TRB Standing Committees

ANB10 – Transportation Safety Management

ANB20 – Safety Data, Analysis and Evaluation

ANB25 – Highway Safety Performance

Synthesis Report

on safety-related papers presented at the 94th TRB Annual Meeting

Prepared by

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TRB Standing Committee ANB10 – Transportation Safety Management

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

Website: http://www.anb10.org

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TRB Standing Committee ANB20 – Safety Data, Analysis and Evaluation

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

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

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

TRB Standing Committee ANB25 – Highway Safety Performance

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

Website: http://www.safetyperformance.org

Membership as of December 2014

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Erin M. Ferguson, Kittelson & Associates, Inc. (KAI)

Contents

1 Introduction 2

2 Crash Data and Data Analysis 6

3 Network Screening 28

4 Safety Performance Functions 32

5 Crash Severity Prediction 63

6 Crash Mofification Factors 80

7 Surrogate Measures of Safety 96

8 Applications of the Highway Safety Manual 122

9 Transportation Safety Management 124

10 Interacting Committees 141

11 Acknowledgements 144

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 94th 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. Indeed, highway safety is a worldwide major social challenge which requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

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

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

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

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

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

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

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

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

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

Time	Title	Location
Monday, 8:00AM – 9:45AM	Animal-Vehicle Collisions Subcommittee, ANB20(2)	Marquis, Ballroom Salon 16 (M2)
Monday, 8:00AM – 9:45AM	Emergency Medical Services Safety Subcommittee, ANB10(5)	Marquis, Eastern Market (M3)
Monday, 10:15AM – 12:00PM	Motorcycle and Moped Safety Joint Subcommittee of ANB20, ANF30	Marquis, Ballroom Salon 16 (M2)
Monday, 1:30AM – 5:30PM	Safety Data, Analysis and Evaluation Committee	Marquis, Ballroom Salon 6 (M2)
Monday, 3:45AM – 5:30PM	School Transportation Subcommittee, ANB10(6)	Marquis, Ballroom Salon 15 (M2)
Tuesday, 8:00AM – 12:00PM	Transportation Safety Management Committee	Marquis, Ballroom Salon 12 (M2)
Tuesday, 10:15AM- 12:00PM	Surrogate Measures of Safety Subcommittee, ANB20(3)	Marquis, Ballroom Salon 15 (M2)
Tuesday, 1:30PM – 3:15PM	Toward Zero Deaths Goal Subcommittee, ANB10(9)	Marquis, Gallaudet University (M1)
Tuesday, 3:45PM – 5:30PM	Future Directions in Safety Analysis Joint Subcommittee of ANB20, ANB25	Marquis, Ballroom Salon 17 (M2)
Tuesday, 7:30PM- 9:30PM	Intersections Joint Subcommittee of AHB65, AFB10, AHB70, and ANB20	Marquis, Ballroom Salon 13 (M2)
Wednesday, 8:00AM – 9:45AM	Global Road Safety Subcommittee, ANB10(8)	Marquis, Ballroom Salon 7 (M2)
Wednesday, 8:00AM – 9:45AM	Traffic Speed and Safety - Cross-cutting Issues Joint Subcommittee of ANB20, AHB65, ANB10	Marquis, Ballroom Salon 13 (M2)
Wednesday, 10:15PM – 12:00PM	Bicycle and Pedestrian Safety Analysis Joint Subcommittee of ANB20, ANF10, ANF20, ANB25	Marquis, Ballroom Salon 13 (M2)
Wednesday, 10:15PM – 12:00PM	Rural Road Safety Policy, Programming, and Implementation Joint Subcommittee of ANB10, AFB30	Marquis, Ballroom Salon 14 (M2)
Wednesday, 12:15PM – 2:15PM	User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marquis, Ballroom Salon 13 (M2)
Wednesday, 2:30PM – 4:00PM	Transportation Safety Planning Subcommittee, ANB10(3)	Marquis, Ballroom Salon 14 (M2)
Wednesday, 2:30PM – 6:00PM	Highway Safety Performance Committee	Marquis, Ballroom Salon 12 (M2)
Wednesday, 6:15PM – 7:15PM	Conferences and Meetings Subcommittee, ANB25(4)	Marquis, Ballroom Salon 13 (M2)
Wednesday, 6:15PM – 7:15PM	Policy and Legal Aspects Subcommittee, ANB25(1)	Marquis, Ballroom Salon 15 (M2)
Wednesday, 6:15PM – 8:15PM	International Research Subcommittee, ANB25(5)	Marquis, Ballroom Salon 9 (M2)
Thursday, 8:00AM – 12:00PM	Highway Safety Performance Committee	Marquis, Liberty K (M4)

Table 2 ANB 10, ANB20, and ANB25 Workshops

Time	Title	Location
Sunday, 9:00AM - 12:00PM	(136) Addressing Global Road Safety: The PIARC Road Safety Manual, 2nd Edition	Convention Center, 103B
Sunday, 9:00AM - 12:00PM	(105) The Art of Urban Street Performance Metrics	Convention Center, 152B
Sunday, 9:00PM – 12:30PM	(145) Freeway and Interchange Design: Applying the Science and Art of Engineering Innovation	Convention Center, 204B
Sunday, 9:00PM- 5:00PM	(146I,) HF-I Applying Human Factors to Roadway Design and Traffic Engineering: Practical Tools, Resources, and Procedures	Ticket required
Sunday, 1:30PM- 4:30PM	(178) The Present and Future of Speed Limits in a Toward Zero Deaths (TZD) Framework	Convention Center, Salon B

Table 3 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(199) Improving Safety Programs Through Data Governance and Data Business Planning	Convention Center, 146C
Monday, 10:15PM – 12:00PM	(281) Safety Management Data Analytics	Convention Center, 103A
Monday, 10:15PM – 12:00PM	(283) Impaired Driving in Low and Middle Income Countries: Challenges and Opportunities for Progress	Convention Center, 103B
Monday, 7:30PM – 9:30PM	(475) Transforming the Future of Safety with a Vision Towards Zero Deaths	Convention Center, 102B
Monday, 7:30PM – 9:30PM	(476) Prevention and Modeling of Severe Crashes	Convention Center, 102A
Tuesday, 8:00AM – 9:45AM	(510) Advancing the Science of Highway Safety Performance	Convention Center, 102A
Tuesday, 10:15AM – 12:00PM	(548) Livable Arterials: Urban Elixir or Oxymoron?	Convention Center, 151B
Tuesday, 3:45PM – 5:30PM	(692) International Benchmarking on Road Safety	Convention Center, 102B
Tuesday, 5:45PM – 7:15PM	(732) Meet the Author: Ezra Hauer, "The Art of Regression Modeling in Road Safety"	Convention Center, 103B
Wednesday, 2:30PM – 4:00PM	(835) Rural Road Safety Research and Practical Applications	Convention Center, 102A

Table 4 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 2:00PM – 3:45PM	(386) Data-Driven Safety Management: Multidisciplinary Approach	Convention Center, Hall E
Monday, 2:00PM – 3:45PM	(387) School Transportation Research	Convention Center, Hall E
Tuesday, 8:30AM – 10:15AM	(540) Crash-Based Safety Analysis and Modeling	Convention Center, Hall E
Tuesday, 10:45AM – 12:30PM	(594) Case Studies in Performance-Based Analysis of Geometric Design	Convention Center, Hall E
Tuesday, 4:15PM – 6:00PM	(728) Recent Research, Best Practices, and Implementation of Zero Death Goals and Plans	Convention Center, Hall E
Tuesday, 7:30PM – 9:30PM	(751) Exploring Safety and Risk of Nonmotorized Vehicles	Convention Center, Hall E
Tuesday, 7:30PM – 9:30PM	(752) Is It Safe to Use Surrogate Measures of Safety?	Convention Center, Hall E
Tuesday, 8:30AM – 10:15AM	(789) Highway Safety Performance	Convention Center, Hall E

2 Crash Data and Data Analysis

Mohamad Banihashemi, GENEX Systems

The Subcommittee identified several papers related to the effect of some relatively new factors on safety, Bayesian and multilevel models, Level of Service of Safety (LOSS) and probabilistic approches, signalized intersections and secondary crashes, pedestrian, bicyclists and school travel safety, driver behavior and safety studies using Naturalistic Driving Study (NDS) data, and data management and quality assessment.

There are several relatively new factors studied with respect to their effects on highway safety. Savolainen and Gates (15-0175) and Amelia et al. (15-0180) have studied the effect of differential speed limit on safety. Harootunian et al. (15-2176) have studied the effect of distance from home on safety. Imprialou et al. (15-3888) have studied the effect of speed at the time of crash and Tasic and Porter (15-4181) have studied the relations between access to multimodal transportation and safety. Relations between access to medical facilities and safety is studied by Hu et al. (15-5290) and Qin and He (15-3027). The effect of speed limit on safety is studied by Green (15-5580). Ewing et al. (15-3063) and Mohanty et al. (15-0205) have studied the effect of urban sprawl and built environment on safety. The effect of socioeconomic classifications on safety is studied by Yu (15-4414). Ale Mohammadi et al. (15-4597) have studied the relations between seasonal factors and safety. Geddes et al. (15-3463) have studies the effect of private road management on safety. And effect of mountainous characteristic on safety is studies by Ma et al. (15-1709).

Full Bayesian and multilevel modeling are used by many researchers. Wang et al. (15-0185), Sacchi and Sayed (15-0622), Mehta (15-5229), and Chen (15-5506) have used Bayesian modeling. Imprialou et al. (15-0216), Yannis (15-3104), and Mulokozi (15-3070) have used multilevel modeling.

Kononov et al. (15-1619) revised the Level of Service of Safety (LOSS) process by addressing correction for Regression to the Mean (RTM), Bias and Azevedo et al. (15-5968) have conducted probabilistic safety anslysis.

Intersection crashes are studied by Polders et al. (15-2648) and secondary crashes are studied by Zheng et al. (15-3185), Song et al. (15-5166), and Sarker et al. (15-2363).

Pedestrian, bicyclist and school travel safety are studied by several researchers. Gaca and Kiec (15-3393) and McAndrews (15-4731), Lowry and Cool (15-5989), and Bergh (15-6003) have studied pedestrian and bicyclist safety. Farah and Shani (15-1223), McDonald et al. (15-1189), and Change et al. (15-4802) have studied school trave safety.

Relations between driver behavior as well as the use of Naturalistic Driving Study (NDS) data in safety analysis are other areas studied by researchers. Eguakun et al. (15-4770) have studied high-risk drivers. Kim et al. (15-4991) and Hutton et al. (15-4794) have studied driver

behavior and safety relations by using NDS data.

Data quality is studied by Ferreira et al. (15-4373) and Alluri et al. (15-5532). Paz et al. (15-1990, and Jalayer et al. (15-2288) have reported the preparation of data for Safety Analyst and Highway Safety Manual (HSM).

Authors	Peter Tarmo Savolainen, Iowa State University Timothy Jordan Gates, Wayne State University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0175
Paper Title	Freeway Crash Trends in Relation to Posted Speed Limits Contrasts between Cross-Sectional and Before-and-After Evaluations
Abstract	As of June 2014, Michigan is one of eight states with a differential speed limit in place on its freeway network, which sets a maximum speed of 70 mph for passenger vehicles and 60 mph for trucks and buses. In select urban environments, these speed limits are both reduced to a uniform 55 mph limit. The purpose of this study was to examine crash trends between urban and rural freeways with differing speed limit policies. A longitudinal study was conducted to examine crash trends on Michigan freeways over the period from 2004 through 2012. Aggregate comparisons were made between all freeway segments that were posted at 70 mph for passenger vehicles (and 60 mph for trucks and buses) and all urban segments posted at a uniform 55-mph speed limit. The results showed that crash, injury, and fatality rates were significantly higher in urban environments, particularly on those segments that were posted at 55 mph. To investigate this issue further, a detailed analysis was conducted of crash data from urban freeways where speed limits had been increased from 55 mph to either 65 mph or 70 mph for passenger vehicles during the study period. Results showed that total and injury crashes increased after the speed limit was raised while no significant difference was observed in fatal crashes. These findings suggest that increased crash risks in urban areas may be reflective of lower design standards and more challenging geometric conditions due to limited right-of-way.

Authors	Amelia Davis, Wayne State University Elizabeth Hacker, Wayne State University Peter Tarmo Savolainen, Iowa State University Timothy Jordan Gates, Wayne State University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-0180
Paper Title	A Longitudinal Analysis of Rural Interstate Fatalities in Relation to Speed Limit Policies
Abstract	The extant research literature has shown traffic fatalities to increase at higher speed limits. A related issue is the establishment of maximum speed limits for trucks and buses. As of 2014, there are eight states that have a differential speed limit in place, which establishes a higher limit for passenger vehicles than for trucks and buses. This study aims to inform continuing debate regarding the safety impacts of speed limits by comparing states with various speed limit policies. The study includes a longitudinal comparison of state-level rural interstate fatalities in the United States from 1999 through 2011. In addition to examining differences in traffic fatalities as a function of maximum speed limits, comparisons were also made among states with differential limits for truck and buses. Random parameter negative binomial models were estimated for annual total and truck-involved fatalities. A random parameter framework allowed for consideration of temporal correlation in annual fatality counts within states, as well as for unobserved heterogeneity across states. The results of this study provide further evidence that both overall and truck-involved fatalities increase with maximum speed limits. Differential speed limits were found to have marginal differences in total fatalities as compared to states with uniform speed limits. However, truck-involved fatalities were significantly lower in states where differential limits were in place. The effects of speed limit policies, as well as other covariates, were found to vary significantly across states. The random parameter models demonstrated significantly improved goodness-of-fit as compared to standard Poisson and negative binomial models.

Authors	Ling Wang, University of Central Florida Qi Shi, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida Pei-Fen Kuo, University of Central Florida
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0185
Paper Title	Predicting Crashes on Expressway Ramps with Real-Time Traffic and Weather Data
Abstract	Very limited research have been conducted on real-time crash analysis of expressway ramps, although there have been many studies in recent years on estimating real-time crash prediction models for mainlines. This study presents Bayesian logistic regression models for single-vehicle (SV) and multi-vehicle (MV) crashes on expressway ramps using real-time Microwave Vehicle Detection System (MVDS) data, real-time weather data, and ramp geometric information. The results find that the Logarithm of vehicle count, average speed in a 5-minute interval, and visibility are significant factors for the occurrence of SV and MV crashes. The Bayesian logistic regression models show that curved ramps and wet road surfaces would increase the possibility of an SV crash, and off-ramps would result in high MV crash risk. The high standard deviation of speed in a 5-minute interval would significantly increase MV crash likelihood. Random forest is applied in variable importance analysis, and the result reveals that the most important factors influencing crashes on ramps are traffic variables, the second most important factors are weather variables, and the least important but still significant factors are the ramp geometry.

Authors	Maria-Ioanna Imprialou, Loughborough University, United Kingdom Mohammed A. Quddus, Loughborough University, United Kingdom David Pitfield, Loughborough University, United Kingdom
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0216
Paper Title	Multilevel Logistic Regression Modeling for Crash Mapping in Metropolitan Areas
Abstract	The spatial nature of traffic crashes makes crash locations one of the most important and informative attributes of crash databases. It is however very likely that recorded crash locations in terms of easting and northing coordinates, distances from junctions, addresses, road names and types are inaccurately reported. Improving the quality of crash locations therefore has the potential to enhance the accuracy of many spatial crash analyses. The determination of correct crash locations usually requires a combination of crash and network attributes with suitable crash mapping methods. Urban road networks are more sensitive to erroneous matches due to high road density and inherent complexity. This paper presents a novel crash mapping method suitable for urban and metropolitan areas that matched all the crashes that occurred in London from 2010-2012. The method is based on a hierarchical data structure of crashes (i.e. candidate road links are nested within vehicles and vehicles nested within crashes) and employs a multilevel logistic regression model to estimate the probability distribution of mapping a crash onto a set of candidate road links. The road link with the highest probability is considered to be the correct segment for mapping the crash. This is based on the two primary variables: (a) the distance between the crash location and a candidate segment and (b) the difference between the vehicle direction just before the collision and the link direction. Despite the fact that road names were not considered due to limited availability of this variable in the applied crash database, the developed method provides a 97.1% (±1%) accurate matches (N=1,000). The method was compared with two simpler, non-probabilistic crash mapping algorithms and the results were used to demonstrate the effect of crash location data quality on a crash risk analysis.

Authors	Jake Kononov, DiExSys LLC Catherine Durso, University of Denver Craig Lyon, Persaud and Lyon Inc., Canada Bryan K. Allery, DiExSys LLC
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-1619
Paper Title	Level of Service of Safety Revisited
Abstract	The concept of the Level of Service of Safety (LOSS) was developed at the Colorado Department of Transportation (CDOT) in 2000. LOSS reflects how a roadway segment or an intersection is performing in reference to the expected frequency and severity of crashes predicted by its Safety Performance Function (SPF). The concept of the LOSS provides quantitative assessment and qualitative description of the degree of safety of a segment or of an intersection. Additionally, it facilitates effective communication about safety problems to other professionals, the traveling public, and elected officials. The LOSS concept was first introduced in the 2003 TRB (1) paper entitled Level of Service of Safety-Conceptual Blueprint and Analytical Framework. LOSS was incorporated into the first edition of the AASHTO Highway Safety Manual (HSM) (2) and is presently used by the Colorado DOT, Wyoming DOT, Montana DOT, Louisiana DOT, Oklahoma DOT and the Ontario Ministry of Transport. LOSS lends itself well to the safety decision making process in the DOT environment. However, it did not initially address correction for the Regression to the Mean (RTM) Bias. This paper introduces a new method for using LOSS in concert with correction for RTM bias using an Empirical Bayes (EB) procedure. Additionally it revisits distributional assumptions associated with the LOSS, explains how the LOSS boundaries are calibrated in the population corrected for the RTM bias, and provides an intuitive percentile-based reporting method. Finally the paper works through a diagnostic example and a before and after study demonstrating the value of LOSS in identifying the safety problem at a real location.

Authors	Kristine Harootunian, University of Vermont Brian H. Y. Lee, University of Vermont Lisa Aultman-Hall, University of Vermont
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-2176
Paper Title	Implications of Distance from Home on Fault Determination for Crashes in Vermont
Abstract	Previous research has shown that both foreign and out-of-state drivers are at a safety disadvantage when compared to “local” drivers. But what defines local? Here, the effect of distance from home was examined with regards to fault in crashes. By estimating the distance between driver’s home and crash locations, we tested the effect increased distance from home had on crash fault determination using five years of data from the Vermont state crash database. A set of logistic regression models showed that greater distances from home increased odds of fault for drivers, particularly in single-vehicle crashes. The odds increased further when distance was interacted with variables such as road geometry, vehicle ownership, and poor road surface condition compared to when distance was held constant. Interestingly, increased distance from home alleviated the effects of certain factors that have been shown in previous research to be hazardous. Holding distance constant, being a non-owner, driving on weekends, or during the summer increased one’s odds of fault; as distance increased, however, the effects of these conditions decreased odds of fault. This phenomenon, although present, was markedly less influential for two-vehicle crashes.

