety and characteristics of the built environment along the route to/from school influence physical activity levels for children. Certain neighborhood characteristics influence physical activity in some studies, but little is known within the realm of safety, physical activity and school travel. Analysis examines specific details along the route to/from school (n=687) by using multiple linear regression to explore any associations between safety, environmental attributes, and physical activity levels. The built environment does relate to children's health. Specific features along the route such as traffic calming devices, distance and mode of travel all influenced activity levels. These findings demonstrate that the trip to/from school is only one source of physical activity for children and health behaviour may relate to other features beyond the construct of school travel.

Authors	Kelly Donoughe, Science Applications International Corporation Bryan Katz, Science Applications International Corporation
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	567
Session Title	Transportation Safety Management
Paper Number	14-3424
Paper Title	Evaluation of Fatal School Bus-Related Crashes and Associated Crash Characteristics
Abstract	School bus crashes are rare in comparison to other crash types, but considering all crashes that are in and around school buses, they begin to become a noticeable problem and one that tends to attract national attention. As defined by the Fatality Analysis Reporting System (FARS), a school bus related crash is a crash that either involves a school bus or the presence of a school bus is considered as a major contributing factor. Ten years of data indicate that the number of fatal school bus related crashes has remained nearly stagnant, despite an increase in the number vehicle safety systems on the market. The findings also highlight the importance of protecting the non-bus occupants since they are the most likely to incur a serious or fatal injury. As the most vulnerable user group, pedestrians (typically school-aged children) are especially at risk when crossing the road while boarding or exiting a school bus. Although the FARS data provides a reliable basis for fatal crashes, more data is needed to fill in the gaps of the less severe, but more prevalent, injury and property damage only crashes. Once the less severe crashes are able to be quantified and further defined, steps to reduce the number of school bus related crashes can be identified.

Authors	Shamsunnahar Yasmin, McGill University, Canada Sabreena Anowar, McGill University, Canada Richard Tay, La Trobe University, Australia
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	567
Session Title	Transportation Safety Management
Paper Number	14-3587
Paper Title	Effects of Drivers' Action on Severity of School Bus Collisions
Abstract	Since parents put their faith in the SB drivers and school divisions to transport their children to and from school safely and these collisions tend to attract a lot of media attention, the safety of these vehicles is a major concern not only for the authorities concerned but also for the general public. To ensure the safety of SB operations, it is necessary to identify the factors that contribute significantly to the likelihood or severity of these collisions. We find that violations of SB driver tend to increase crash severity whereas non-SB driver errors tend to decrease crash severity. Other factors that increase crash severity are frontal primary direction of force, head-on collision, female driver, unrestrained drivers, foggy/smoky weather, rural area, and traffic signal, whereas the factors that decrease crash severity are senior drivers, and slushy/snowy/icy road surface.

Authors	Alireza Ermagun, Sharif University of Technology, Iran Taha Hossein Rashidi, University of New South Wales, Australia Ali Arian, Sharif University of Technology, Iran Amir Samimi, Sharif University of Technology, Iran
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	567
Session Title	Transportation Safety Management
Paper Number	14-2560
Paper Title	Joint Model for Mode Choice and Escort Decisions in School Trips
Abstract	A considerable shift has happened in mode choice and students' escort decisions regarding the school trip around the world during the last decades. This shift of using more non-active modes has undesirable consequences including: physical inactivity among students, traffic jams during peak hours, and adverse environmental impacts. Hence, understanding the behavior of decision makers in regard to mode choice and escorting decisions is crucial for controlling this trend and promoting active modes of travel. This study is an effort to evaluate transportation mode choice decision and the way that students are accompanied by their parents to school, in a joined modeling structure as it is believed that these decisions are jointly made by parents. Two modeling formulations are used a nested logit model and a copula-based model. Results showed that the copula model outperforms the nested logit model. It was also found that modeling these two decisions in an independent way can mislead the policy assessment.

Authors	Isabel Cristina Victoria, CDM Smith Oscar Daniel Galvis, CDM Smith
Sponsoring Committee	ANB10, Transportation Safety Management

Session Number	699
Session Title	Transportation Safety Management
Paper Number	14-5432
Paper Title	Road Safety Conditions and Estimated Economic Cost of Traffic Fatalities in Colombian Medium-Sized Cities
Abstract	The Colombia Ministry of Transport, by Resolution No. 001282 of March 30, 2012, adopted the National Road Safety Plan 2011-2016 (PNSV 2011-2016), which consists of five lines of action for achieving national objectives, including institutional aspects, strategies on human behavior, strategies on motor vehicles, strategies on road infrastructure, and the attention and rehabilitation system of victims of traffic accidents. In late 2012, the national government, through the Ministry of Transport, subscribed agreements with ten medium-sized Colombian cities to advance theirs Local Road Safety Plans. These ten cities are among the 25 cities with the highest crash fatality rates per 100,000 habitants. The paper presents an overview of the safety conditions in the study cities, which included valuable input provided by Municipal Road Safety Committees, couple with data collected in field inspections and review of secondary data sources. This analysis shows that motorcyclists are the most vulnerable road users, followed by pedestrians and cyclists. These road users accounted for between 57.7 percent and 98.5 percent of the total traffic fatalities in 2011. This suggests the urgent need for government policies and actions to protect the lives of the most vulnerable road users. The investment of the cities in road safety and related projects is low compared to their Gross Domestic Product (GDP) and crash fatality costs. This analysis indicates that an effective traffic fine collection system would provide the cities with the money they need to increase by 50, 100, or even 200 percent their annual investment on road safety projects.