Authors	Evelien Polders, Hasselt University, Belgium Stijn Daniels, Hasselt University, Belgium Elke Hermans, Hasselt University, Belgium Tom Brijs, Hasselt University, Belgium Geert Wets, Hasselt University, Belgium
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-2648
Paper Title	Crash Patterns at Signalized Intersections
Abstract	Traffic signals are often implemented to provide for efficient movement and to improve traffic safety. Nevertheless, severe crashes still occur at signalized intersections. This study aims to improve the understanding of signalized intersection safety by identifying crash types, locations and factors that are associated with signalized intersections. For this purpose, 1295 police-reported crashes at 87 signalized intersections are analyzed based on detailed crash descriptions, i.e. crash data and collision diagrams. The information of the collision diagrams is used to distinguish 6 different crash types and to divide the signalized intersection into 13 detailed and different typical segments. Negative binomial and logistic regression modeling techniques are used to identify relations between the crash types, their crash location on certain signalized intersection segments, the crash severity and the different features that affect their crash occurrence. Four dominant crash types are identified: rear-end, side, head-on and vulnerable road user crashes. The results of the logistic regression model showed that the crash location of these crash types is related to specific signalized intersection segments. The results of both model techniques also reveal important signalized intersection features that affect the crash occurrence. As a result, connections between certain signalized intersection crash types, their crash location and signalized intersection design characteristics have been found.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-3185
Paper Title	Analyses of Multiyear Statewide Secondary Crash Data and Automatic Crash Report Reviewing
Abstract	Secondary crashes are undesired consequences following other highway incidents. Previous studies used different methods to identify secondary crashes. However, due to the expense of accurate identification, most of them only focused on small scale highway networks (e.g., from highway segments up to urban arterials). Some studies looked into the state level by allowing many false secondary crashes, which weakens their findings. Recently, the authors proposed an efficient method to identify secondary crashes on statewide freeway networks with reasonable accuracy. A one-year case study was conducted for preliminary analysis. As a continuing effort, this research included four more years of secondary crash data and 1) found rear-ends and sideswipes in the same direction to be the top two secondary crash types, 2) identified inattentive driving condition, debris in road, construction zone, and obscured visibility as potential highway contributing factors, 3) identified following too close, inattentive driving, losing vehicle control, and speeding to be potential driver contributing factors, 4) found that the temporal distributions by hour of day and by month of year were different between secondary crashes and general crashes, and 5) showed that secondary crash hotspots clustered around urban areas and were within one mile from major freeway interchanges. In addition, an algorithm was proposed to detect secondary crashes based on scanned crash reports. This algorithm was evaluated using the 5-year secondary crash data (4 years for training and 1 year for testing). By choosing an optimal threshold, this algorithm can identify all true secondary crashes while keeping false positives at a low number.

Authors	Stanislaw Gaca, Cracow University of Technology, Poland Mariusz Kiec, Cracow University of Technology, Poland
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	751
Session Title	Exploring Safety and Risk of Nonmotorized Vehicles
Paper Number	15-3393
Paper Title	Assessment of Pedestrian Risk at Crossing Using Kinematic-Probabilistic Model
Abstract	One of the primary road safety problems in Poland are accidents involving pedestrians. Accident statistics indicate a significant, 26.5% share of pedestrians in accidents and their effects, i.e. the number of the injured and killed pedestrians exceeds 1/3 of all accident fatalities. Many factors affect accidents involving pedestrians, such as those related to the road characteristics, speed or traffic volume. This paper presents a method with a surrogate safety measure, allowing assessment of the influence of various pedestrian crossings on road safety. The authors used surrogate measures of road safety risk assessment which included speed change when approaching a crossing. This assessment was carried out by applying kinematic modeling taking into account the fatality risk as a function of impact speed for pedestrians struck by the front of a passenger car and the initial vehicle speed. Initial speed was analyzed in relation to vehicle speeds recorded when approaching various pedestrian crossings with different signs and location. The analysis method allowed comparison of road safety on several different pedestrian crossings while taking into account a number of variables: lighting and surface conditions and distance, at which pedestrians are noticed in the moment when braking begins. Basing on the research results, levels of hazard caused by sudden pedestrian appearance on the road, depending on the type of infrastructure were evaluated. Values of ratio of probability of lack of road accident at compared types of pedestrian crossings were evaluated, as well as the probability of fatalities caused by intrusion on the pedestrian crossing.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-3888
Paper Title	Exploring the Role of Speed in Highway Crashes Pre-Crash-Condition-Based Multivariate Bayesian Modeling
Abstract	Although traffic speed is considered as one of the major contributory factors for crashes, research findings on the relationship of speed and crash frequency are not consistent. This is possibly because the overly aggregated data, used by segment-based crash modelling approaches, fail to describe the pre-crash traffic conditions that are related with crash occurrences. This paper presents an alternative data-aggregation method aiming at a more accurate representation of the pre-crash traffic and geometrical conditions that are identified based on their geo-coded crash locations. Crashes are classified into homogeneous pre-crash-condition scenarios (defined by speed, volume and geometric characteristics) and are modelled by severity type (i.e. fatal, serious, slight) employing multivariate Poisson log-normal regression using the Bayesian inference. The main findings of the analyses suggest that speed is proportionally related with both crash frequency and severity and that this relationship is described better by a quadratic rather than a linear specification. Speed variance, that is indirectly represented by traffic volume, is also found to contribute to fatal and serious-injury crashes. From a methodological point of view, crash location accuracy is found to affect analyses significantly and improves the modelling results.

Authors	Ivana Milorad Tasic, University of Utah Richard Jon Porter, University of Utah
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-4181
Paper Title	Modeling Spatial Relationships between Access to Multimodal Transportation and Traffic Safety Outcomes
Abstract	The interest in multimodal transportation improvements in urban areas is increasing in cities across the U.S. Inherent with this interest is the need to continue to develop methods for measuring safety performance in these environments. Improved access to multimodal transportation attracts new users, but can increase their exposure to risk from crashes. The relationship between access to multimodal transportation and safety in urban environment is complex, as non-motorized user vulnerability becomes a predominant risk factor. This paper aims to evaluate the relationship between access to multimodal transportation, expressed through infrastructure presence and user exposure, and traffic safety outcomes. Using the City of Chicago as a case study, a comprehensive dataset is developed that significantly contributes to the existing literature by including socio-economic, land use, road network, travel demand, and crash data. Area-wide analysis on the census tract level provides a broader perspective about safety issues that multimodal users encounter in cities. Negative-binomial regression models with fixed and random effects are estimated to account for data overdispersion and spatial effects. Total vehicle-only crashes, total crashes with at least one non-motorized user, and fatal vehicle-only crashes are modeled. The results show strong association between the variables related to multimodal transportation access and usage, and both motorized and non-motorized crashes. Although simplified in terms of some spatial correlation assumptions, demonstrated methods prove to be a beneficial and computationally efficient tool for estimating and easily interpreting modeled relationships. Further research efforts to address the limitations of the presented approach are proposed.

Authors	Carolyn McAndrews, University of Colorado, Denver
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	751
Session Title	Exploring Safety and Risk of Nonmotorized Vehicles
Paper Number	15-4731
Paper Title	Pedestrian and Motor Vehicle Occupant Safety in Rural and Urban Communities Comparison of Fatality Risk per Trip
Abstract	Walking is typically characterized as part of an urban lifestyle, but walking is also an important travel mode and form of recreation in rural and small communities. With respect to safety, rural places are known as high-risk areas for transportation fatalities, but most research about rural transportation safety has focused on motor vehicle travel and little is known about the patterns of pedestrian safety in rural and small communities. To address the gap, we compared the fatality risk of walk and motor vehicle trips in rural and urban areas by sex. The analysis used three different constructs of rurality, including population density, the U.S. Census definition of urban and rural places, and the Rural Urban Commuting Area classification system. The analysis focuses on Wisconsin, and uses the 2001 Wisconsin Add-On to the National Household Travel Survey to estimate exposure for pedestrians and motor vehicle occupants, and the Fatality Analysis Reporting System (FARS) for information about fatalities for 2001-2009. For motor vehicle occupants the fatality rates per trip were consistently higher in rural places than urban places. In contrast, there was no statistically significant difference in pedestrian fatality rates per trip across rural and urban places as they were defined. One explanation for this result is that commonly used urban-rural constructs are not able to distinguish the protective aspects of pedestrian-friendly environments.

Authors	George Eguakun, Saskatchewan Government Insurance, Canada Peter Y. Park, University of Saskatchewan, Canada Kwei Quaye, Saskatchewan Government Insurance, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-4770
Paper Title	Identifying Optimal High-Risk Driver Segments for Safety Messaging Geodemographic Modeling Approach
Abstract	Given the public safety risk posed by high-risk drivers, most traffic safety agencies consider the group as one of the key targets for strategic planning purposes. The aim of this research is to develop a framework for traffic safety professionals that can be used to efficiently and effectively segment and target high-risk drivers. The specific objectives are to establish whether high-risk drivers are homogenous, and if not, and to determine the optimal set of primary and clusters that could be reached efficently and effectively with minimal resources. Multiple databases including Saskatchewan Government's traffic collision, insurance claims and conviction data formed the basis for the research. Geodemographic modeling, which uses the geographic neighborhood as the unit of analysis and a large number of variables, along with probabilistic clustering techniques, were used analyze the data. The results indicate that the high-risk driver group is not homogenous, but exist as sub clusters with varying collision and traffic behaviour profile. The study found that in Saskatchewan, high-risk drivers are dominating in the major cities (56%), rural municipalities (18%) and towns (16%). However, the optimal primary high-risk segments for efficient targeting lie in major cities and towns where both the risk of collision involvement and penetration of high-risk drivers are higher than the average cluster population. Members of the primary segment exhibit higher levels of distracted, impaired and aggressive driving behaviors. They are also significantly impacted by human conditional factors such as driver-inexperience, extreme fatigue, falling asleep behind the wheel, and inattention. Suggestions for future work and practical application of the finding are provided.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-4991
Paper Title	Exploring Association of Crash Propensity and Microscale Driver Behavior
Abstract	The relationship between driver behavior at the tactical level and crash experience is a long sought association that has been elusive to explore. Generally speaking, crash models have investigated such associations on the basis of demographics, driver and driving conditions, roadway geometry, exposure and the like. The availability of in-vehicle sensing devices capable of capturing and documenting micro-scale dynamic driver behavior offers the opportunity to begin such an exploration. Initial such efforts have been documented in the Naturalistic Driving Study sponsored by the SHRP-2 Safety program. The research documented in this paper integrates rear-end crash data experienced on an extended freeway facility over a four-year period with three months of micro-scale driving behavioral data gathered by an in-vehicle sensing system (i2D) that records and dispatches second by second vehicle dynamics data to a central database. The information collected by the i2D devices came from a fleet of about 20 vehicles driven by volunteers in their naturalistic driving environment. Additionally all crash and driver data were geo-located using a link-based standard called the Traffic Message Channel (TMC). There were 60 such TMC's on the extended freeway facility that was studied. The initial findings of this research are promising. First, the crash data revealed hotspot locations starting at the on-ramp gore and extend 2,000 feet upstream. Over 85% of all rear end crashes occurred at those 30 hotspots on internal TMC's. Secondly, on those TMC with high crash rates we have detected a high propensity of drivers to decelerate at high rates (4 m/sec2 or more). The TMC based measure of that propensity is the fraction of time drivers decelerate at those rates. We have also tested and confirmed that the sharp deceleration phenomenon is not confined to a few drivers, but appears to be common for the high-crash TMC's, using trip-based analyses.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5166
Paper Title	Novel Collision Classification Methodology Based on Temporal Link Speed Data and Congestion Thresholds
Abstract	The key to precise classification of primary and secondary crashes lies in identification of primary crash impact areas. Previous studies have used either fixed or dynamic impact area boundaries to investigate whether or not specific crashes occurred within the impact area of a preceding crash. This general approach is unable to identify secondary crashes that occur either in the impact area of primary crashes that are not locatable in time and space or in the impact area of non-crash incidents. Furthermore, there is value in further distinguishing between primary crashes that occur in recurring congestion versus uncongested conditions. Assuming that congestion occurring at a location and time that is not normally congested is the result of a non-recurring incident (crash or non-crash), this study develops a robust and easily implementable methodology to classify crashes in different types of congestion. The methodology directly exploits link-based speed data with no requirement for identifying the precipitating incident or defining the impact area boundary. This study also proposes a novel approach for defining recurring congestion areas as a basis for distinguishing between recurrent and non-recurrent congestion. A 500 crash case study was performed on a 170-mile section of I-40 in North Carolina. Twelve percent of the case study crashes are classified as having occurred in non-recurring congestion. The remaining crashes can be considered as primary crashes occurring either in uncongested conditions (84%) or in recurring congestion (4%). The proposed methodology can be implemented in any advanced traffic management system in which crash time and link location and corresponding archived link speed data are available.

Authors	Wei Hu, University of Tennessee Knoxville Qiao Dong, University of Tennessee, Knoxville Baoshan Huang, University of Tennessee, Knoxville
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5290
Paper Title	Effects of Distance to Medical Facilities and Rescue Time on Traffic Mortality Utilizing Geographic Information System
Abstract	Albeit supported by little scientific evidence, the concept of “golden hour,” which claims that mortality for trauma patients rises significantly over rescue time, plays a vital role in the design of our current trauma system. In this study, only the contrary results could be found by using Fatality Analysis Reporting System (FARS) data from 2010 to 2012. The results of logistic regression showed that longer time intervals were associated with lower traffic mortality, regardless of the specific year or time interval. Utilizing the closest facility solver in the Geographic Information System (GIS), a potential explanation was discovered for this phenomenon and existing issues with the FARS dataset were discussed. Furthermore, based on the Kentucky Collision Analysis for the Public (KCAP) data from 2010 to 2012, a correlation was identified between increased journey distance and increased mortality through logistic regression for both hospitals and trauma centers. The journey distance to trauma centers was found to be more significant than the journey distance to hospitals for the mortality of seriously injured patients.

Authors	CoDanielle Green, South Carolina State University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5580
Paper Title	Relevance of Posted Minimum Speed Limit along Interstate Highways of South Carolina in Relation to Effects It Maintains on Varying Speeds of Vehicles
Abstract	This study investigates South Carolina's crash data along the state's interstate highways during a three-year time span. The most current South Carolina Department of Transportation map (2012) was used to determine the length of each segment and the corresponding speed limit. Segments along the highways were categorized by county (length), interstate, and related speed limit (55mph, 60mph, 65mph and 70mph). Crash rates were computed for the four speed limit segments. Subsequently, due to the known negative impacts of speed variation, the estimated collision speed variance between vehicles on the highways was ascertained in order to determine any associations regarding the difference between the speed limit, the speed of the car at impact and whether the percentage of cars traveling at or above the minimum speed limit and below the speed limit retained an influence on the crash rates along the interstate. Under significant findings, the implementation of proper minimum speed limits will serve as an affordable method of further protecting the lives of travelers along the interstate; as will, the elimination of minimum speed limit signs that have shown to be ineffective.

Authors	Michael B. Lowry, University of Idaho Seth Cool, University of Idaho
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	751
Session Title	Exploring Safety and Risk of Nonmotorized Vehicles
Paper Number	15-5989
Paper Title	Defining a Typology of Dangerous Situations for Bicyclists
Abstract	This paper presents a new method to evaluate bicycle infrastructure plans in terms of exposure to dangerous situations. Central to the new method is a typology of 23 dangerous situations for bicyclists that were identified through a literature review. The first step of the analysis is to define exposure indicators for these dangerous situations. Example indicators are presented for 12 situations. In practice, a community should define their own indicators based on public input, local circumstance, and current research. Next, the analyst can assess dangerous situation exposure for proposed bicycle improvement scenarios using a GIS tool created for this project. The results from the tool provide a means to compare projects and communicate the impact of infrastructure investments. For example, the proposed bicycle master plan for the case study would decrease the exposure indicator for cycling in hazardous conditions by 55% and decrease the exposure indicator for the right hook situation by 7%, but increase the exposure indicator for cycling along streets with frequent access points by 4%. Engineers and planners can use the tool and process presented in this paper to help improve safety for bicyclists.

Authors	Casey Ryan Bergh, Kittelson & Associates, Inc.
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	751
Session Title	Exploring Safety and Risk of Nonmotorized Vehicles
Paper Number	15-6003
Paper Title	Implementing a Risk-Based Systemic Safety Prioritization Method for Pedestrian and Bicycle Crashes in Oregon
Abstract	This paper demonstrates an innovative application of a risk-based systemic safety prioritization method by the Oregon Department of Transportation (ODOT) to reduce pedestrian and bicycle crashes statewide. Traditional systemic safety analysis relies on identifying locations with frequent and severe crash history and applying low-cost, proven countermeasures at these locations. This traditional method is not effective when applied to pedestrian and bicycle crashes for two reasons: 1) the frequency of these crashes at one location is rarely enough to establish a clear understanding of the crash cause and identify an effective countermeasure, and 2) there are few low-cost, proven countermeasures available to reduce these crashes. The risk-based approach prioritizes locations with the greatest potential for crash reduction. Risk is identified as roadway characteristics that contribute to pedestrian and bicycle crashes statewide. Pedestrian risk factors identified for ODOT include: presence of enhanced or signalized crossing; vehicular volume and posted speed; cross-section of adjacent roadways; presence of transit stops; and, crash history. Bicycle risk factors identified for ODOT include: driveway density; vehicular volumes and speeds; cross-section of adjacent roadways; presence of traffic signals; presence of transit stops; and, crash history. A scoring methodology and worksheet was developed to prioritize corridors, based on these risk factors. GIS tools were used to score and prioritize corridors for project development. Using risk in a systemic safety process increased ODOT's confidence that countermeasures will be effectively implemented where they will have the most influence and that funding will be efficiently allocated.

Authors	Reid Ewing, University of Utah Shima Hamidi, University of Utah James B. Grace, University of Louisiana, Lafayette
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3063
Paper Title	Urban Sprawl as a Risk Factor in Motor Vehicle Crashes
Abstract	A decade ago, compactness/sprawl indices were developed for metropolitan areas and counties which have been widely used in health and other research. In this study, we first update the original county index to 2010, then develop a refined index that accounts for more relevant factors, and finally seek to test the relationship between sprawl and traffic crash rates using structural equation modeling. Controlling for covariates, we find that sprawl is associated with significantly higher fatal crash rates likely due to the higher traffic speeds and greater vehicle miles driven in such areas. Conversely, sprawl may negatively related to total crashes and nonfatal injury crashes. The most likely explanation is the greater prevalence of fender benders and other minor accidents in the low speed, high conflict traffic environments of compact areas, negating the lower vehicle miles traveled per capita in such areas.

Authors	Xiao Qin, South Dakota State University Zhaoxiang He, South Dakota State University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3027
Paper Title	Rural Emergency Medical Service Needs Assessment
Abstract	Unintentional mortality rate attributed to diseases, fertility, and motor vehicle crashes is higher in rural areas than urban areas because of limited accessibility and mobility of emergency medical services (EMS), hospitals as well as the highway network connecting them. For rural states with a long travel distance due to the sparsely distributed population, it is important to gain a reliable assessment of EMS demand and an unbiased evaluation of service performance within the current highway system. The goal of this research was to conduct a needs assessment for rural EMS and to identify issues with respect to delivering quality services. The dataset was from the National EMS Information System (NEMSIS) consisting of 50,396 EMS responses in 2012 in South Dakota. Spatial analysis was focused on visual presentation and cluster analysis of service demand and performance on a county level. Temporal analysis was performed to magnify the service demand by month of year, day of week, and time of day. Descriptive statistics and two-tailed t test were applied for describing and comparing variables of interest. The findings not only offer a comprehensive view of EMS from the geographic and temporal perspectives but also stresses on key time- and distance-dependent factors such as response time, en-route time, on-scene time, and transporting time. For on-going endeavor to enhance EMS, we call for continued effort to improve EMS data quality and recommend linking EMS data with crash outcome for establishing specific, data-driven, and performance-based measures.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-4373
Paper Title	Quality of Injury Severity Classification by Police: Important Step for Reliable Assessment
Abstract	This study aims to assess the under-reporting and misclassification of the traffic injury severity reported by the police for the first time in Portugal. The non-fatality traffic injuries classified by the police are compared with the information recorded by the hospitals using linked data. The underreporting in the police data was found to be of 29%. Therefore, a significant number of road traffic casualties admitted in the hospitals were not known by the police. Taking advantage of the linked information on accident injuries, the misclassification in the police reports is assessed considering two criteria: the length of hospital stay (LS) and the maximum abbreviated injury scale (MAIS). The latter criterion corresponds to the common definition recently established by the European Commission, which has the advantage of representing the medical conditions of the casualty. The comparison between police classification and LS indicates that a discrepancy between the police reports and the established police definition exists maybe because no systematic communication between the police and the hospitals is established. Notably, the police classification shows inferior levels of misclassification regarding the MAIS when compared to the LS, with a tendency to overclassified the injury severity. A remarkable proportion of severe injuries reported by the police are, in fact, slight injuries. Additionally, using univariate and multivariate analyses, factors contributing to the misclassification of casualties by the police are identified. Finally, similarly to the fatality adjustment coefficient used in Portugal and in other European countries in the past, non-fatality adjustment coefficients were computed to estimate the total casualties taking into account the under-reporting and misclassification phenomena.

Authors	Chia-Yuan Yu, Texas A&M University, College Station
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-4414
Paper Title	Disparity in Traffic Safety Across Neighborhoods with Different Economic Statuses and Ethnic Compositions
Abstract	Crashes are not equally distributed across different communities or different socioeconomic groups. For example, more socioeconomically deprived areas experienced more traffic crashes. Several possible reasons were identified in previous studies, including the possibility of lower household vehicle ownership in low income areas (which in turn generate more pedestrian activities and lead to more conflicts between pedestrians and vehicles), insufficient non-motorized infrastructure in low income areas (which increase the danger for pedestrians), and higher traffic volumes in areas with more non-white populations. Moreover, most studies on disparity issues primarily focused on pedestrian injuries. Current evidence regarding disparities in crashes with different levels of injury severity is still limited. Further, possible moderator effects of socio-demographic characteristics on built environment–traffic safety relationships are unclear. This study explored differences in crash frequency across neighborhoods with different economic statuses and ethnic compositions, and further tested the potential moderator effect of socio-demographic characteristics on the built environment–traffic safety association. The results revealed that some built environmental variables (e.g., arterial roads, office uses, and schools) showed significant impacts on traffic safety only in areas with high percentages of non-white population and population below the poverty line and not in low-percentage areas. This suggested that policies and programs related to these built environmental attributes in promoting traffic safety may bring more benefits to areas with more non-white or lower-income populations. Tailored traffic safety strategies are need for areas with more non-white and low-income people.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-5532
Paper Title	Preparing Input Data for SafetyAnalyst Implementation: Florida Experience
Abstract	SafetyAnalyst is a set of state-of-the-art software tools that integrates all the steps in the roadway safety management process. The software automates the advanced empirical Bayes (EB) analysis procedures, requiring agencies to only need minimum statistical knowledge. Agencies that have implemented SafetyAnalyst have consistently identified converting local data into SafetyAnalyst import files as the most challenging step in deploying the software. This paper summarizes the Florida's efforts in implementing SafetyAnalyst for its state road network. The SafetyAnalyst application process was first introduced. The process integrates the SafetyAnalyst tools, a data conversion tool developed to automatically generate SafetyAnalyst import files, and a Geographic Information System (GIS) tool used to spatially display high crash locations. The procedure employed to generate SafetyAnalyst import files for the state road network in Florida was then presented. A major effort was to collect the data variables that are required by SafetyAnalyst and are currently unavailable in Florida databases. A second major effort involved the conversion of local attribute codes to the standard codes required by SafetyAnalyst. Moreover, a sizeable amount of roadway network data was assigned to the user-defined Florida-specific site subtypes as the data do not match the SafetyAnalyst's default subtypes. Another undertaking was to manipulate the roadway network data since Florida data has several unique characteristics that could not be directly accommodated within SafetyAnalyst. The experience documented in this paper should help provide useful information for agencies that have just gotten started with SafetyAnalyst or are contemplating its implementation.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-4597
Paper Title	Seasonal Effects of Crash-Contributing Factors on Highway Safety
Abstract	A longitudinal negative binomial model is developed in this paper that takes into account the seasonal effects of crash causality factors based on ten years (2002-2011) of Missouri Interstate highway crash data. The technique of generalized estimating equation (GEE) with autoregressive correlation structure is used. The results explain the overall effect of seasonality and whether the magnitude and/or type of various effects are different according to climatic changes. Traffic volume was found to have an appreciable effect in increasing the crash occurrence in spring and lower effect in winter, compared to the fall season. Fewer crashes were associated with higher pavement serviceability (measure of pavement surface quality, higher value is better) and this effect was found to be highest in the spring season followed by summer and winter, again when compared to the fall season. Heavy vehicles were found to reduce the likelihood of crash occurrences and this effect is higher in urban areas; although compared to other times of the year, the effect of heavy vehicles is lower during the summer season. The results indicated that the fall season is associated with the lowest crash frequency compared to the other seasons; winter season having the highest impact followed by summer and spring. This paper also evaluated the effects of the Missouri's Strategic Highway Safety Plan (MSHSP) implemented from 2005-2011. The plan was found to be effective as it reduced the crash frequency. Similar strategic plans therefore should be initiated in the future as well.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-1990
Paper Title	Development of Comprehensive Database System for SafetyAnalyst
Abstract	This study developed a comprehensive database system to provide data to multiple traffic safety applications with focus on Safety Analyst. A number of data management tools were developed to extract, collect, transform, integrate, and load the data. In addition, the proposed system includes consistency-checking capabilities to ensure the adequate insertion and update of data into the database system. The proposed system caters roadway, ramp, intersection, and traffic characteristics data for Safety Analyst. The database was developed for the entire Clark County, the largest county in Nevada including the cities of Las Vegas, Henderson, Boulder City, and North Las Vegas. The developed database was then used to identify the sites with potential for safety improvements based on various analyses. In this study, specifically two case studies result were reported and analyzed. The first case identified sites, including all roadway elements with default and calibrated Safety Performance Functions (SPFs), with potential for safety improvements considering fatal and all injury crashes. The second case identified sites, intersections with default and calibrated SPFs, with potential for safety improvements considering fatal and all injury crashes. Conclusions were developed about the calibration of safety performance functions and the classification of site subtypes. Guidelines were provided about selection of a particular network screening type or performance measure for network screening. In general, this study addressed barriers associated with the use of Safety Analyst.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2363
Paper Title	Identification of Secondary Crashes in Large-Scale Highway Networks
Abstract	Secondary crash (SC) occurrences are non-recurrent in nature and lead to significant increase in traffic delay and reduced safety. National, state, and local agencies are investing substantial amount of resources to identify and mitigate secondary crashes, reduce congestion, related fatalities, injuries, and property damages. Though a relatively small portion of all crashes are secondary, their identification along with the primary contributing factors is imperative. The objective of this study is to develop a procedure to identify SCs using a static and a dynamic approach in a large-scale multimodal transportation network. The static approach is based on pre-specified temporal and spatial thresholds while the dynamic is based on shockwave principles. The procedure is applied in the State of Tennessee and results show that the dynamic approach can identify secondary crashes with better accuracy and consistency.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2288
Paper Title	Comprehensive Assessment of Highway Inventory Data Collection Methods for Implementing Highway Safety Manual
Abstract	The implementation of the Highway Safety Manual (HSM) at the state level has the potential to allow transportation agencies to proactively address safety concerns. However, the widespread utilization of HSM faces significant barriers as many state Department of Transportations (DOTs) do not have sufficient HSM-required highway inventory data. Many techniques have been utilized by state DOTs and local agencies to collect highway inventory data for other purposes. Nevertheless, it is unknown which of these methods or any combination of them is capable of efficiently collecting the required dataset while minimizing cost and safety concerns. The focus of this study is to characterize the capability of existing methods for collecting highway inventory data vital to the implementation of the recently published HSM. More specifically, this study evaluates existing highway inventory methods through a nationwide survey and a field trial of the identified-promising highway inventory data collection (HIDC) methods for various types of highway segments. A comparative analysis was conducted to present an example on how to incorporate weights provided by state DOT stakeholders to select the most suitable HIDC method for the specific purpose.

Authors	George Yannis, National Technical University of Athens, Greece Eleonora Papadimitriou, National Technical University of Athens, Greece Marianthi Mermygka, National Technical University of Athens, Greece
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3104
Paper Title	Multilevel Comparative Analysis of Road Safety in European Capital Cities
Abstract	The objective of this research is the comparative road safety analysis in selected European capital cities, aiming to a better understanding of road accident characteristics and causes in European megacities. Despite the continuous urbanization and the shift of population to large urban areas, this research question has received little attention in the existing literature. A database was developed for this analysis containing data regarding the number and the characteristics of road fatalities, the population and other demographic, socioeconomic and transport indicators of nine selected European capital cities for the period 2007 - 2011. Multilevel Poisson statistical models were developed, allowing for a more accurate representation of the hierarchical structure of road safety data, and they led to the identification of several factors affecting the road safety level in the selected European capital cities, revealing some additional aspects of road safety performance in these cities. Factors found with a statistically significant effect concerned city characteristics (road network length, population density, public transport use) and accident characteristics (road user and vehicle type). The comparison between the European capital cities showed that the larger the city's road network is, the higher the level of road safety is in this city.

Authors	Raymond Richard Geddes, Cornell University Xiaodi Li, Cornell University Omid M. Rouhani, Cornell University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3463
Paper Title	Effects of Private Road Management on Traffic Safety: Evidence from Mexico
Abstract	There has been increasing scholarly interest in public-private partnerships (PPPs) and innovative financing approaches to deliver transportation infrastructure. Researchers have examined such issues as the effect of PPPs on delivery times, on cost efficiency, and on the cost of capital. There has, however, been relatively little empirical study of the effects of private participation in road management on road safety. We contribute to the literature on PPPs by conducting an empirical study of the effects of alternative types of toll road management, including private, on road safety in Mexico. We utilize an extensive data set examining accidents at the municipal level from 1997 to 2009, resulting in 10,772 observations. We consider several safety measures, including the overall number of accidents, the number of fatal accidents, the number of car collisions, and the number of fixed-object collisions. We control for a number of independent variables in addition to the type of road manager. We find little evidence that private management of Mexican toll roads has a statistically discernible effect on road safety, either positive or negative. Our findings may help to allay fears that private participants will sacrifice road safety in the interest of greater profits. Keywords: Road Safety, accident rates, public-private partnerships, Mexico, road management.

Authors	Haneen Farah, Delft University of Technology, Netherlands Maor Shani, Jacobs University Bremen, Germany
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	387
Session Title	School Transportation Research
Paper Number	15-1223
Paper Title	A Multi-Faceted Approach for Assessing the Safety of Israeli Arab Kids in their Travel to and from School
Abstract	Road crashes are considered one of the main threats to human life around the world. Children as pedestrians are most at risk to be seriously injured in road crashes because of their fragility and because the road environment is not designed specifically from the children perspective and their needs. The contribution of the Arab children in Israel to children pedestrian fatalities far exceeds their fraction of this age group. Therefore, the main focus of this research is to study their characteristics, behavioral patterns, and their road environment in order to recommend effective measures that would decrease their involvement in road crashes. The present research, a part of a larger ongoing project, utilizes a multifaceted approach and applies it to a case study in the Arab local council of Jadeidi-Makr in the Israeli North District. The adopted approach relies on: (1) data collected by means of questionnaires posted to the children and their parents concerning characteristics of the children travel to school; (2) objective data on the children walking routes collected by GPS-enabled watches; and (3) road safety auditing of the school environment and the main approaches to the school. The results of this study found that children characteristics, their travel behavioral patterns, their parents' safety perceptions, and the road environment are all important factors when considering children safety. It is concluded that a multifaceted approach is necessary when studying public health problems and it is recommended to apply this approach to other schools and communities.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	387
Session Title	School Transportation Research
Paper Number	15-1189
Paper Title	Assessing Multimodal School Travel Safety in North Carolina
Abstract	School transportation has been the subject of numerous federal and state policies since the early twentieth century--the Safe Routes to School program is the most recent example. However, few recent studies have thoroughly analyzed the risks and costs associated with different modes of transportation to school. Our study assesses the relative risk and related safety costs of different modes of transportation to school using crash and exposure data from North Carolina. We find that school buses provide the safest way to travel to school in North Carolina. Riding with a teen driver is the most dangerous mode on a per-trip basis with injury rates 23 times higher and fatality rates nearly 90 times higher than school buses. Bicycling is the most dangerous mode on a per-mile basis with injury rates 26 times those for school buses. The economic costs of school travel-related injuries and fatalities for walking, biking, and teen drivers are substantially higher than other modes. This research has important policy implications because it quantifies the risks of different school travel modes and allows policymakers to consider how safety investments can reduce risks. As more improvements are made to infrastructure around schools, repeated studies of this type will allow practitioners to examine whether the improvements help mitigate the risks over time.

Authors	Kevin N. Chang, University of Idaho Charles Vits, IMMI Brett Seely, University of Idaho
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	387
Session Title	School Transportation Research
Paper Number	15-4802
Paper Title	School Bus Safety: Evaluating the Evolution of Compartmentalization and Seat Belt Restraints
Abstract	Nearly twenty-five million school children in the United States rely on the school bus for transport from home to their local school each day. In 1977, the Federal Motor Vehicle Safety Standard (FMVSS), Number 222, was enacted into law and established the requirements for seating and restraining barriers on school buses, and these requirements have essentially remained unchanged since that time. The compartmentalization component, in which passengers are surrounded by heavy-padded seats, remains as the defining characteristic of FMVSS, Number 222. The safety record of school buses is attributable in large part to the passive passenger protection provided by this standard and other school bus-specific safety standards, along with specialized licensure and training of qualified school bus drivers. This research paper documents the evolution of the modern day school bus and explores the need to consider an update to this standard by examining whether or not additional safety measures such as lap and shoulder restraints should be considered. Two bus crash demonstrations were conducted in August 2013 and November 2013 and the conditions on the school bus during those simulated collisions using full-scale anthropomorphic test devices are described in this paper. The results from the crash demonstrations indicate that there are opportunities to further enhance the safety environment for school bus riders.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-5968
Paper Title	Probabilistic Safety Analysis using Traffic Microscopic Simulation
Abstract	Traffic microscopic simulation applications are currently a common tool in road system analysis and several application attempts to safety performance assessment have been recently carried out. However, current approaches still ignore causal relationships between different levels of vehicle interactions or/and accident types, lacking a physical representation of the accident phenomena itself. In this paper, a new generic probabilistic safety assessment framework for traffic microscopic simulation tools is proposed. The probability of a specific accident occurrence is assumed to be estimable by an accident propensity function, consisting in a deterministic safety score component and a random component. The formulation of the safety score component may be specified as dependent on the type of occurrence, detailed vehicle interactions and maneuvers, and on selected key simulation modelling features. This generic model was applied to the case of urban motorways and specified to four types of events: non-accident events and three types of accidents in a nested logit structure: rear-end and lane-changing conflicts, and run-off-road events. As there is still no available large disaggregated data set linking trajectories to accident occurrence, artificial trajectories from a detailed calibrated microscopic simulation tool were used. These trajectories were obtained following a comprehensive calibration effort: extracting real trajectories for a generic non-accident scenario, calibration of the simulation tool using the collected trajectories, and re-calibration of the simulation model using aggregate data for each event selected for replication and used in the safety model estimation phase. The final estimated safety model allowed for the identification and interpretation of several simulated vehicle interactions at stake. The fact that these considerations were extracted from simulated analysis shows the real potential of well (detailed) calibrated traffic microscopic simulation for detailed safety assessments and their potential as a lay-out design tool.

Authors	Emanuele Sacchi, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0622
Paper Title	Bayesian Estimation of Conflict-Based Safety Performance Functions
Abstract	Most of the current research on road safety relies on the analysis of collision data which is challenged by well-recognized availability and quality issues. Therefore, the use of surrogate safety measures such as traffic conflicts has been gaining acceptance as an alternative or complementary approach to analyze traffic safety from a broader perspective than collision data alone. However, there is a need to develop statistical techniques to analyze conflict data to support various road safety applications. This paper discusses the development of conflict-based safety performance functions (SPFs) within the framework of Bayesian statistics. The Bayesian approach was selected as it represents the state-of-the-art technique in the statistical analysis of collisions. In particular, SPFs were developed to predict the number of rear-end conflicts at different intersection approaches. The functions were validated using posterior predictive checking indicators. Data for traffic conflict observations were automatically extracted with computer vision techniques at several urban and suburban intersections in British Columbia (Canada). The results indicate that the models developed have a good fit of the observed conflict data and can offer a useful tool for conducting safety analysis.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0205
Paper Title	Effect Of Built Environment On Traffic Fatalities In Indian And Us Cities
Abstract	The main aim of this study is to model the correlation between built environment parameters and traffic fatalities in Indian and US cities. In the past models, built environment parameters have usually been studied along with traffic parameters. Macro-level safety models with focus on the built environment have also been attempted for the first time. Lastly, comparison of models across geographical locations (India and USA) has also been made. To test the framework in India, the cities of Agra (a high crash-rate city) and Ludhiana (a low crash-rate city) have been analyzed. For comparison, the US cities chosen were Chicago (a high crash-rate city) and Baltimore (a low crash-rate city). Two Negative Binomial regression models have been developed for each city. The first involves population data. The entire city is divided into grids (based on latitude/longitude) and the number of traffic fatalities in each grid is correlated with the lengths of different types of roads and the number of intersections in that grid. The second model involves survey data. Number of fatalities in small buffer regions is correlated with 16 other built environment parameters in these buffer regions. Results showed that lengths of highways and arterial roads were significant in increasing the expected number of fatalities in Indian cities. For the cities in USA, the length of highways in a region was found to be insignificant. This strengthens the argument that highway design is a major contrasting element between Indian and US cities. In the second model, pavement quality showed varying impacts in Indian and US roads mostly due to unsafe designs in India whereas road markings showed similar and intuitive effects in both India and the USA.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-4794
Paper Title	Evaluation of Left-Turn Lane Offset Using the Naturalistic Driving Study Data
Abstract	The SHRP 2 Naturalistic Driving Study (NDS) data were used to evaluate the gap acceptance behavior of drivers at left-turn lanes with offsets ranging from –29 ft to 6 ft. The study included 3,350 gaps evaluated (accepted or rejected) by 145 NDS drivers and 275 non-NDS drivers (whose turns were visible from the in-vehicle camera of an NDS driver) at 14 two-way stop-controlled intersections and 44 signalized opposing left-turn pairs. Logistic regression was used to model the critical gap length for drivers as a function of offset, under conditions when their view was either blocked by an opposing left-turning driver or not. The analysis found that the critical gap was longer for negative offsets than for zero or positive offsets, and also longer when sight distance was blocked by an opposing left-turning driver than when it was not. These longer gap lengths can result in decreased operational efficiency of an intersection. Sight distance was much more likely to be restricted by an opposing left-turning driver at negative-offset intersections than at zero- or positive-offset intersections, and drivers at negative-offset intersections were less likely to accept a gap when an opposing left-turn driver was present. An analysis of the shortest post-encroachment times showed that while drivers making left-turns at negative-offset left-turn lanes wait to accept longer gaps, they are, on average, also more likely to leave the shortest amount of time between their turn and the arrival of the next opposing through vehicle, which may present a potential safety concern.

Authors	Xiaoxiang Ma, Colorado State University Feng Chen, Tongji University, China Suren Chen, Colorado State University
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-1709
Paper Title	Empirical Analysis of Driver-Injury Severity on Mountainous and Non-Mountainous Interstate Highways: A Comparative Study
Abstract	Mountainous highways usually exhibit complex geometry features such as steep gradients or sharp curves, which can cause considerably different driver behavior and vehicle performance as compared to non-mountainous highways. In addition, mountainous highways are more vulnerable to adverse weather conditions. Therefore, a uniform traffic safety performance function for both mountainous and non-mountainous highways across the same region may not be sufficient. One major interstate highway with typical mountainous (MT) characteristics and another one with non-mountainous (NM) characteristics in Colorado have been selected for this study. A comparative investigation about the impact on injury severity from mountainous and non-mountainous highways is conducted. Separate mixed logit models are estimated for both highways with four-year detailed crash data. Some new findings about injury severity are made possible for the first time. Incorporating two major interstate highways from the same region into the comparative study offers some unique strength on investigating the impacts. As a result, the study provides better insights about contributing factors and associated mechanism for injury severity on mountainous highways. Substantial differences in the magnitude and direction of the influence of contributing factors between MT and NM models are observed. Differences in a comprehensive set of contributing factors of injury severity such as roadway characteristics, temporal and environmental characteristics, driver characteristics, accident characteristics, and vehicle characteristics are summarized. The findings in this study provide scientific guidance to potentially improve the current highway design and traffic management policy on thousands of miles of mountainous highways.