Authors	Andrew Kubas, North Dakota State University Kim Vachal, North Dakota State University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	699
Session Title	Transportation Safety Management
Paper Number	14-0518
Paper Title	Oil County Traffic Safety: Perspective of Western North Dakota Residents
Abstract	The sharp increase in travel volumes, shift in traffic mix, and large increases in traffic crashes have transformed the travel environment in the oil region of western North Dakota. Roads once used only for local access and agricultural purposes are now being used at high volumes to serve expanding oil production. Oil companies, oil workers, commercial trucks, and industrial equipment associated with gas and oil development all use these roads to access oil drilling and production sites. This has led to an increase in traffic volume and an increase in the number of overweight and oversized vehicles on the road. A survey questionnaire was sent to drivers to better understand the perceptions and behaviors of road users in this region. County-level crash data were gathered for the state of North Dakota to understand changes in driving conditions during the latest oil boom between 2004 and 2011. This research report aims to address two key goals relating to improving traffic safety in the region: first, to examine public perceptions of traffic safety issues and priorities; and, second, to address crash trends and possible intervention strategies with a focus on large truck/passenger vehicle interaction. Survey results indicate that drivers perceive the region to be dangerous and driving improvements can be made. Crash data reveal that most crash statistics are increasing at exponential rates. Safety initiatives such as ProgressZone: Moving Forward Safely appear to be beneficial, but further improvements must take place.

Authors	Hamed Ahangari, University of Connecticut Jason Outlaw, University of Connecticut Carol Atkinson-Palombo, University of Connecticut Norman Garrick, University of Connecticut
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	699
Session Title	Transportation Safety Management
Paper Number	14-5433
Paper Title	Investigation into Impact of Fluctuations in Gasoline Prices and Macroeconomic Conditions on Road Safety in Developed Countries
Abstract	In most developed countries, the total number of road fatalities peaked in the 1970s. Although the data for road fatalities evidence a distinctive downwards trend, a secondary signal that is more cyclical in nature is also evident. These cyclical variations closely track macroeconomic conditions (usually represented by the unemployment rate) and gasoline prices. While the relationship between transportation safety and unemployment and gasoline prices have been investigated, studies have looked at these variables in isolation from other important factors that impact traffic safety.

Accordingly, we have developed a comprehensive conceptual model which considers a wide array of factors influencing traffic safety and used this framework to inform an empirical model. To study variation across both time and location, we employed a panel data model using observations for 16 industrialized countries between 1990 and 2010. In the panel model, the dependent variable was fatality per population, and gas price, unemployment, health index, mobility, and vehicle ownership were the independent variables. The results revealed a significant inverse relationship between gas prices and the road fatality rate after controlling for Vehicle Miles Travelled (VMT). The elasticity analysis indicates that a 10% decrease in gasoline prices resulted in a 2.19% increase in road fatalities. Likewise, a 10% decrease in unemployment rate resulted in a 0.65% increase in road fatalities. Also, the results implied that the health index has the highest impact on road fatality rates. Overall, these results provide a better understanding of the underlying causes of periodic variations in road fatalities.

Authors Rune Elvik, Institute of Transport Economics, Norway
Sponsoring Committee ANB10, Transportation Safety Management
Session Number 699
Session Title Transportation Safety Management
Paper Number 14-0296
Paper Title Rewarding Safe and Environmentally Sustainable Driving: Systematic Review of Trials
Abstract The paper reviews trials designed to reward safe and environmentally sustainable driving. The most common type of trial offered monetary rewards to drivers for not speeding or for reducing mileage. Seven trials were identified. The most successful incentive schemes for reducing speeding were associated with a 60-80 percent reduction of speeding. Trials designed to reduce mileage were not as successful and resulted in mileage reductions of 0 to 10 percent. Small samples and high attrition rates (i.e. participants dropping out of the study before it was completed) characterized most trials. There is also likely to be self-selection bias, but the size of this bias is difficult to determine. Data for Sweden and Denmark suggest that it could be substantial. Hence, the effects found in the trials reported so far reflect what can be accomplished in groups of highly motivated drivers.