Authors	Eneliko Mujuni Mulokozi, University of Nevada, Las Vegas
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3070
Paper Title	Safety Analysis Of Freeway Segments With Random Parameters
Abstract	The purpose of this study was to analyze the impact of geometric features on freeway crashes while accounting for the effect of unobserved factors likely to influence crash occurrence. The investigation was also motivated by the fact that the distribution of crashes in space is not limited to only the influence areas of the divergence and convergence segments as well as weaving segments. Areas beyond the influence areas were observed to have crashes occurred and by including these areas data within the weaving and non-weaving segments can be clustered to quantify the variability of unobserved factors through the variance of random parameters using multilevel count models. The model results indicated that 13.9% of the variation in crash frequency is unaccounted for, which is an indication of the existence of unobserved factors influencing the occurrence of crashes. It was also revealed that weaving segments (EN-EX) had the highest between segment variance compared to non-weaving segments. In addition to these results, it was revealed that more vehicles and short segments increased crash frequency while wider right shoulder decreased the crash frequency. It was also revealed that weaving segments decreased crash frequency compared to non-weaving segments. These results indicate that by allowing parameters to vary across segments it is possible to capture and quantify unobserved factors. Ignoring these factors results in biased coefficients in a multilevel setting because the estimate of the standard errors will be wrong.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-5229
Paper Title	A Bayesian Analysis of Crash Severities with Multivariate Conway-Maxwell Poisson Distribution
Abstract	Numerous efforts have been devoted to understand the relationship between crash severities and roadways using different statistical techniques. Most efforts have resulted in univariate count models for individual crash severity, with a few exceptions of Multivariate Poisson Lognormal model, Ordered Probit and Logit choice models. Although, such models have been proved to perform well with over-dispersed datasets, they are not as effective for under-dispersed datasets. This paper offers a multivariate extension of the Conway-Maxwell Poisson Distribution, a very flexible distribution that has been shown to perform well with both over- and under-dispersion. The multivariate extension accounts for correlation among different crash severities that can exist because of missing variables or unobserved information. The parameters of this model are estimated using Bayesian paradigm as conventional techniques can be inefficient. A component-wise Monte Carlo Markov Chain (MCMC) simulation with Gibbs and Metropolis Hastings samplers is developed and coded in Matlab to estimate the parameters. The algorithm is validated using a simulated data set. The convergence of the MCMC simulation is verified using trace plots and running mean plots. An application of the proposed model on a real-world dataset is provided to demonstrate the use of the model along with its interpretation.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-5506
Paper Title	Examining Driver Injury Severity on Rural Interstate Highways Using a Hierarchical Bayesian Approach
Abstract	Rural interstate highways are major corridors carrying a significant portion of high speed traffic and have high risks for crashes with severe injuries and fatalities. Hierarchical Bayesian models incorporate between-crash variance and within-crash correlations into hierarchical traffic data modeling and therefore outperform ordinary regression models in traffic safety analysis. This paper applies a hierarchical Bayesian logistic model to examine the significant factors at crash and vehicle/driver levels and their influence on driver injury severity in rural interstate crashes. The intra-class correlation (ICC) and deviance information criterion (DIC) are summarized to illustrate the suitability of the proposed model. The research results demonstrate that the major portion of the total variance is resulted from between-crash variance, indicating the appropriateness of using hierarchical modeling. Two crash-level variables and four vehicle/driver-level variables are identified to be significant based on the 95% Bayesian credible interval (BCI) of odds ratio: the number of vehicles in a crash, wet road surface, vehicle type, driver age, gender and driver alcohol or drug involvement. Single-vehicle crashes, female drivers, senior drivers, motorcycles and driver alcohol or drug involvement tend to increase the odds of drivers being incapably injured or killed in rural interstate crashes. Wet road surface and male drivers are more likely to decrease the probability of severe driver injuries. It is also indicated that the potential interactive effects among demographic variables and other crash-related variables should be further examined. The results provide insightful understanding of rural interstate crashes to develop effective countermeasures for rural interstate crash prevention.

3 Network Screening

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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 were used:

- Mixed effects negative binomial modeling with and without the use of geometric design consistency parameters (Butsick et al., 15-0797);
- Multivariate versus simple crash prediction models (Ambros et al., 15-1242);
- Level of Service of Safety (LOSS) with correction for the regression to the mean (RTM) bias (Kononov et al., 15-1619);
- Six different methods for screening including Equivalent Property Damage Only (PDO), crash frequency, Crash rate, Empirical Bayes (EB), Potential for Safety Improvement (PSI), and Excess crash frequency (Kuo et al., 15-4445);
- Distance from intersection (Avelar et al., 15-5726).

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

- Network level (Schultz et al., 15-0616 and Ambros et al., 15-1242);
- Two lane rural roadways (Butsick et al., 15-0797);
- Signalized intersections (Kononov et al., 15-1619 and Avelar et al., 15-5726);
- Macro (traffic analysis zones) (Kuo et al., 15-4445).

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0616
Paper Title	Hot Spot Identification and Analysis Methodology for Roadway Safety
Abstract	The Utah Department of Transportation (UDOT) Traffic and Safety Division continues to advance the safety of roadway sections throughout the state. To aid UDOT in meeting their current goal of zero fatalities the Department of Civil and Environmental Engineering at Brigham Young University has worked with the Statistics Department in developing analysis tools for safety. The most recent of these tools has been the development of the Utah Crash Prediction Model to evaluate traffic crashes and safety on UDOT roadways statewide using hierarchical Bayesian models. The results of this model are integrated in a Geographic Information System framework. This research focuses on the enhancement of the Framework for Highway Safety Mitigation in Utah with its six primary areas of emphasis. The framework was enhanced by developing a methodology for accomplishing the areas of network screening, diagnosis, and countermeasure selection. This methodology is titled, "Hot Spot Identification and Analysis," and consists of the following seven steps: 1) identify problematic segments with safety concern, 2) identify problem spots within the segments, 3) micro analysis of problematic segments and spots, 4) defining the segment, 5) defining the problem, 6) evaluation of possible countermeasures, and 7) selection and recommendation of feasible countermeasures. This methodology is to help in the identification of hot spots with safety concerns so that they can be analyzed and countermeasures can be identified to mitigate the safety issues.

Authors	Andrew J. Butsick, Kittelson & Associates, Inc. Paul P. Jovanis, Safety and System Users Group Chair Jonathan Sayre Wood, Pennsylvania State University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0797
Paper Title	Modeling Safety Effects of Geometric Design Consistency on Two-Lane Rural Roads Using Mixed Effects Negative Binomial Regression
Abstract	Previous research has examined the relationship between roadway safety and design consistency using measures such as the difference between design and operating speeds and changes to driver workload. While such measures have proven effective in identifying inconsistences in the roadway, they do not directly identify the conditions associated with safety performance. The purpose of this research was to directly quantify the effects of geometric design consistency on roadway safety using measures that can be linked to specific geometric elements. Using mixed effects negative binomial modeling, two safety performance functions (SPFs) were developed. The first contains typical roadway parameters that are suggested for use by several contemporary safety management tools, while the second contains additional geometric design consistency parameters. After Empirical Bayes adjustments were performed on 5 years of crash data from over 2,100 fixed-length (2.5 miles) segments of two-lane rural roadway, the sites with potential (SWiPs) were identified. The disparity between SWiPs identified by the two SPFs was evident; 40 unique sites were identified by each model out of the top 220 sites identified. Along with a marked shift of rankings, this constitutes a 19 percent change in the top 10 percent of sites.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-1242
Paper Title	Investigation of Difference between Network Screening Results Based on Multivariate and Simple Crash Prediction Models
Abstract	Identification of hazardous road locations (network screening) is the first step of road network safety management process. According to state-of-the-art knowledge it should be conducted using empirical Bayes technique which relies on a crash prediction model (safety performance function). However there is a dilemma in choice of a model: researchers strive for multivariate models, which demand area-wide databases of several variables; on the other hand practitioners require simple models, based only on fundamental variables, which are more easily available and able to be periodically updated. The research question was: "What is the difference between network screening results based on multivariate and simple crash prediction models?" For the purpose of investigation multivariate and simple crash prediction models were developed for regional road network of South Moravia (Czech Republic) and used in network screening. The results based on both models were compared and discussed – the conclusion is that results from network screening with simple model are generally comparable to the multivariate model.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-1619
Paper Title	Level of Service of Safety Revisited
Abstract	The concept of the Level of Service of Safety (LOSS) was developed at the Colorado Department of Transportation (CDOT) in 2000. LOSS reflects how a roadway segment or an intersection is performing in reference to the expected frequency and severity of crashes predicted by its Safety Performance Function (SPF). The concept of the LOSS provides quantitative assessment and qualitative description of the degree of safety of a segment or of an intersection. Additionally, it facilitates effective communication about safety problems to other professionals, the traveling public, and elected officials. The LOSS concept was first introduced in the 2003 TRB (1) paper entitled Level of Service of Safety-Conceptual Blueprint and Analytical Framework. LOSS was incorporated into the first edition of the AASHTO Highway Safety Manual (HSM) (2) and is presently used by the Colorado DOT, Wyoming DOT, Montana DOT, Louisiana DOT, Oklahoma DOT and the Ontario Ministry of Transport. LOSS lends itself well to the safety decision making process in the DOT environment. However, it did not initially address correction for the Regression to the Mean (RTM) Bias. This paper introduces a new method for using LOSS in concert with correction for RTM bias using an Empirical Bayes (EB) procedure. Additionally it revisits distributional assumptions associated with the LOSS, explains how the LOSS boundaries are calibrated in the population corrected for the RTM bias, and provides an intuitive percentile-based reporting method. Finally the paper works through a diagnostic example and a before and after study demonstrating the value of LOSS in identifying the safety problem at a real location.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-4445
Paper Title	Comparing Hot Spot Identification Methods at Macroscopic Safety Analysis Level
Abstract	Compared to micro scale safety studies, macroscopic-focused research is more efficient at integrating zone-level features into crash prediction models and identifying hot zones in large study areas. However, few studies have focused on the limitations of current hotspot/hot-zone identification methods (HSID) applied at the macro level. This study applied six common HSID methods and compared their consistency in identifying hot-zones. The crash data was based on five years of crash records from Central Florida (Orange, Seminole, and Osceola Counties). The results showed that the hot-zones identified by the crash frequency, Empirical Bayesian, and Potential for Safety Improvement methods all had high consistency and stability over time, followed by the crash rate and Equivalent Property Damage Only methods. The Proportion method had the lowest consistency. Other possible factors related to the methods' performance were also examined, which included the time length of the before period, the time length of the after period, the time gap, hot-zone threshold, and different crash types. However, these factors affected the performance of the methods only slightly. Also, the main problem of the crash frequency method, regression-to-the-mean, was not found to affect the performance of the method at the macro level because the consistency stayed high even in cases where the time length of the before period was as low as one year. The detail proof is given in Appendix A.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5726
Paper Title	Evaluation of Intersection-Related Crash Screening Methods Based on Distance from Intersection
Abstract	This paper uses a probability sample of signalized intersections located in the State of Oregon to review various strategies of assigning crashes to intersections. Most of the strategies are based on the distance between the intersection and the crashes geo-location. The researchers collected detailed data from 73 intersections using state databases and satellite imagery. 1535 crashes were identified for years 2010 to 2012 in the vicinity of those intersections. The researchers then classified the identified crashes as either intersection related or not intersection related, based on geo-location, crash database related fields, and geometric information about the intersections. Ultimately, the authors identified 1130 intersection-related crashes from the larger corridor crash population. Using the pool of classified crashes, the authors fitted regression models to study the relationship between the distance (D) of a crash to an intersection, and the probability of that crash being associated with that intersection. For this task, the research team used only 55 intersections, leaving the remaining 18 for performance evaluation of different classification methods. The developed models identified D as a significant predictor that a crash is associated to an intersection. The evaluation also included additional candidate predictors, such as speed limit and the extent of the Intersection Functional Areas (IFA) of the study sites. During the validation phase, however, the authors determined that the models including predictions other than D provided comparable results to the model using D alone. The validation analysis also compared methods currently used in safety modeling to the performance of these models. That analysis found that the popular method of selecting crashes that are within a radius of 250 ft is appropriate if the selection is for studying the safety effects of treatments, such as the development of Crash Modification Functions (CMFs). However, this analysis found that utilizing a threshold of 250 ft would result in underprediction of intersections crashes, if the intent is to develop frequency prediction models, such as Safety Performance Functions (SPFs). Instead, the researchers found that a threshold of 300 ft potentially minimizes the risk of underestimating crash frequency, given that the frequencies of type-I and type-II errors are roughly equal at this threshold.

4 Safety Performance Functions

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Fifty-five papers were found to have developed or used safety performance functions (SPFs). These papers could be categorized by their research objectives, the study unit, methodologies used, and applications based on their conclusions. Regarding the objectives of the identified studies, the majority aimed at bring down motor vehicle crashes while other papers focused on specific issues such as pedestrian safety, cyclist safety and so on. Numerous statistical methods have been found in these papers to construct the safety performance functions. The basic models are Poisson model, Negative binomial model and Poisson log-normal model. However, extensions such as random effects model, random parameters model, Empirical Bayes (EB) model, Full Bayes (FB) model, multilevel model, Negative binomial-generalized exponential distribution (NB-GE), generalized estimating equation (GEE) model, and models considering temporal and spatial correlations could all be found. These papers covered both macro- and micro-level safety analyses. Macro-level studies investigated into safety issues at area basis, such as traffic zone, and city. Micro-level studies were conducted on urban or rural areas for roadway networks, and specific locations such as freeways, curves, intersections and roundabouts. Applications of these safety performance functions include identification of crash contributing factors for safety improvement, identification of crash hotspots, quantifying the safety effectiveness of particular treatments, and application of the Highway Safety Manual (HSM).

As mentioned, the majority of the papers had objectives of general or motor vehicle safety improvement. However, there are several papers addressing specific safety issues. Several papers discussed pedestrian safety (15-4619, 15-0115, 15-5938), cyclist safety (15-0886, 15-0887, 15-1036, 15-6141, 15-5938), seasonal effects on safety (15-4597, 15-4452), and speed limit (15-0180, 15-2342). These studies were carried out at both macro- and micro-level. Macro-level studies implemented safety performance functions at different geographic basis, such as neighborhood area (15-4414, 15-2342), traffic analysis zones (15-0886, 15-0887, 15-4445, 15-0432, 15-2774, 15-2442, 15-5109), and cities (15-4422, 15-3104, 15-0205, 15-4181). Micro-level safety performances were evaluated for roadway networks in urban and rural areas (15-5108, 15-5690, 15-4597, 15-0180, 15-1036, 15-1983, 15-0797,15-1467, 15-2539, 15-1242, 15-1038, 15-3001, 15-3054), freeway (15-4452, 15-0503, 15-3070,15-3070, 15-2433), curves (15-2226,15-4452, 15-0503), urban intersections (15-4619, 15-6141, 15-5938, 15-5028, 15-5726, 15-3076, 15-4643), ramps and interchanges (15-5881), toll-road (15-2711, 15-2700), roundabouts (15-0115, 15-0800, 15-1983,15-5703, 15-0830), and railroad crossing (15-5109, 15-2754).

In safety performance functions, Poisson models, Negative Binomial (also known as Poisson-gamma) models and Poisson-lognormal models often served as the starting point to model the crash mechanisms on the studied objects. Nevertheless, more advanced variations based on the above models have been introduced: Empirical Bayesian methods (15-5108, 15-4422,

15-5017, 15-1036, 15-1983, 15-0830, 15-2342,15-2700,15-0503, 15-1252, 15-3472, 15-0179, 15-4445, 15-2754, 15-1038, 15-3001), Full Bayesian methods (15-4422, 15-0830, 15-2314, 15-2342), random effects (15-4422, 15-0115, 15-4181), random parameters (15-0180, 15-3070), Generalized Estimating Equation methods (15-4597), Negative Binomial-Generalized Exponential models (15-3383), multilevel models (15-3104), mixed effects (15-0797), and Zero-Inflated models (15-2539, 15-5109). There also exist papers considering the spatial autoregressive correlation (15-4597, 15-0886, 15-0887, 15-2774, 15-2442).

From an application point of view, although almost all of the papers shared the same goal to reduce crash occurrence and improve traffic safety, they still had their own priorities. A large body of papers developed safety performance functions to understand crash contributing factors and proposed tailored countermeasures (15-4414, 15-4597, 15-0180, 15-4619, 15-0886, 15-0887, 15-0115, 15-5881, 15-1983, 15-2433, 15-3070, 15-6141, 15-0797, 15-4181, 15-2539, 15-1242, 15-0432, 15-2774, 15-2442, 15-5109, 15-2754). Some papers utilized safety performance functions to quantify the safety effects of particular treatments (15-2226, 15-5017, 15-1036, 15-2314, 15-2342, 15-2711, 15-2700, 15-1252, 15-3472, 15-0179, 15-5726, 15-3076, 15-1038, 15-3001, 15-3054). Some papers checked the applicability for HSM (15-2298, 15-1783, 15-3093, 15-2301, 15-4110, 15-5873, 15-1467, 15-1038, 15-3054, 15-4643). Other papers endeavored to identify and rank crash hotspots for improvement by safety performance functions (15-5108, 15-4422, 15-5690, 15-4445).

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Sponsoring Committee	ABE90
Session Number	797
Session Title	Traffic Safety and Traffic Management in Developing Countries
Paper Number	15-0115
Paper Title	Investigating Pedestrian Injury Crashes on Modern Roundabouts in Addis Ababa, Ethiopia
Abstract	Pedestrian crashes are one of the major road safety problems in developing countries representing about 40% of total fatal crashes in low income countries. Despite the fact that many pedestrian crashes in these countries occur at unsignalized intersections such as roundabouts, studies focussing on this issue are limited—thus representing a critical research gap. The objective of this study is to develop safety performance functions for pedestrian crashes at modern roundabouts to identify significant roadway geometric, traffic and land use characteristics related to pedestrian safety. To establish the relationship between pedestrian crashes and various causal factors, detailed data including various forms of exposure, geometric and traffic characteristics, and spatial factors such as proximity to schools and proximity to drinking establishments were collected from a sample of 22 modern roundabouts in Addis Ababa, Ethiopia, representing about 56% of such roundabouts in Addis Ababa. To account for spatial correlation resulting from multiple observations at a roundabout, both the random effect Poisson (REP) and random effect Negative Binomial (RENB) regression models were estimated and compared. Model goodness of fit statistics reveal a marginally superior fit of the REP model compared to the RENB model of pedestrian crashes at roundabouts. Pedestrian crossing volume and the product of traffic volumes along major and minor road had significant and positive associations with pedestrian crashes at roundabouts. The presence of a public transport (bus/taxi) terminal beside a roundabout is associated with increased pedestrian crashes. While the maximum gradient of an approach road is negatively associated with pedestrian safety, the provision of a raised median along an approach appears to increase pedestrian safety at roundabouts. Remedial measures are identified for combating pedestrian safety problems at roundabouts in the context of a developing country.

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Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0179**
Paper Title	Safety Impacts of a Statewide Centerline Rumble Strip Program
Abstract	Lane departure events result in the majority of all traffic fatalities in the United States, a problem that is particularly pronounced on high-speed undivided highways, which are prone to cross-centerline crashes. A common countermeasure to reduce such crashes involves the installation of centerline rumble strips (CLRS), which provide an audible and tactile warning to alert drivers of an impending lane departure event. This study assessed the safety impacts of a statewide CLRS implementation program conducted in Michigan between 2008 and 2010. This program included the installation of more than 5,000 miles of CLRS, covering the majority of the rural non-freeway highways maintained by MDOT. Shoulder rumble strips (SRS) were installed in combination with the CLRS at locations with paved shoulders of at least 6 ft in width. The empirical Bayes method was utilized to assess the effectiveness of more than 4,200 miles of centerline rumble strips that were installed along two-lane highways. CLRS were found to reduce target cross-centerline crashes by 27.3 percent and by 32.8 percent when used in combination with SRS. In addition to these overall reductions, rumble strips were also effective in reducing crashes under adverse pavement conditions, as well as crashes involving passing maneuvers and impaired driving. This study also provided important insights into the necessary methods for identification of correctable target crashes through a comprehensive manual review of over 72,000 crash report forms. This review found that approximately 10 percent of target crashes were misclassified in the statewide crash database due to coding errors.

Authors	Amelia Davis, Wayne State University Elizabeth Hacker, Wayne State University Peter Tarmo Savolainen, Iowa State University Timothy Jordan Gates, Wayne State University
Sponsoring Committee	ANB20
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-0180
Paper Title	A Longitudinal Analysis of Rural Interstate Fatalities in Relation to Speed Limit Policies
Abstract	The extant research literature has shown traffic fatalities to increase at higher speed limits. A related issue is the establishment of maximum speed limits for trucks and buses. As of 2014, there are eight states that have a differential speed limit in place, which establishes a higher limit for passenger vehicles than for trucks and buses. This study aims to inform continuing debate regarding the safety impacts of speed limits by comparing states with various speed limit policies. The study includes a longitudinal comparison of state-level rural interstate fatalities in the United States from 1999 through 2011. In addition to examining differences in traffic fatalities as a function of maximum speed limits, comparisons were also made among states with differential limits for truck and buses. Random parameter negative binomial models were estimated for annual total and truck-involved fatalities. A random parameter framework allowed for consideration of temporal correlation in annual fatality counts within states, as well as for unobserved heterogeneity across states. The results of this study provide further evidence that both overall and truck-involved fatalities increase with maximum speed limits. Differential speed limits were found to have marginal differences in total fatalities as compared to states with uniform speed limits. However, truck-involved fatalities were significantly lower in states where differential limits were in place. The effects of speed limit policies, as well as other covariates, were found to vary significantly across states. The random parameter models demonstrated significantly improved goodness-of-fit as compared to standard Poisson and negative binomial models.

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Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0205
Paper Title	Effect of Built Environment on Traffic Fatalities in Indian and US Cities
Abstract	The main aim of this study is to model the correlation between built environment parameters and traffic fatalities in Indian and US cities. In the past models, built environment parameters have usually been studied along with traffic parameters. Macro-level safety models with focus on the built environment have also been attempted for the first time. Lastly, comparison of models across geographical locations (India and USA) has also been made. To test the framework in India, the cities of Agra (a high crash-rate city) and Ludhiana (a low crash-rate city) have been analyzed. For comparison, the US cities chosen were Chicago (a high crash-rate city) and Baltimore (a low crash-rate city). Two Negative Binomial regression models have been developed for each city. The first involves population data. The entire city is divided into grids (based on latitude/longitude) and the number of traffic fatalities in each grid is correlated with the lengths of different types of roads and the number of intersections in that grid. The second model involves survey data. Number of fatalities in small buffer regions is correlated with 16 other built environment parameters in these buffer regions. Results showed that lengths of highways and arterial roads were significant in increasing the expected number of fatalities in Indian cities. For the cities in USA, the length of highways in a region was found to be insignificant. This strengthens the argument that highway design is a major contrasting element between Indian and US cities. In the second model, pavement quality showed varying impacts in Indian and US roads mostly due to unsafe designs in India whereas road markings showed similar and intuitive effects in both India and the USA.

Authors	Jaeyoung Lee, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida Ximiao Jiang, Federal Highway Administration
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-0432
Paper Title	Traffic Safety Analysis Zones for Macroscopic Crash Investigation
Abstract	Various geographic units have been used in macro-level modeling. Amongst these units, traffic analysis zones (TAZs) have been broadly employed in many macroscopic safety studies. Nevertheless, no studies questioned the validity of TAZs for crash analysis at the macro-level crash modeling. In this study, we point out several possible problems of TAZs as spatial units for macroscopic safety studies. Current TAZs with homogenous crash rates were combined into new single zones. Then we created ten new zonal systems by different zone aggregation levels. The optimal zonal scale for Traffic Safety Analysis Zones (TSAZ) was determined using the Brown-Forsythe test. It was found that the zone system with about 1:2 aggregation was the optimal zone system for macroscopic safety modeling. Thus we develop what we call Traffic Safety Analysis Zones (TSAZs) that has the potential of reducing several possible problems of TAZs. Also it was shown that TSAZ based models had better fit compared to TAZ based models.

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Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0503**
Paper Title	Development of Crash Modification Factors of Alignment Elements and Safety Countermeasures for Korean Freeways
Abstract	Recently, many efforts have been devoted to improving the safety of freeways in Korea, as freeways are the most important roadways in the transportation network. As a part of these efforts, this research aims to develop crash modification factors (CMFs) of two alignment elements, as well as eight safety countermeasures for Korean freeways. To do this, we first developed classical safety performance functions (SPFs) for each freeway. To develop the CMFs of two alignment elements, horizontal curve and vertical grade, we also estimated inclusive SPFs that include the alignment elements together with traffic volume and segment length as independent variables. The CMFs of horizontal curve and vertical grade were calculated as the marginal effect of their coefficients on the inclusive SPFs. Then, we developed eight CMFs for safety countermeasures including delineator posts, automated speed enforcement cameras, rumble strips, chevron signs, roadside barriers, grooving, illumination and median barriers. We also corrected for regression-to-the-mean (RTM) bias, time trend of crash count, and effect of traffic volume change by using the empirical Bayes (EB) method. We compared the developed CMFs in this study with those from previous literature and discussed the findings from the comparison. The results from this study contribute to enhancing the safety of Korean freeways and act as a reference guide for other Korean roadways, as well as roadways in other countries.

Authors	Emanuele Sacchi, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0622
Paper Title	Bayesian Estimation of Conflict-Based Safety Performance Functions
Abstract	Most of the current research on road safety relies on the analysis of collision data which is challenged by well-recognized availability and quality issues. Therefore, the use of surrogate safety measures such as traffic conflicts has been gaining acceptance as an alternative or complementary approach to analyze traffic safety from a broader perspective than collision data alone. However, there is a need to develop statistical techniques to analyze conflict data to support various road safety applications. This paper discusses the development of conflict-based safety performance functions (SPFs) within the framework of Bayesian statistics. The Bayesian approach was selected as it represents the state-of-the-art technique in the statistical analysis of collisions. In particular, SPFs were developed to predict the number of rear-end conflicts at different intersection approaches. The functions were validated using posterior predictive checking indicators. Data for traffic conflict observations were automatically extracted with computer vision techniques at several urban and suburban intersections in British Columbia (Canada). The results indicate that the models developed have a good fit of the observed conflict data and can offer a useful tool for conducting safety analysis.

Authors	Paul P. Jovanis, Safety and System Users Group Chair Jonathan Sayre Wood, Pennsylvania State University
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-0797
Paper Title	Modeling Safety Effects of Geometric Design Consistency on Two-Lane Rural Roads Using Mixed Effects Negative Binomial Regression
Abstract	Previous research has examined the relationship between roadway safety and design consistency using measures such as the difference between design and operating speeds and changes to driver workload. While such measures have proven effective in identifying inconsistences in the roadway, they do not directly identify the conditions associated with safety performance. The purpose of this research was to directly quantify the effects of geometric design consistency on roadway safety using measures that can be linked to specific geometric elements. Using mixed effects negative binomial modeling, two safety performance functions (SPFs) were developed. The first contains typical roadway parameters that are suggested for use by several contemporary safety management tools, while the second contains additional geometric design consistency parameters. After Empirical Bayes adjustments were performed on 5 years of crash data from over 2,100 fixed-length (2.5 miles) segments of two-lane rural roadway, the sites with potential (SWiPs) were identified. The disparity between SWiPs identified by the two SPFs was evident; 40 unique sites were identified by each model out of the top 220 sites identified. Along with a marked shift of rankings, this constitutes a 19 percent change in the top 10 percent of sites.

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Sponsoring Committee	ANB75
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-0800
Paper Title	Comparison of Geometric Design-Traffic Operations and Safety Performance Metrics of Roundabouts vs. Other Circular Intersections in the State of New Jersey
Abstract	There may be some confusion regarding the difference between roundabouts and other circular intersections forms. This paper identifies and explores the differences between modern roundabouts and circular intersection using safety and operational performance metrics using case studies from data collected at sites in New Jersey. Ten year crash data from twenty sites that include roundabouts and other circular intersections were chosen from the state of New Jersey and analyzed on the basis of crash type frequency, severity, and exposure-based crash rates. Pairwise comparison for sites that exhibit similar traffic data was further investigated. The findings from this study would provide transportation engineers and practitioners with empirical observations in support of a consistent standard for roundabout design which will improve safety and fully demonstrate the benefits of roundabouts in the modern era.

Authors	Mohamed M. Ahmed, University of Wyoming Mohamed A. Abdel-Aty, University of Central Florida Juneyoung Park, University of Central Florida
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0830
Paper Title	Evaluation of the Safety Effectiveness of the Conversion of Two-Lane Roadways to Four-Lane Divided Roadways: Bayesian vs. Empirical Bayes
Abstract	This paper utilized various observational before-after analyses to evaluate the safety effectiveness of widening urban and rural two-lane to four-lane divided roadways. These methodologies ranged from simple (naïve) before-after, before-after with comparison group, Empirical Bayes (EB), and Bayesian approach. The EB method requires Safety Performance Functions (SPFs) to be calibrated; the simple AADT-based SPF is used widely. In this paper, two sets of Negative Binomial models were calibrated; 'full' SPF model that utilizes various explanatory covariates and 'simple' SPF using AADT only. The preliminary results from the calibrated models indicated that the SPF is pivotal in the EB method; the more accurate the models, the more pragmatic the evaluation of the safety effectiveness of a treatment. The proposed methodology of using the 'Full' SPF in EB method is recommended over the conventional EB observational before-after. In order to obtain more reliable estimates, Bayesian before-after approach was performed. The Bayesian Bivariate Poisson-Lognormal approach provided comparable results and might have several advantages over the EB technique. The results from this paper indicated that the conversion from two-lane roadways to four-lane divided roadways resulted in a notable reduction of more than 63 percent on urban roadways and 45 percent reduction on rural roadways for fatal and injury (F+I) crashes. Conversion to 4-lane divided roadway yielded a higher reduction in total and property damage only crashes in urban areas than in rural areas. Additionally, the safety effects of the conversion appear to be more effective on roadway segments with high AADT in urban areas.

Authors	Sigal Kaplan, Technical University of Denmark Carlo Giacomo Prato, Technical University of Denmark
Sponsoring Committee	ANF20
Session Number	849
Session Title	Bicycle Transportation, Part 2: Safety and Infrastructure (Part 1, Session 477)
Paper Number	15-0886
Paper Title	Spatial Analysis of Land Use and Network Effects on Frequency and Severity of Cyclist-Motorist Crashes in Copenhagen Region, Denmark
Abstract	Urban and transport planners worldwide have recently designed and implemented policies for increasing the number of cyclists. Although cycling is on the rise even in car-oriented cities and regions, the fear to be involved in a crash is still the main obstacle to further increases in cycling market shares. The current study proposes the first joint model of frequency and severirty of cyclist-motorist collisions with the aim of unraveling the factors contributing to both the probability of being involved in a crash and, provided that a crash occurred, experiencing a severe injury outcome. A multivariate Poisson-lognormal model with MCAR priors was estimated on a sample of 5349 cyclist-motorist crashes occurred in the Copenhagen Region between 2009 and 2013. The model considered the links of the road network in the region as the unit of observation, controlled for traffic exposure of non-motorized and motorized transport modes, evaluated effect of infrastructure and land use, and accounted for heterogeneity and spatial correlation across links. Results confirmed the existence of the phenomenon of safety in numbers and added to the narrative by emphasizing that the most severe crashes are the ones most benefitting from an increase in the number of cyclists. Also, results argued that the construction of Copenhagen-style bicycle paths would significantly contribute to increasing safety, especially in suburban areas where the speed differential between cyclists and motorists is greater. Last, results illustrated a need for thinking about cycling safety in intersection design and reflecting on the importance of spatial and a spatial correlation both within and between injury categories.

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Sponsoring Committee	ANF20
Session Number	849
Session Title	Bicycle Transportation, Part 2: Safety and Infrastructure (Part 1, Session 477)
Paper Number	15-0887
Paper Title	Infrastructure and Spatial Effects on the Frequency of Cyclist-Motorist Collisions in the Copenhagen Region, Denmark
Abstract	Promoting cycling aims at reducing congestion and pollution and encouraging healthy and sustainable lifestyles, but generally clashes with the perception of crash risk while riding a bicycle that is still the most significant disincentive to cycling. The current study analyzed the factors contributing to increase crash risk while riding a bicycle by focusing on the variation of 5349 cyclist-motorist collisions within 269 traffic zones in the Copenhagen Region. The model controlled for traffic exposure for both bicycles and motorized transport modes, evaluated the effects of infrastructure and socio-economic characteristics of the zones, and accounted for heterogeneity and spatial correlation across the zones. A Poisson-lognormal model with second-order CAR priors confirmed the existence of the safety in numbers phenomenon, contradicted previous literature about bicycle facilities not being helpful in reducing crash risk, highlighted the need for Copenhagen-style bicycle paths especially in suburban areas, and emphasized how heterogeneity and spatial correlation play a significant role in explaining the probability of cyclist-motorist crash occurrence.

Authors	Juneyoung Park, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida Chris Lee, University of Windsor, Canada
Sponsoring Committee	ANF20
Session Number	849
Session Title	Bicycle Transportation, Part 2: Safety and Infrastructure (Part 1, Session 477)
Paper Number	15-1036
Paper Title	Evaluation of Safety Effectiveness of Adding Bike Lane for Urban Arterials with Different Roadway and Socioeconomic Characteristics
Abstract	Although many researchers have estimated crash modification factors (CMFs) for specific treatments (or countermeasures), there is a lack of studies that explored the heterogeneous effects of roadway characteristics on crash frequency among treated sites. Generally, the CMF estimated by before-after studies represents overall safety effects of the treatment in a fixed value. However, as each treated site has different roadway characteristics, there is a need to assess the variation of CMFs among the treated sites with different roadway characteristics through crash modification functions (CMFunctions). The main objective of this research is to determine relationships between the safety effects of adding a bike lane and the roadway characteristics through 1) evaluation of CMFs for adding a bike lane using observational before-after with empirical Bayes (EB) and cross-sectional methods and 2) development of simple and full CMFunctions which are describe the CMF in a function of roadway characteristics of the sites. Data was collected for urban arterials in Florida, and the Florida-specific full SPFs were developed. Moreover, socio-economic parameters were collected and included in CMFunctions and SPFs 1) to capture the effects of the variables that represent volume of bicyclists and 2) to identify general relationship between the CMFs and these characteristics. In order to achieve better performance of CMFunctions, data mining techniques were used. The results of both before-after and cross-sectional methods show that adding a bike lane on urban arterials has positive safety effects (i.e. CMF < 1) for All crashes and bike crashes. It was found that adding a bike lane is more effective in reducing bike crashes than All crashes. It was also found that the CMFs vary across the sites with different roadway characteristics. In particular, Annual Average Daily Traffic (AADT), number of lanes, AADT per lane, median width and bike lane width are significant characteristics that affect the variation in safety effects of adding a bike lane. Some socio-economic characteristics such as bike commuter rate also have significant effect on the variation in CMFs. The findings suggest that full CMFunctions showed better model fit than simple CMFuncttions since they account for the heterogeneous effects of multiple roadway and socio-economic characteristics. The proposed CMFunctions provide insights into bike lane design and selection of sites for bike lane installation for reducing crashes.

Authors	Juneyoung Park, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida Chris Lee, University of Windsor, Canada
Sponsoring Committee	ANB25
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-1038
Paper Title	A Study on Development and Comparison of Crash Modification Factors for Combining Multiple Treatments on Rural Multilane Roadways
Abstract	As multiple treatments (or countermeasures) are simultaneously applied to roadways, there is a need to assess their combined safety effects. Due to a lack of empirical Crash Modification Factors (CMFs) for multiple treatments, the Highway Safety Manual (HSM) and other related studies developed various methods of combining multiple CMFs for single treatments. However, the literature did not evaluate the accuracy of these methods using CMFs obtained from the same study area. Thus, the main objectives of this research are: 1) develop CMFs for two single treatments (shoulder rumble strips, widening shoulder width) and one combined treatment (shoulder rumble strips + widening shoulder width) using before-after and cross-sectional methods and 2) evaluate the accuracy of the combined CMFs for multiple treatments estimated by the existing methods based on actual evaluated combined CMFs. Data was collected for rural multi-lane highways in Florida and four safety performance functions (SPFs) were estimated using 360 reference sites for two crash types (all crashes and Single Vehicle Run-off Roadway (SVROR) crashes) and two severity levels (all severity (KABCO) and injury (KABC)). The results of both before-after and cross-sectional methods show that the two single treatments and the combined treatment produced safety improvement. It was found that safety effects were higher for the roadway segments with shoulder rumble strips and wider shoulder width. It was also found that the treatments were more safety effective (i.e. lower CMF) for the roadway segments with narrower original shoulder width in the before period. However, although CMFs for multiple treatments were generally lower than CMFs for single treatments, they were similar for the roadway segments with shoulder width of 8~12 feet. Among different methods of combining CMFs, the HSM, Systematic Reduction of Subsequent CMFs, Applying only the most effective CMF, and Weighted average of multiple CMFs (Meta-Analysis) showed good estimates of the combined CMFs for multiple treatments with 2.2% difference between actual and estimated CMFs. The findings suggest that the existing methods of combining multiple CMFs are generally valid but they need to be applied for different crash types and injury levels separately. Lastly, an average of the combined CMFs from the best two methods was closer to the actual CMF than the combined CMF from only one best method. This indicates that it is better not to rely on only one specific existing method of combining CMFs for predicting CMF for multiple treatments.

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Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-1242
Paper Title	Investigation of Difference Between Network Screening Results Based on Multivariate and Simple Crash Prediction Models
Abstract	Identification of hazardous road locations (network screening) is the first step of road network safety management process. According to state-of-the-art knowledge it should be conducted using empirical Bayes technique which relies on a crash prediction model (safety performance function). However there is a dilemma in choice of a model: researchers strive for multivariate models, which demand area-wide databases of several variables; on the other hand practitioners require simple models, based only on fundamental variables, which are more easily available and able to be periodically updated. The research question was: “What is the difference between network screening results based on multivariate and simple crash prediction models?” For the purpose of investigation multivariate and simple crash prediction models were developed for regional road network of South Moravia (Czech Republic) and used in network screening. The results based on both models were compared and discussed – the conclusion is that results from network screening with simple model are generally comparable to the multivariate model.