Authors Nang Ngai Sze, University of Canterbury, New Zealand
S. C. Wong, University of Hong Kong
C.Y. Lee, Hong Kong University
Sponsoring Committee ANB10, Transportation Safety Management
Session Number 699
Session Title Transportation Safety Management
Paper Number 14-0346
Paper Title Likelihood of Achieving Quantified Road Safety Targets
Abstract Since the 1970s, many countries have set quantified road safety targets to motivate transport authorities to develop systematic road safety strategies and measures and facilitate the achievement of continuous road safety improvement. Studies have been conducted to evaluate the association between the setting of quantified road safety targets and road fatality reduction, in both the short and long run, by comparing road fatalities before and after the implementation of a quantified road safety target. However, not much work has been done to evaluate whether the quantified road safety targets are actually achieved. In this study, we used a binary logistic regression model to examine the factors ¡V including a target¡¦s geographical region, time of implementation, and level of ambition, in addition to the economic development of the region setting the target ¡V that contribute to a target¡¦s success. We analyzed 77 quantified road safety targets set by 31 countries from 1970 to 2010, and the results indicate that targets set by countries in the advanced stages of road safety development and with less ambitious targets had a higher likelihood of eventually being achieved.

---

10 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.

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**.**

ABJ50 Information Systems and Technology

This committee is concerned with reviewing and assessing the state-of-the-art in the development and application of information systems and technologies in transportation for productivity improvements. Areas of emphasis are: system user interfaces, data management, and data sharing; web technologies and e-government; delineation and prioritization of research, development, and demonstration programs; encouragement of common semantics and standards in the transportation field; technology transfer among transportation organizations, vendors, and universities; and the impact of computer technologies on transportation organizations.

ABJ60, Geographic Information Science and Applications

The scope of this committee includes all aspects of the spatial, locational and temporal data used in transportation. The committee is interested in both research into and applications of this information and its associated information systems, commonly referred to as Geographic Information Systems in Transportation (GIS-T). The committee will provide a focal point for and promote coordination of GIS- T activities within the TRB committee structure. Relevant activities include the application of spatial data and spatial sciences across the entire domain of transportation information systems.

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.

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.

AFB30, Low-Volume Roads

This committee is concerned with all aspects of low-volume roads including planning, design, construction, safety, maintenance, operations, environmental, and social issues.

AH010, Surface Transportation Weather

This committee is concerned with the exchange of information on the effects of weather on all modes of surface transportation both within and between the transportation and meteorological communities; identification and development of research needs and technology transfer on techniques to better manage surface transportation; and promotion of efforts to minimize the impacts of weather and maximize safety and mobility.

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.

AHB60, Highway/Rail Grade Crossings

This committee is concerned with the safety and other affected characteristics (including economic considerations, traffic flow and delay, and countermeasures) of both highway and rail traffic at points where they intersect at grade, including the proximate surrounding environment and also including rail transit facilities.

AHB55, Work Zone Traffic Control

This committee is concerned with optimizing traffic flow and with minimizing hazards to work crews and road users, including pedestrians, in a cost-effective manner during maintenance, construction, and utility operations on streets and highways. These concerns include improved methods, procedures, materials, equipment, devices, and systems applicable to traffic control in work zones. They extend to the planning, design, installation, operation, maintenance, and removal of such traffic control zones.

AHD10, Maintenance and Operations Management

This Committee is concerned with all aspects of managing the maintenance and operations of highway transportation facilities.

ANB40, Traffic Law Enforcement

This committee is concerned with research relating to safety effects of enforcement activity and other traffic supervision measures, including those involving the driver and vehicle.

ANB70, Truck and Bus Safety

This committee will focus on motor carrier safety in all its aspects. This will include research and evaluation in human, roadway, vehicle, operational, organizational, and regulatory arenas as they relate to motor carrier 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.

AND10, Vehicle User Characteristics

This committee is concerned with the needs, capabilities, and limitations of vehicle users as these considerations affect the design, operation, and maintenance of personal, commercial and public transportation systems embracing highway and rail operations. The objectives of this committee are to maximize performance, safety, comfort, and efficiency of such systems.

AND20, User Information Systems

The committee's activities will focus on the information exchange between the transportation mode and the user. Particular attention will be placed on defining the informational requirements, user capabilities, and situation and environmental conditions that affect the adequate and accurate transmission of user information. The committee's purview will include all modes of transportation and will also address the interface between modes.

AND30, Simulation and Measurement of Vehicle and Operator Performance

This committee is concerned with the development and use of technology for the measurement and prediction of vehicle and operator performance and behavior. This technology includes simulators, instrumented vehicles, instrumented environments, and models.

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.

ANF30, Motorcycles and Mopeds

This committee is concerned with all aspects of motorcycles and mopeds, including the operator, the vehicle, and the transportation environment.

11 Acknowledgements

The authors are most grateful to Muamer Abuzwidah (University of Central Florida), Lella Liana Imbriani (University of Naples Federico II), Filomena Mauriello (University of Naples Federico II), Juneyoung Park (University of Central Florida), and Qi Shi (University of Central Florida) for their precious collaboration.