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Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-1252
Paper Title	Assessing Safety Effects of Widening Four-Lane to Six-Lane Roadways using a Nonlinearizing Link Function Accounting for Time Changes in Developing Crash Modification Functions
Abstract	Since a crash modification factor (CMF) represents the overall safety performance of specific treatments in a single fixed value, there is a need to explore the variation of CMFs with different roadway characteristics among treated sites over time. Therefore, in this study, we 1) evaluated the safety performance of a sample of urban four-lane roadway segments that have been widened with one through lane in each direction and 2) determined the relationship between safety effects and different roadway characteristics over time. Observational before-after analysis with the Empirical Bayes (EB) method was assessed in this study to evaluate the safety effects of widening urban four-lane roadways to six-lanes. Moreover, the nonlinearizing link function was utilized to achieve better performance of crash modification functions (CMFunctions). The full CMFunctions were developed using multivariate linear regression and Bayesian random parameter regression methods including the estimated nonlinearizing link function to incorporate changes in safety effects of treatment over time. Data was collected for urban arterials in Florida, and the Florida-specific full SPFs were developed and used for EB estimation. The results indicated that the conversion of four-lane roadways to six-lane roadways resulted in a crash reduction of 15 percent for total crashes, and 24 percent for fatal and injury crashes on urban roadways. The results show that the safety effects vary across the sites with different roadway characteristics. In particular, LOS changes, time changes, shoulder widths, paved shoulder types, and speed limits are significant parameters that affect the variation of CMFs. Moreover, it was found that narrowing shoulder and median widths to make space for an extra through lane shows negative safety impacts. It was also found that including the nonlinearizing link function in developing CMFunctions shows more reliable estimates, if the variation of CMFs with specific parameters has a nonlinear relationship. The findings provide insights into the selection of roadway sites for adding through lanes.

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Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-1467
Paper Title	Validation of Crash Modification Factors Derived from Cross-Sectional Studies Using Regression Models
Abstract	Crash modification factors (CMFs) can be used to capture the safety effects of countermeasures and play significant roles in traffic safety management. As an alternative to the before-after study, the regression model method has been widely used for estimating CMFs. Although before-after studies are considered to be superior, the use of regression models for estimating CMFs has never been fully investigated. This paper consequently sought to examine the conditions in which regression models could be used for such purpose. CMFs for three variables, lane width, curve density and pavement friction, were assumed and used for generating random crash counts. Then, CMFs were derived from regression models using the simulated crash data for three different scenarios. The results were then compared with the assumed true value. The study results showed that (1) the CMFs derived from the regression models should be unbiased when all factors affecting traffic safety are identical in all segments, except those of interest; (2) if some factors having minor safety effects are omitted from the models, the accuracy of estimated CMFs can still be acceptable; (3) if some factors already known to have significant effects on crash risk are omitted, the CMFs derived from the regression models are generally unreliable. Thus, depending on the missing variables that are not included in the model, the transportation safety analyst can decide if the CMFs developed from the regression models should be used for highway safety applications.

Authors	Mohamadreza Banihashemi, Genex Systems
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-1783**
Paper Title	Is Horizontal Curvature a Significant Factor of Safety in Rural Multilane Highways?
Abstract	The Highway Safety Manual (HSM) crash prediction models estimate the expected number of crashes for different facility types. Models in Part C of the first edition of the HSM include crash prediction models for divided and undivided rural multilane highway segments. Each of the HSM crash prediction models for highway segments is comprised of a "Safety Performance Function" (SPF) that is a function of AADT and segment length plus, a series of "Crash Modification Factors" (CMFs). The SPF estimates the number of crashes for the site if the site features are of base condition. The effects of the other features of the site, if their values are different from base condition, are carried out through use of CMFs. The existing models for rural multilane segments do not have any CMF for horizontal curvature. The goal of this research is to investigate if the horizontal alignment has any significant effect on crashes on these types of facilities and if so, to develop a CMF for this feature. Washington State cross sectional data from the Highway Safety Information System (HSIS) lab is used in this research. Data from 2007 to 2009 is used to do the investigation. The 2010 and 2011 data is used to validate the results. As the results show the horizontal curvature has significant safety effect on rural multilane highways and using a CMF for horizontal curvature improves the prediction of crashes significantly, for both tangent and curve segments.

Authors	Shanshan Zhao, University of Nebraska, Lincoln Aemal Khattak, University of Nebraska, Lincoln Eric Thompson, University of Nebraska-Lincoln
Sponsoring Committee	ANB75
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-1983**
Paper Title	Safety and Economic Assessment of Roundabouts on High Speed Rural Highways
Abstract	This study addressed two questions: "Are modern roundabouts on rural high-speed roadways safer than traditional stop controlled intersections?" and "What economic benefits can be expected for the conversion from two-way stop controlled intersections (TWSC) to roundabouts in terms of safety improvement?" Crash and traffic data on four TWSC intersections that were converted to modern roundabouts in Kansas were obtained from the Kansas Department of Transportation. Empirical Bayes analysis was used to evaluate the safety changes and crash costs were applied to the estimated crash changes to yield an estimate of average annual value of enhanced safety from the TWSC intersection conversion to roundabouts. Analysis showed that all types of crashes including fatal, non-fatal injury and property-damage-only (PDO) were reduced after conversion to roundabouts. Total crashes reduced by 58.13% on the whole. Fatal and non-fatal injury crashes reduced by 100% and 76.47%, respectively while PDO crashes were reduced by 35.49%. The annual value of the reduction in comprehensive crash costs from conversion of a TWSC intersection on a rural, high-speed roadway to a modern roundabout was between $1.0 million and $1.6 million in 2014 dollars.

Authors	Salvatore Cafiso, University of Catania, Italy Carmelo D'Agostino, University of Catania, Italy
Sponsoring Committee	ANB10
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2226
Paper Title	Reliability-based assessment of Benefits in roadway safety management
Abstract	Road Agencies set quantitative targets and adopt related road safety strategies within the priorities and the available resources funds at a time of economic crisis. In this framework, benefit-cost analyses (BCA) are carried out to support the decision making process and alternative measures are ranked according to their expected benefit and benefit-cost ratio calculated using a Safety Performance Function (SPF) and Crash Modification Factors (CMFs) as predictor of future safety performances. Due to the variance of CMFs and crash frequency we are uncertain what the benefits of some future actions will be. The chance of making a wrong decision depends on the size of the standard deviation of the probability distribution of CMFs and SPF, as well. To deal with the uncertainty inherent in the decision making process, a reliability based assessment of Benefits must be performed introducing a stochastic approach. In the paper the variance of the CMFs and SPFs are taken into account in a reliability based BCA to address improvements and issues of an accurate probabilistic approach when compared to the deterministic results or other approximated procedures. A case study is presented comparing different safety countermeasures selected to reduce crash frequency and severity on sharp curves in motorway. These measures include retrofitting of old safety barrier, delineation systems, shoulder rumble strips and their combinations. The methodology was applied using Monte Carlo simulations to calculate the probability of failure of BCA statements. Results and comparisons with alternative approaches, like that proposed in the HSM, are presented showing remarkable differences in the evaluation outcomes that can be achieved.

Authors	Mohammad Jalayer, Auburn University Huaguo Zhou, Auburn University Michael R. Williamson, Indiana State University Jeffrey J. LaMondia, Auburn University
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2298**
Paper Title	Developing Calibration Factors for Crash Prediction Models with Consideration of Crash Recording Threshold Change
Abstract	The focus of this manuscript is to present a revised method to develop calibration factors for five different types of urban and suburban roadways with consideration of the recent crash recording threshold (CRT) change, a minimum value to report crashes, in the state of Illinois. These roadway types include two-lane undivided, two-lane with a two-way left-turn lane (TWLTL), four-lane undivided, four-lane divided, and four-lane with a TWLTL. Five years of crash data were gathered and utilized in order to develop calibration factors. Due to a change in the recording threshold for property damage only (PDO) crashes in 2009, the study established a revised method to supplement and adopt the standard approach to develop calibration factors in the Highway Safety Manual (HSM), considering the impact of the new CRT. The higher the CRT, the fewer the amount of recorded PDO crashes. In this paper, a threshold adjustment factor was defined and employed to estimate the new calibration factor values. These values for two-lane undivided and two-lane with a TWLTL arterials before/after considering the threshold adjustment factor were 1.44/1.32 and 1.24/1.12, respectively, while the calibration factors before/after the threshold change for four-lane undivided, four-lane divided, and four-lane with a TWLTL arterials were 0.99/0.85, 0.68/0.55, and 0.77/0.69, respectively. By virtue of the fact that the threshold change only affects the total number of crashes and PDO crashes, the percentage distributions of fatal and injury (F/I) crashes before the threshold change need to be adjusted to properly estimate the total number of F/I crashes. This study provides a revised method to help the state and local agencies predict the number of crashes without redeveloping new calibration factors due to the change in CRT.

Authors	Brian Wolshon, Louisiana State University Bridget Robicheaux, Louisiana State University
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2301**
Paper Title	Highway Safety Manual Calibration and the Quantitative Effects of Data Availability and Assumption-Making
Abstract	The application of the American Association of State Highway and Transportation Officials' (AASHTO) Highway Safety Manual (HSM) to Louisiana roads is a key component to the Louisiana Department of Transportation and Development's (LA DOTD) plan to improve safety on state highways and reach the goal of Destination Zero Deaths. To apply the HSM, the LA DOTD sought to develop state-specific HSM calibration factors for eight facility types. During the development process, the data-intensive computational procedure followed to compute the calibration factors revealed numerous issues associated with the inclusion and definitions of various data elements required by the HSM. These included coding errors, missing required data elements in the Louisiana roadway and crash databases, and varying definitions of which specific crashes should or should not be included in the sample. Because of this, some of the resulting factors were unexpected, in particular, those for urban three-lane and urban five-lane highways which were lower than anticipated. To investigate the effect of including or excluding various data elements and varying crash definition assumptions in HSM calibration factor development a series of computational iterations in which the amount of data and assumed crash conditions were varied from one iteration to the next. The overall results of this work demonstrate the extent of the variability and sensitivity of HSM calibration factors to the inclusion of data that may or may not be included in roadway databases and how crashes that occur within various distances away from intersections are included or excluded.

Authors	Prasad N. V. S. R. Buddhavarapu, University of Texas, Austin Andre de Fortier Smit, University of Texas, Austin Jorge A. Prozzi, University of Texas, Austin
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2314
Paper Title	A Fully Bayesian Before-After Analysis of Permeable Friction Course (PFC) Pavement Wet Weather Safety
Abstract	Permeable friction course (PFC), open-graded hot-mix asphalt used in Texas, is typically applied to improve wet weather safety. This paper aims to quantify the effectiveness of PFC in terms of reducing wet weather crashes. The majority of the earlier literature on the safety effectiveness of porous mixes has been limited and inconclusive. This paper thoroughly evaluates the wet weather safety effectiveness of porous asphalt mixes using a fully Bayesian before-after safety analysis. A negative binomial count specification was employed to model the underlying reference and treatment population of crash counts. A computationally efficient procedure was utilized for fully Bayesian estimation of the proposed crash count model and to perform Bayesian inference on the safety effectiveness. Based on the the crash data from a pool of PFC and reference road segments across Texas, the hypothesis that PFC is effective in reducing wet weather crashes is rejected. It is interesting to note that the findings of this study are in agreement with most of the earlier literature on the safety benefits of porous surfaces. The study highlights the importance of the interaction between the road user's behavior and the safety infrastructure.

Authors	Md Tazul Islam, University of Alberta, Canada Karim El-Basyouny, University of Alberta, Canada
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2342
Paper Title	Full Bayesian Evaluation of the Safety Effects of Reducing the Posted Speed Limit in Urban Residential Neighbourhoods
Abstract	Full Bayesian (FB) before-after evaluation is a newer approach than the empirical Bayesian (EB) evaluation in traffic safety research. While a number of earlier studies have conducted univariate and multivariate FB before-after safety evaluations and compared the results with the EB method, often contradictory conclusions have been drawn. To this end, the objectives of the current study were to i) perform before-after safety evaluation using both the univariate and multivariate FB methods in order to enhance our understanding of these methodologies, ii) perform the EB evaluation and compare the results with those of the FB methods, and iii) apply the FB and EB methods to evaluate the safety effects of reducing the urban residential posted speed limit (PSL) for policy recommendation. In addition to three years of crash data for both the before and after periods, traffic volume, road geometry, and other relevant data for both the treated and reference sites were collected and used. According to the model goodness-of-fit criteria, the current study found that the multivariate FB model for crash severities outperformed the univariate FB models. Moreover, in terms of statistical significance of the safety effects, the EB and FB methods led to opposite conclusions when the safety effects were relatively small with high standard deviation. Therefore, caution should be taken in drawing conclusions from the EB method. Based on the FB method, the PSL reduction was found effective in reducing crashes of all severities and thus is recommended for improving safety on urban residential collector roads.

Authors	Liyu Wu, Tongji University, China Jian Sun, Tongji University, China
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2433
Paper Title	Relationship of Lane Width to Safety for Urban Expressways
Abstract	Urban expressways served as the backbone of road traffic system in metropolitan cities. In order to increase the capacity of urban expressways in Shanghai, several cross-section reconstruction projects (the cross-section width remained the same) took place in past ten years. Site investigation found that the maximum lane width was 4.05m and the minimum lane was only 2.73m. To examine the safety influence of lane width on urban expressway, crash data and the corresponding traffic flow data from 2010 to 2013 were extracted from Shanghai Expressway Surveillance System for cross-sectional study. Negative binominal model (NB) was selected as the function form of the predicted crash frequency. Three datasets corresponding to undersized (average lane width ¡Ü 3.25m), standard-sized (average lane width ~ 3.45m), and oversized lanes (average lane width ¡Ý 3.75m) were collected for the development of crash modification factors (CMFs). Since lane width might exert different influence to different type of crash, different models were established by involved-vehicle number (two-vehicle crash and multi-vehicle crash) and traffic condition (congestion-flow crash and free-flow crash), and CMFs were developed respectively. The results showed that standard-sized lanes experienced the lowest crash frequency in all kind of crash. Specifically, the crash frequency of undersized lanes and oversized lanes would increase 190% and 134% compared with standard-sized lanes in total crash.

Authors	Pengpeng Xu, Central South University, China Helai Huang, Central South University, China Qiang Zeng, Central South University, China
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-2442
Paper Title	Modeling Crash Spatial Heterogeneity: Random Parameter Versus Geographical Weighting
Abstract	The widely adopted techniques for regional crash modeling include the negative binomial model (NB) and the Bayesian spatial model with conditional autoregressive prior (CAR). The outputs from both models consist of a set of fixed global parameter estimates. However, the impacts of predicting variables on crash counts might not be stationary over space. This study intended to quantitatively investigate the spatial heterogeneity in regional safety modeling. Two advanced approaches, the random parameter negative binomial model (RPNB) and semi-parametric geographically weighted Poisson regression model (S-GWPR), were employed to account for the locally spatial variations in the relationships between total/severe crash counts and potential transportation planning predictors. Based on a 3-year data set from the county of Hillsborough, Florida, results revealed that (1) both RPNB and S-GWPR successfully capture the spatially varying relationship, but the two methods yield notably different sets of results; (2) the S-GWPR performs best with the lowest values of mean absolute deviance and mean squared prediction error. While the RPNB is comparable to the CAR, in some cases, it provides less accurate predictions; (3) a moderately significant spatial correlation is found in the residuals of RPNB and NB, implying the inadequacy in accounting for the spatial correlation existed across adjacent zones. The analysis suggested that with respect to regional safety analysis, it is desirable to make use of the geographical component to explicitly explore spatial aspects of the crash data. The S-GWPR was proven to be more preferred for regional crash modeling as the method outperforms the global models (i.e. CAR and NB) in capturing the spatial heterogeneity occurring in the relationship that is model, and compared with the non-spatial model (i.e. RPNB and NB), it is capable of accounting for the spatial correlation in crash data.

Authors	Subasish Das, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-2539
Paper Title	Zero-Inflated Models for Different Severity Types in Rural Two-Lane Crashes
Abstract	This research aims to investigate the application of zero-inflated models for different severity types in rural two-lane highway crashes. These roadways carry one-third of the total vehicle miles traveled (VMT) and have experienced a considerably high percentage of fatal crashes in Louisiana. A careful analysis indicates that a wide variety of factors appear to be associated with the crash dynamic of rural two-lane highways. The roadway variables include segment length, pavement width and type, shoulder type, and traffic volume. Crashes recorded from 2004 to 2011, of which 1,780 were fatal, and 36,569 resulted in injuries, were analyzed. It is found that there are a large number of highway segments which contain no crashes under the recorded years. To tackle this issue, zero-inflated models, zero-inflated Poisson (ZIP) models and zero-inflated negative binomial (ZINB) models, have been developed for crash frequencies of different severity types. The researchers of this study have used the qualitative values of the variables to develop the model for convenient interpretation. The results shows that specific categories of traf?c ?ow, segment length, pavement type and width, and shoulder type were found to be statistically signi?cant variables for total, injury, and property damage only (PDO) crashes. Two additional findings are: 1) wider shoulder and pavement width reduced the likelihood of crash occurrence, and 2) roadways with gravel-top pavements were inclined towards crash proneness. The findings of this paper will help highway professionals improve the safety outcome of rural two-lane roadways.

Authors	Muamer Abuzwidah, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2700**
Paper Title	Safety Evaluation of All-Electronic Toll Collection System
Abstract	Traditional mainline toll plaza (TMTP) is considered the most high risk locations on the toll roads. Conversion from TMTP or Hybrid Mainline Toll Plaza (HMTP) to an All-Electronic Toll Collection (AETC) system has demonstrated measured improvements in traffic operations and environmental issues. However, there is a lack of research that quantifies the safety impacts of these new tolling systems. This study evaluated the safety effectiveness of conversion from TMTP or HMTP to AETC system. An extensive data collection was conducted that included a hundred mainline toll plazas located on more than 750 miles of the toll roads in Florida. Various observational before-after studies including the Empirical Bayes method were applied. The results indicated that the conversion from the TMTP to an AETC system resulted in an average crash reduction of 77, 76, and 67 percent for total, fatal-and-injury and Property Damage Only (PDO) crashes, respectively; for rear end and Lane Change Related (LCR) crashes the average reductions were 81 and 75 percent. The conversion from HMTP to AETC system enhanced traffic safety by reducing crashes by 23, 29 and 19 percent for total, fatal-and-injury, and PDO crashes; also, for rear end and LCR crashes, the average reductions were 15 and 21 percent, respectively. Overall, this paper provided an up-to-date safety impact of using different toll collection systems. The results proved that the AETC system significantly improved traffic safety for all crash categories; and changed toll plazas from the highest risk on Expressways to be similar to regular segments.

Authors	Muamer Abuzwidah, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2711
Paper Title	Traffic Safety Evaluation and Modeling of Toll Collection Systems
Abstract	The use of toll roads has risen dramatically in many countries around the world. Although toll roads offer a high level of service, and in general they are well-maintained roadways, there is a lack of research that quantifies the safety impacts of using different toll collection systems. This study examines the traffic safety impact of using different designs of the Hybrid Mainline Toll Plaza (HMTP). HMTP are plazas that combines open road tolling for Electronic Toll Collection (ETC) and plaza structure for manual payment. Also, this study helps understand the relationship between the crash frequency and several important crash-related factors and circumstances. Crash data from a seven-year period was investigated, and a hundred mainline toll plazas in Florida were evaluated. The analysis was conducted using Negative Binomial and Log-Linear models. The results of this study proved that there is a significant difference between the different designs of the HMTP. And there is an indication that the majority of crashes occurred at diverge-and-merge areas before and after the plaza. Moreover, the results indicated significant relationships between the crash frequency and toll plaza types, annual average daily traffic, and driver-age. This study has also proved that the HMTP and the All-Electronic Toll Collection were associated with less number of crashes than the traditional mainline toll plazas by 44.7 and 72.6 percent, respectively. For those countries who cannot adopt the HMTP and AETC systems, improving traffic safety at traditional mainline toll plazas should take a priority.

Authors	Pamela M. Fischhaber, Colorado Pulbic Utilities Commission Bruce N. Janson, University of Colorado, Denver
Sponsoring Committee	AHB60
Session Number	506
Session Title	Highway/Rail Grade Crossing Research
Paper Number	15-2754
Paper Title	Light Rail Crossing Safety Performance Functions
Abstract	This paper presents the development of Safety Performance Functions (SPF's) for light rail crossings or roadways. The paper also develops an Empirical Bayes (EB) Method to adjust the initial crash estimates from the SPF to account for the actual crash experiences at the light rail crossings. This paper compares the validity of the light rail crossing SPF'sto the United States Department of Transportation (USDOT) crash prediction models and finds that the light rail crossing specific SPF's provides improvements to the crash estimates that are statistically significant compared to the USDOT crash prediction models.

Authors	Bo Song, Central South University, China Helai Huang, Central South University, China Qiang Zeng, Central South University, China Qichun Deng, Hunan Communications Research Institute, China Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-2774
Paper Title	Comparative Analysis of Macro and Micro Models for Zonal Crash Prediction
Abstract	Zonal crash prediction has become one of the most important topics in the field of traffic safety analysis. In general, zonal safety level is evaluated by relating aggregate crash statistics in zones to various zone-level factors such as demographic, socioeconomic, road length and intersection density etc. Another recent perspective is from the micro level, where zonal crash frequency is estimated by summing up the expected crashes of all the road entities (i.e. road segments and intersections) located within the zones of interest, estimated by micro-level factors. This study aims to compare the two types of zonal crash prediction models with consideration of spatial correlation of road entities and traffic zones. The macro-level conditional autoregressive model and the micro-level spatial joint model were developed and empirically evaluated based on three years data of 346 segments and 198 intersections of 155 TAZs at Hillsborough County in the state of Florida. Cross validation approach is employed to assess the model fitting and predictive performance. Results reveal that the micro-level spatial joint model has a better predictive performance than the macro-level model. Consistent with previous research and well-known facts, the two groups of parameter estimation justify the model validity. Suggestions for how to apply the two types of models in zonal crash prediction are provided so as to better incorporate safety measures in transportation planning and traffic engineering.

Authors	Hui Wu, University of Texas, Austin Zhe Han, University of Texas, Austin Mike Murphy, University of Texas, Austin Zhanmin Zhang, University of Texas, Austin
Sponsoring Committee	ANB25
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-3001
Paper Title	Empirical Bayes Before-After Study on Safety Effect of Narrow Pavement Widening Projects in Texas
Abstract	Texas has approximately 40,000 lane miles (64,000 km) of two-lane farm-to-market (FM) and ranch-to-market (RM) roads with total paved widths of 18 to 22 ft (5.5 to 6.7 m), most of which are in rural areas. Narrow pavement widening in Texas typically involves adding a total of 1- to 9-ft (0.3- to 2.4-m) lane width and/or a narrow shoulder to each direction of a narrow FM/RM road. The main reasons for roadway widening are usually to improve safety, increase structural capacity, and/or enhance pavement performance. The goal of this study is to investigate the safety effects of narrow pavement widening projects for rural two-lane FM/RM roads in Texas. A before-after comparison study was conducted using the empirical Bayes method to evaluate how wider lanes/shoulders impact crash occurrence by type and severity. Of the 22 studied projects, analysis showed a 31.5 percent reduction in total crashes; a 35.7 percent in run-off-the-road crashes; and a 55.4 percent reduction in head-on crashes after narrow widening projects were constructed. The projects were also effective in reducing fatal crashes and injuries by about 29.5 percent. These findings suggest that narrow pavement widening is an effective safety countermeasure on narrow two-lane FM/RM roads in rural areas.

Authors	Khalid Ahmed Hafidh Al Kaaf, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB25
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-3054
Paper Title	Transferability and Calibration of Highway Safety Manual Performance Functions and Development of New Models for Urban Four-Lane Divided Roads in Riyadh
Abstract	The first edition of the Highway Safety Manual (HSM) provides a number of safety performance functions (SPFs), which can be used to predict severe collisions on a roadway network. This paper examined the calibration of the HSM SPFs for Urban Four-lane divided roadway segments (U4D) with angle parking in Riyadh, Kingdom of Saudi Arabia (KSA) and the development of new SPFs. This study first calibrates the HSM SPFs using HSM default Crash Modification Factors (CMFs), then new local CMFs are proposed, which adjust the estimation of calibration factors using fatal and injury crash data. In addition, new forms for specific SPFs are further evaluated to identify the best model using the Poisson-Gamma regression technique. It was found that the jurisdiction-specific SPFs provided the best fit of the data used in this study, and would be the best SPFs for predicting severe collisions in the City of Riyadh. The best fatal and injury model describes the mean crash frequency as a function of natural logarithm of the annual average daily traffic, segment length, speed limit, and driveway density. The study finds that the HSM calibration using Riyadh local CMFs outperforms the calibration method using HSM default values. Based on these results, potential countermeasures were proposed to reduce severe crashes on Riyadh urban roads, and the potential for HSM application in KSA are addressed.

Authors	Eneliko Mujuni Mulokozi, University of Nevada, Las Vegas
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3070
Paper Title	Safety Analysis of Freeway Segments with Random Parameters
Abstract	The purpose of this study was to analyze the impact of geometric features on freeway crashes while accounting for the effect of unobserved factors likely to influence crash occurrence. The investigation was also motivated by the fact that the distribution of crashes in space is not limited to only the influence areas of the divergence and convergence segments as well as weaving segments. Areas beyond the influence areas were observed to have crashes occurred and by including these areas data within the weaving and non-weaving segments can be clustered to quantify the variability of unobserved factors through the variance of random parameters using multilevel count models. The model results indicated that 13.9% of the variation in crash frequency is unaccounted for, which is an indication of the existence of unobserved factors influencing the occurrence of crashes. It was also revealed that weaving segments (EN-EX) had the highest between segment variance compared to non-weaving segments. In addition to these results, it was revealed that more vehicles and short segments increased crash frequency while wider right shoulder decreased the crash frequency. It was also revealed that weaving segments decreased crash frequency compared to non-weaving segments. These results indicate that by allowing parameters to vary across segments it is possible to capture and quantify unobserved factors. Ignoring these factors results in biased coefficients in a multilevel setting because the estimate of the standard errors will be wrong.

Authors	Joshua Fink, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-3076
Paper Title	Impact of Adaptive Traffic Control Systems on Crash Frequency and Severity
Abstract	Despite seeing widespread usage worldwide, adaptive traffic control systems have experienced relatively little use in the United States. Of the systems used, the Sydney Coordinated Adaptive Traffic System (SCATS) is the most popular in America. Safety benefits of these systems are not as well understood nor as commonly documented. This study investigates the safety benefits of adaptive traffic control systems by using the large SCATS-based system in Oakland County, MI known as FAST-TRAC. This study uses data from FAST-TRAC-controlled intersections in Oakland County and compares a wide variety of geometric, traffic, and crash characteristics to similar intersections in metropolitan areas elsewhere in Michigan. Data from 498 signalized intersections are used to conduct a cross-sectional analysis. Negative binomial models are used to estimate models for three dependent crash variables. Multinomial logit models are used to estimate an injury severity model. A variable tracking the presence of FAST-TRAC controllers at intersections is used in all models to determine if a SCATS-based system has an impact on crash occurrences or crash severity. It is found to be statistically significant in 8 models. Estimates show angle crashes could be reduced by up to 19.3% at intersections with SCATS-based controllers. Severity results show a statistically significant increase in non-serious injuries, but not a significant reduction in incapacitating injuries or fatal accidents.

Authors	Kate Bradbury, CH2MHILL Derek A Troyer, Ohio Department of Transportation Cindy Juliano, CH2M HILL
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3093**
Paper Title	Strength of the Variable: Calculating and Evaluating Safety Performance Function Calibration Factors for the State of Ohio
Abstract	The AASHTO Highway Safety Manual (HSM) provides methodologies for DOTs and other agencies to incorporate high quality quantitative safety analyses into project development and decision-making. Taking full advantage of the HSM, though, requires states to collect and maintain more detailed and comprehensive data on their roadway system. Moreover, given that the methods in the HSM were based on research using select state databases, full use of the HSM requires that states calibrate the models to their own databases and systems. Calibration is needed to account for differences in state reporting thresholds, terrain, driver demographics, climate, and other unique crash attributes. This paper outlines the efforts undertaken by the Ohio Department of Transportation (ODOT) to implement the HSM through data collection and calibration. Historically, ODOT has not collected data for all of the attributes included in the Part C predictive models. Over the past two years, ODOT collected additional data elements for their roadway system, including parking, driveways, and roadway curvature. ODOT staff also undertook calibration of the HSM Safety Performance Functions (SPFs) using the collected data, historic observed crashes, and specialized spreadsheet tools. In some cases, calibration factors cannot adequately adjust the HSM models, which may instead require the development of agency-specific SPFs. Cumulative Residual (CURE) plots were used to evaluate how closely calibrated SPFs predicted crash frequency compared to the observed frequency. ODOT determined that the calibration factors were currently sufficient to adjust the HSM models and the development of Ohio-specific SPFs can be prioritized based on calibration evaluations.

Authors	George Yannis, National Technical University of Athens, Greece Eleonora Papadimitriou, National Technical University of Athens, Greece Marianthi Mermygka, National Technical University of Athens, Greece
Sponsoring Committee	ANB10
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-3104
Paper Title	Multilevel Comparative Analysis of Road Safety in European Capital Cities
Abstract	The objective of this research is the comparative road safety analysis in selected European capital cities, aiming to a better understanding of road accident characteristics and causes in European megacities. Despite the continuous urbanization and the shift of population to large urban areas, this research question has received little attention in the existing literature. A database was developed for this analysis containing data regarding the number and the characteristics of road fatalities, the population and other demographic, socioeconomic and transport indicators of nine selected European capital cities for the period 2007 - 2011. Multilevel Poisson statistical models were developed, allowing for a more accurate representation of the hierarchical structure of road safety data, and they led to the identification of several factors affecting the road safety level in the selected European capital cities, revealing some additional aspects of road safety performance in these cities. Factors found with a statistically significant effect concerned city characteristics (road network length, population density, public transport use) and accident characteristics (road user and vehicle type). The comparison between the European capital cities showed that the larger the city's road network is, the higher the level of road safety is in this city.

Authors	Prathyusha Vangala, Texas A&M University Dominique Lord, Texas A&M University Srinivas Reddy Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	303
Session Title	Research in Statistical Methods in Transportation
Paper Number	15-3383
Paper Title	An Application of the Negative Binomial-Generalized Exponential Model for Analyzing Traffic Crash Data with Excess Zeros
Abstract	In order to analyze crash data, many new analysis tools are being developed by transportation safety analysts. The Negative Binomial-Generalized Exponential distribution (NB-GE) is such a tool that was recently introduced to handle datasets characterized by a large number of zero counts and are over-dispersed. As the name suggests, this three-parameter distribution is a combination of both Negative binomial and Generalized Exponential distributions. So far, nobody has used this distribution in the context of a regression model for analyzing datasets with excess zeros. This paper therefore describes the application of the NB-GE generalized linear model (GLM). The distribution and GLM were applied to four datasets known to have large dispersion and/or a large number of zeros. The NB-GE was compared to the Poisson, NB as well as the Negative Binomial- Lindley (NB-L) model, another three-parameter recently introduced in the safety literature. The study results show that for datasets characterized by a sizable over-dispersion and contain a large number of zeros, the NB-GE performs as well as the NB-L, but significantly outclass the traditional NB model. Furthermore, the NB-GE model has a simpler modeling framework than the NB-L, which makes its application relatively straight forward.

Authors	Jiaqi Ma, University of Virginia Michael Daniel Fontaine, Virginia Center for Transportation Innovation and Research Fang Zhou, Mississippi State University David Kivilcim Hale, Leidos Michael Clements, Virginia Department of Transportation
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3472**
Paper Title	Estimation of the Safety Effects of an Adaptive Traffic Signal Control System
Abstract	Adaptive traffic signal control (ATSC) is a traffic management strategy in which traffic signal timings change, or adapt, based on observed traffic demand. While ATSC can improve mobility, it also has the potential to reduce crashes since mainline stops are reduced. This paper aims to evaluate the safety effectiveness of ATSC using the Empirical Bayes method. This analysis examines 47 urban or suburban intersections where ATSC was deployed in Virginia using 235 site-years of before data and 66 site-years of after data. Installing ATSC was found to produce a crash modification factor (CMF) for total intersection crashes of 0.83 with a standard error of 0.05. This CMF was statistically significant at a 95 percent confidence level. Fatal and injury crashes did not change by a statistically significant amount. Analyses of ATSC safety effects on crash type proportion, by traffic volume level, and by operational improvement magnitude were also performed. All crash types were found to be reduced, but safety benefits vary from corridor to corridor and at different volume levels. It was concluded that ATSC installation can potentially reduce both total and FI crashes at highway intersections, and public agencies should consider both its safety and mobility benefits when justifying ATSC projects.

Authors	Sarah El-Dabaja, Ohio University, Athens Deborah McAvoy, Ohio University, Athens
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-4110**
Paper Title	Application of the Highway Safety Manual Predictive Method: A Before/After Case Study of Ohio State Route 682 in The Plains, Ohio
Abstract	This research presents a case study of Ohio State Route 682, a two-lane highway with a center two-way left turn lane, located in The Plains, Ohio. The primary objective of this investigation was to utilize crash data from periods before and after improvements were made to the roadway such that calibration factors for segments and intersections could be determined and applied to the predictive models. These calibration factors were calculated through a before period analysis for segments as well as for three-leg stop-controlled, four-leg stop-controlled, and four-leg signalized intersections. Each of the calculated calibration factors was applied in the after period analysis, along with the Highway Safety Manual default factor and the factor calculated for the state of Ohio, such that comparisons could be made between the three factors. As for the segments, the Ohio calculated factor produced the most accurate estimates, with percent differences between 4% and 48%. However, the crash frequencies at the intersections were best described by the default Highway Safety Model, for which percent differences ranged from 8% to 22%. The reliability of the generalized models over the jurisdiction-specific model indicates that while more specific calibration factors should produce more accurate estimates, such factors are not reliable when developed on the level of a single municipality.

Authors	Ivana Milorad Tasic, University of Utah Richard Jon Porter, University of Utah
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-4181
Paper Title	Modeling Spatial Relationships Between Access to Multimodal Transportation and Traffic Safety Outcomes
Abstract	The interest in multimodal transportation improvements in urban areas is increasing in cities across the U.S. Inherent with this interest is the need to continue to develop methods for measuring safety performance in these environments. Improved access to multimodal transportation attracts new users, but can increase their exposure to risk from crashes. The relationship between access to multimodal transportation and safety in urban environment is complex, as non-motorized user vulnerability becomes a predominant risk factor. This paper aims to evaluate the relationship between access to multimodal transportation, expressed through infrastructure presence and user exposure, and traffic safety outcomes. Using the City of Chicago as a case study, a comprehensive dataset is developed that significantly contributes to the existing literature by including socio-economic, land use, road network, travel demand, and crash data. Area-wide analysis on the census tract level provides a broader perspective about safety issues that multimodal users encounter in cities. Negative-binomial regression models with fixed and random effects are estimated to account for data overdispersion and spatial effects. Total vehicle-only crashes, total crashes with at least one non-motorized user, and fatal vehicle-only crashes are modeled. The results show strong association between the variables related to multimodal transportation access and usage, and both motorized and non-motorized crashes. Although simplified in terms of some spatial correlation assumptions, demonstrated methods prove to be a beneficial and computationally efficient tool for estimating and easily interpreting modeled relationships. Further research efforts to address the limitations of the presented approach are proposed.

Authors	Chia-Yuan Yu, Texas A&M University, College Station
Sponsoring Committee	ANB10
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4414
Paper Title	Disparity in Traffic Safety Across Neighborhoods with Different Economic Statuses and Ethnic Compositions
Abstract	Crashes are not equally distributed across different communities or different socioeconomic groups. For example, more socioeconomically deprived areas experienced more traffic crashes. Several possible reasons were identified in previous studies, including the possibility of lower household vehicle ownership in low income areas (which in turn generate more pedestrian activities and lead to more conflicts between pedestrians and vehicles), insufficient non-motorized infrastructure in low income areas (which increase the danger for pedestrians), and higher traffic volumes in areas with more non-white populations. Moreover, most studies on disparity issues primarily focused on pedestrian injuries. Current evidence regarding disparities in crashes with different levels of injury severity is still limited. Further, possible moderator effects of socio-demographic characteristics on built environment–traffic safety relationships are unclear. This study explored differences in crash frequency across neighborhoods with different economic statuses and ethnic compositions, and further tested the potential moderator effect of socio-demographic characteristics on the built environment–traffic safety association. The results revealed that some built environmental variables (e.g., arterial roads, office uses, and schools) showed significant impacts on traffic safety only in areas with high percentages of non-white population and population below the poverty line and not in low-percentage areas. This suggested that policies and programs related to these built environmental attributes in promoting traffic safety may bring more benefits to areas with more non-white or lower-income populations. Tailored traffic safety strategies are need for areas with more non-white and low-income people.

Authors	Wen Cheng, California State Polytechnic University, Pomona Ximiao Jiang, University of Tennessee, Knoxville Weihua Lin, University of Arizona Xudong Jia, California State Polytechnic University, Pomona Xinkai Wu, California State Polytechnic University, Pomona Jiao Zhou, Wipro (Shanghai) Limited, China
Sponsoring Committee	ANB10
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4422
Paper Title	Ranking Cities for Safety Investigation by Potential for Safety Improvement
Abstract	Numerous methods have been proposed in the past to conduct the identification of hotspots (HSID). However, most of them are dedicated to the micro-level analysis such as roadway segments and intersections. Very limited studies are focused on the HSID of more aggregate levels, which in general have larger sample means and wider dispersion in the collision counts. The authors performed a city-level HSID by using the four-year data of 265 cities in California. It is intended to equip road safety professionals with more useful tools to compare the safety performance of city as a whole. Potential for Safety Improvement (PSI) was adopted as a measure of crash risk to compare alternate HSID methods, including the Empirical Bayes (EB) and three full Bayesian (FB) alternatives, Negative-Binomial (FBNB), Poisson Log-Normal (FBPLN), and the Poisson Temporal Random Effect (FBPTRE), for ranking the safety performance of cities. Five evaluation tests which contain the Site Consistency Test, the Method Consistency Test, the Total Rank Difference Test, the Total Performance Difference Test and the Total Score Test were applied to evaluate the performance of the four HSID methods. Moreover, two cutoff levels, top 5% and 10% cities, were employed for more reliable results. Overall, the study results are consistent with the results of previous quantitative evaluations focused on micro-level HSID. The three FB approaches significantly outperform the EB counterpart. The method accounting for temporal random effect produces more reliable HSID results than those without considering the serial correlations in collision counts.

Authors	Pei-Fen Kuo, University of Central Florida Jaeyoung Lee, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-4445
Paper Title	Comparing Hot Spot Identification Methods at Macroscopic Safety Analysis Level
Abstract	Compared to micro scale safety studies, macroscopic-focused research is more efficient at integrating zone-level features into crash prediction models and identifying hot zones in large study areas. However, few studies have focused on the limitations of current hotspot/hot-zone identification methods (HSID) applied at the macro level. This study applied six common HSID methods and compared their consistency in identifying hot-zones. The crash data was based on five years of crash records from Central Florida (Orange, Seminole, and Osceola Counties). The results showed that the hot-zones identified by the crash frequency, Empirical Bayesian, and Potential for Safety Improvement methods all had high consistency and stability over time, followed by the crash rate and Equivalent Property Damage Only methods. The Proportion method had the lowest consistency. Other possible factors related to the methods' performance were also examined, which included the time length of the before period, the time length of the after period, the time gap, hot-zone threshold (á), and different crash types. However, these factors affected the performance of the methods only slightly. Also, the main problem of the crash frequency method, regression-to-the-mean, was not found to affect the performance of the method at the macro level because the consistency stayed high even in cases where the time length of the before period was as low as one year. The detail proof is given in Appendix A.

Authors	Promothes Saha, University of Wyoming Mohamed M. Ahmed, University of Wyoming Rhonda Kae Young, University of Wyoming
Sponsoring Committee	AFB10
Session Number	766
Session Title	Safety and Speed Effects of Geometric Design Decisions
Paper Number	15-4452**
Paper Title	Safety Effectiveness of Variable Speed Limit (VSL) Systems In Adverse Weather Conditions On Challenging Roadway Geometry
Abstract	This study examines the interaction between roadway geometric characteristics, adverse weather conditions on crash occurrence on rural Variable Speed Limit (VSL) freeway corridors through mountainous terrain. On Wyoming Interstate 80, winter crashes are three times higher than summer crashes and adverse weather conditions are a contributing factor for more than 70 percent of the winter crashes. As a quantitative measure of the effect of geometrics in adverse weather conditions, a safety performance function was developed with explanatory variables including snow, ice, frost, wind, horizontal curvature and steep grades. The Generalized Linear Regression Model was used for finding the significance of the explanatory variables. This research concluded that the interaction between grades and horizontal curves with weather variables have a significant impact on crash occurrence. The results from the models suggest that distinct VSL strategies should be implemented on segments with challenging roadway geometry.

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
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4597
Paper Title	Seasonal Effects of Crash-Contributing Factors on Highway Safety
Abstract	A longitudinal negative binomial model is developed in this paper that takes into account the seasonal effects of crash causality factors based on ten years (2002-2011) of Missouri Interstate highway crash data. The technique of generalized estimating equation (GEE) with autoregressive correlation structure is used. The results explain the overall effect of seasonality and whether the magnitude and/or type of various effects are different according to climatic changes. Traffic volume was found to have an appreciable effect in increasing the crash occurrence in spring and lower effect in winter, compared to the fall season. Fewer crashes were associated with higher pavement serviceability (measure of pavement surface quality, higher value is better) and this effect was found to be highest in the spring season followed by summer and winter, again when compared to the fall season. Heavy vehicles were found to reduce the likelihood of crash occurrences and this effect is higher in urban areas; although compared to other times of the year, the effect of heavy vehicles is lower during the summer season. The results indicated that the fall season is associated with the lowest crash frequency compared to the other seasons; winter season having the highest impact followed by summer and spring. This paper also evaluated the effects of the Missouri's Strategic Highway Safety Plan (MSHSP) implemented from 2005-2011. The plan was found to be effective as it reduced the crash frequency. Similar strategic plans therefore should be initiated in the future as well.

Authors	Jonathan Auger, Concordia University, Canada Marie-Soleil Cloutier, Institut National de la Recherche Scientifique, Canada Patrick Morency, Montreal Department of Public Health, Canada
Sponsoring Committee	ANF10
Session Number	847
Session Title	Pedestrian Safety Policy, Planning, and Design Issues
Paper Number	15-4619
Paper Title	A Built Environment for an Ageing Society: A Subpopulation Analysis of Pedestrian Crashes at Signalized Intersections in Montreal, Canada
Abstract	Concern for pedestrian safety has grown recently because of ageing population not only in North-America but globally. Meanwhile the overrepresentation of older adults in fatal pedestrian crashes has been a longstanding problem. As sustainable transport policy becomes prevalent, planners and practitioners will have the opportunity to introduce countermeasures to better meet senior pedestrian needs. In this paper we focus on the built environment because this variable category translates into more accessible countermeasures. However, a gap in the literature makes it difficult for planners and practitioners to choose these. Past empirical studies suggest there is an observed risk increase for older adult pedestrians due to their slower walking speed, while crash history studies have yet to provide evidence for this. This gap in the literature begs the question: if there is a link between slower walking seniors and crash incidence. Two models were specified according to younger and older pedestrians involved in crashes that occurred at 191 signalized intersections in Montreal, Canada. We sought to determine if older adult pedestrian crash incidence was explained by different characteristics compared to the younger. Results not only showed that older pedestrians were more vulnerable and influenced by some different risk factors than the younger, but that they may be more responsive to some potential countermeasures.

Authors	Hyeon-Shic Shin, Morgan State University Seyedehsan Dadvar, Morgan State University Young-Jae Lee, Morgan State University
Sponsoring Committee	ANB25
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-4643
Paper Title	Results and Lessons from Local Calibration Process of Highway Safety Manual for the State of Maryland
Abstract	The paper discusses Marylandį¯s experience in developing local calibration factors (LCFs) in the application of the Highway Safety Manual (HSM), the required process for adjusting predicted crashes estimated by HSMį¯s safety performance functions (SPFs) to local jurisdictions. LCFs for 18 facility types were calculated using data for the years 2008 to 2010. Additional variables were gathered by alternative data collection methods. Due to the difference with HSMį¯s crash proportion, Marylandį¯s crash proportion was used to predict crash frequency and calculate LCFs. Maryland in general had fewer crashes than predicted crash frequency generated by HSMį¯s SPFs. LCFs for 15 out of 18 facility types were less than 1.0.Especially, intersection LCFs intersections were extremely low. Due to potential issues with unreported minor and property damage only crashes, the authors recommend using LCFs for fatal and injuries crashes where available. The pair-wise comparison of Maryland LCFs with LCFs of nine case studies showed statistically significant differences among states, providing grounds for jurisdiction-specific LCF development.

Authors	Craig Lyon, Persaud and Lyon Inc., Canada Bhagwant Persaud, Ryerson University, Canada David K. Merritt, Transtec Group, Inc.
Sponsoring Committee	AFD90
Session Number	443
Session Title	Pavement Surface Characteristics
Paper Number	15-5017
Paper Title	Large-Scale Safety Evaluation of Low-Cost Treatments That Improve Pavement Friction
Abstract	Roadway safety is a complicated issue to say the least, in part because of the challenge in predicting how drivers will respond to road conditions. While we cannot control human response to road conditions, we can control the properties of pavement surfaces to help reduce the probability of skid-related crashes. One factor that is fairly well understood in this regard is the link between pavement friction and safety, or more specifically, the probability of wet weather skidding crashes. What is not well understood are the comparative quantitative effects on safety for specific treatments that improve pavement friction. The large-scale study on which this paper is based aimed to provide this knowledge for a variety of low-cost treatments. This was a retrospective study for pavement safety performance, looking back at crash data before and after treatments were installed. Crash data were analyzed to evaluate the effectiveness of pavement renewal strategies using the state of the art empirical Bayes (EB) before-after study methodology. Both flexible and rigid pavement treatment were analyzed and crash modification factors (CMFs) were estimated for several target crash types. The majority of the low-cost treatments considered under this effort are typically used for pavement preservation or minor rehabilitation purposes. Although highway agencies recognize that these treatments generally improve pavement friction, they are not typically installed explicitly for safety improvement. The combined results for most treatment types suggested that the treatments nevertheless resulted in benefits for wet road crashes, with a few exceptions.

Authors	Adrian C. Lorion, BA Consulting Group Ltd. Canada Bhagwant Persaud, Ryerson University, Canada
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-5028
Paper Title	Investigation of Surrogate Measures for Safety Assessment of Urban Two-Way Stop-Controlled Intersections
Abstract	Crash prediction models used to estimate safety of highway segments and intersections are traditionally developed using various traffic volume measures. There are issues with this approach and surrogate safety measures such as conflicts and delays have been proposed to overcome them. This study investigates the relationships between crash frequencies and traffic volume, intersection delay, and simulated conflicts to explore and compare the viability of these models for estimating safety at urban two-way stop controlled intersections. The database used includes 78 three leg and 55 four leg intersections within the Greater Toronto Area. Crash prediction models were developed and evaluated based on various goodness-of-fit measures. With the developed models, an alternate approach to crash based evaluations of intersection improvements is presented. A case study is developed to investigate and demonstrate the use of the models for estimating the safety impact of implementing a left turn lane on a major approach of an urban three leg stop controlled intersection.

Authors	Pierre Michel Rondier, Institut National de la Recherche Scientifique, Canada Marie-Soleil Cloutier, Institut National de la Recherche Scientifique, Canada Nicolas Saunier, Polytechnique Montreal, Canada Juan Felix Soto-Rodriguez, Polytechnique Montreal, Canada Luis Fernando Miranda-Moreno, McGill University, Canada
Sponsoring Committee	ANB10
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5108
Paper Title	Exploring Road Safety Analysis and Stakeholder Engagement for Small and Medium-Sized Communities
Abstract	Identifying thematic issues and Accident Prone Locations (APLs) on rural local road network is challenging because of the length and scope of the network and the spatial and temporal variability of crashes. The objective of this paper is to explore the complementarity between road safety stakeholders' point of view and the identification of APLs through an Empirical Bayes (EB) method in a rural, less-dense area of Quebec, Canada. The first step of the method consists in EB analyses with a spatial database containing the accident data, the road network and several environmental attributes of the road sites. The second step is to recruit, interview and summarize the road safety perceptions of various stakeholders, both spatially and thematically. An application of this comparative method in a local and predominantly rural county of 23 municipalities in Quebec shed light on the usefulness of combining qualitative and quantitative data in the identification of possible APLs. The knowledge of the stakeholders gives an insight on the most important road safety issues, while the quantitative analyses tend to both confirm and nuance the APLs to be further investigated.

Authors	Yue Zhao, University of Nevada, Reno Zong Z. Tian, University of Nevada, Reno Chuck Reider, Nevada Department of Transportation
Sponsoring Committee	ANB10
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5690
Paper Title	Screening Urban Road Networks for Corridors with Promise
Abstract	Both federal and state policy makers increasingly emphasize the need to reduce traffic fatalities and serious injuries. Finding improved methods to enhance roadway safety has become a top priority. In an attempt to reduce the number of crashes and the resulting injuries and fatalities, high crash locations should be identified for increased law enforcement activities, education programs, and engineering improvements. Prioritizing high crash locations for potential improvements would benefit local agencies with limited budgets. The role of corridor level screening is to examine periodically the entire urban roadway network in order to generate a list of corridors ranked in order of priority by which detailed engineering studies should be conducted. Ongoing debates in regards to corridor level network screening include what should constitute a corridor for the purpose of network screening, and how a local agency should perform a corridor screening. This study investigated several options to determine urban corridor limits and discussed the merits and weaknesses of different options. A Corridor Safety Index (CSI) is proposed as a performance measure for corridor screening. The index can be used to screen sites that have promise as locations where improvements will result in substantial crash reduction. The findings will assist engineers to proactively identify and analyze high crash locations from a corridor perspective and detect potential problematic locations not identified through the traditional hotspot analysis.

Authors	Li-Hong Chiu, Univerisity of Wisconsin - Madison Zhixia Li, University of Wisconsin, Madison Andrea R. Bill, University of Wisconsin, Madison David A. Noyce, University of Wisconsin, Madison
Sponsoring Committee	ANB75
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-5703
Paper Title	Roundabout Safety Performance Functions of Wisconsin and Comparison with National Models
Abstract	The number of roundabouts has increased rapidly during the past several years. There is a strong need to develop an assessment model based on the local condition to evaluate the safety performance of Wisconsin roundabouts. Safety performance functions (SPFs) model the crash frequency and determine the critical contributing factors to crashes. With SPFs, limited funds for safety improvements can be allocated appropriately to potential problem areas, which can maximize safety benefits. Existing SPFs for roundabouts were developed using crash data collected at other states in 2007. With the increasing driver¡¦s familiarity of driving through roundabouts during the past few years, the crash pattern and frequency may change accordingly. Therefore, there is a need to develop updated SPFs based on the most recent crash data. In this context, the paper develops two safety performance functions for roundabouts. The first SPF is of intersection -level, which models the intersection crash frequency, with consideration of geometric features of entire roundabout. The second SPF is of approach-level, which models the crash frequency of a roundabout entrance with consideration of entering AADT, circulating AADT, and various geometric features pertaining to the roundabout approach. Results show that for the intersection-level SPF has only one significant contributing factor, which is AADT. Comparison with the SPF developed by NCHRP report 572 shows that Wisconsin SPF for intersection-level predicts less crash frequency than the national SPF. The less crash frequency can be attributed to the increased familiarity of driving through roundabouts . On the other hand, the approach-level SPF is contributed by entering and circulating AADTs as well as flaring length. Crash frequency decreases as flare length increases. This is a new finding which has not been captured in the NCHRP Report 572. Further comparison with the national model indicates that as flare length increases, better safety performance can be achieved as compared to the national model. Although these results provide direction for future roundabout design, more conclusive studies should be conducted that utilizes a larger sample size in developing the SPF.

Authors	Raul E. Avelar, Texas A&M Transportation Institute Karen K. Dixon, Texas A&M Transportation Institute Patricia Escobar, Texas A&M Transportation Institute
Sponsoring Committee	ANB20
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-5726
Paper Title	Evaluation of Intersection-Related Crash Screening Methods Based on Distance from Intersection
Abstract	This paper uses a probability sample of signalized intersections located in the State of Oregon to review various strategies of assigning crashes to intersections. Most of the strategies are based on the distance between the intersection and the crashes geo-location. The researchers collected detailed data from 73 intersections using state databases and satellite imagery. 1535 crashes were identified for years 2010 to 2012 in the vicinity of those intersections. The researchers then classified the identified crashes as either intersection related or not intersection related, based on geo-location, crash database related fields, and geometric information about the intersections. Ultimately, the authors identified 1130 intersection-related crashes from the larger corridor crash population. Using the pool of classified crashes, the authors fitted regression models to study the relationship between the distance (D) of a crash to an intersection, and the probability of that crash being associated with that intersection. For this task, the research team used only 55 intersections, leaving the remaining 18 for performance evaluation of different classification methods. The developed models identified D as a significant predictor that a crash is associated to an intersection. The evaluation also included additional candidate predictors, such as speed limit and the extent of the Intersection Functional Areas (IFA) of the study sites. During the validation phase, however, the authors determined that the models including predictions other than D provided comparable results to the model using D alone. The validation analysis also compared methods currently used in safety modeling to the performance of these models. That analysis found that the popular method of selecting crashes that are within a radius of 250 ft is appropriate if the selection is for studying the safety effects of treatments, such as the development of Crash Modification Functions (CMFs). However, this analysis found that utilizing a threshold of 250 ft would result in underprediction of intersections crashes, if the intent is to develop frequency prediction models, such as Safety Performance Functions (SPFs). Instead, the researchers found that a threshold of 300 ft potentially minimizes the risk of underestimating crash frequency, given that the frequencies of type-I and type-II errors are roughly equal at this threshold.

Authors	Karen K. Dixon, Texas A&M Transportation Institute Raul E. Avelar, Texas A&M Transportation Institute
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-5873**
Paper Title	Validation Technique Applied To Oregon Safety Performance Function Arterial Segment Models
Abstract	Recently the Oregon Department of Transportation (ODOT) developed segment arterial safety performance functions (SPFs) to help quantify the safety performance of driveways located on state urban and rural arterial highways. For this previous effort, the research team determined that the crash reporting that indicated a driveway may have been involved in the crash was not a dependable variable, so they developed SPFs for all non-intersection-related arterial crashes (of which many were likely due to vehicle interactions at driveway locations). The information included in this paper reviews the subsequent validation effort and highlights innovative techniques used for the analysis. A common validation approach is assessing model performance for spatial transferability. For this effort, however, the authors evaluated spatial transferability, spatial-temporal transferability, and individual coefficient stability and significance. These procedures are highlighted in this paper and applied to an example urban model. The urban model performed well with the spatial transferability resulting in statistically equivalent values, the spatial-temporal transferability provided similar values but was not statistically equivalent at the 95 percent level, and all but one of the model variables were determined to be statistically significant.

Authors	Michael Scott Shea, University of Utah Thanh Q. Le, University of Utah Richard Jon Porter, University of Utah
Sponsoring Committee	AFB10
Session Number	766
Session Title	Safety and Speed Effects of Geometric Design Decisions
Paper Number	15-5881**
Paper Title	A Combined Crash Frequency – Crash Severity Evaluation of Geometric Design Decisions: Entrance-Exit Ramp Spacing and Auxiliary Lane Presence
Abstract	This paper quantifies the effects of freeway ramp spacing and auxiliary lane presence on crash frequency and crash severity. Crash frequencies are predicted using a safety performance function and crash severities are estimated using a "severity distribution function." The paper then demonstrates how to combine quantitative knowledge related to the effects of ramp spacing and auxiliary lane presence on both crash frequency and severity into a framework for assessing the overall crash cost for different ramp configurations. Geometric features, traffic characteristics, and crash data were collected for 404 freeway segments in California and Washington State. Negative binomial regression models and multinomial logit regression models are used to estimate the effects of ramp spacing and auxiliary lane presence on expected crash frequencies and crash severities, respectively. Results show that expected multi-vehicle crash frequency increases when ramp spacing decreases. Meanwhile, there is a decrease in the proportion of severe crashes (fatal, incapacitating injury) with a decrease in ramp spacing, even though the overall frequency of these severe crashes remains relatively unchanged. Providing an auxiliary lane is expected to decrease crash frequency, although this reduction appears to be primarily in less severe crashes (possible injury and property damage only). The findings appear to effectively capture the complex relationships between geometric design designs and operations and the high sensitivity between speed and crash severity. The paper provides quantitative tools for making informed freeway and interchange design decisions where ramp spacing is a consideration.

Authors	Alex Riemondy, Florida State University
Sponsoring Committee	ABG00 and AFB00
Session Number	642
Session Title	Dwight David Eisenhower Transportation Fellowship Program, Part 1 (Part 2, Session 712)
Paper Number	15-6141
Paper Title	Estimating Bicycle Crash Risk at Intersections in Tallahassee, Florida
Abstract	According to a traffic safety study published by the National Highway Traffic Safety Administration, bicycle fatalities accounted for 726 traffic fatalities in 2012. As the number of trips taken by bicycle continue to grow, it is important to understand the characteristics of the built environment that contribute to increased crash risks. Intersections are a major point of conflict between bicycles and motor vehicles, and contribute to a high proportion of bicycle crashes. In 2012, 37 percent of bicyclist fatalities occurred at intersections (Insurance Institute for Highway Safety, 2012). Without a greater understanding of the characteristics that make intersections dangerous for bicyclists, it is difficult to predict the effectiveness of specific intersection design improvements. This study seeks to better understand the relationship between intersection design characteristics and bicycle crash risk. Five-year accident histories from approximately 100 intersections in Tallahassee, Florida will be used in a multivariate regression analysis to determine statistically significant factors of intersection characteristics (such as the number of approach lanes, lane width, and intersection type) that contribute to increased risks for bicyclists. Although this study is still in the preliminary stages, the goal of the research findings is to serve as a tool for planners to prioritize intersection improvements based on exposure risk to bicyclists, and promote safer design standards in the context of their city.

Authors	Juan C. Medina, University of Illinois, Urbana-Champaign Rahim F. Benekohal, University of Illinois, Urbana-Champaign
Sponsoring Committee	AHB60
Session Number	506
Session Title	Highway/Rail Grade Crossing Research
Paper Number	15-5109
Paper Title	Macroscopic Models For Accident Prediction at Railroad Grade Crossings and Comparisons with the U.S. D.O.T. Accident Prediction Formula
Abstract	Accident prediction and ranking of high accident locations at railroad grade crossings is often performed using the U.S. DOT accident prediction formula, as described in the Railroad-Highway Grade Crossing Handbook from the Federal Highway Administration. However, the current version of the model was developed in the 1980s, and all model coefficients remain unchanged except for a normalizing constant that the Federal Railroad Administration (FRA) updates every few years to reflect recent nationwide accident trends. This paper presents accident prediction models for the same warning device categories defined in the U.S. DOT model, but using a zero inflated negative binomial form. The accuracy of the two models is compared using 10 years of data from the State of Illinois. Five years of data are used to create the model and estimate predictions, and the following five years are used to evaluate the predictions. The prediction accuracy is measured in terms of the cumulative accident frequency of the crossings represented in the model, and also in the accuracy for ranking high accident locations. Results highlight advantages of a model built with recent data to predict the overall accident trends and the absolute accident frequencies, as well as the benefits the U.S. DOT prediction formula still may provide for ranking high accident locations.

Authors	Salvatore Cafiso, University of Catania, Italy Carmelo D'Agostino, University of Catania, Italy
Sponsoring Committee	ANB10
Session Number	
Session Title	
Paper Number	15-2226
Paper Title	Reliability-based assessment of Benefits in roadway safety management
Abstract	Road Agencies set quantitative targets and adopt related road safety strategies within the priorities and the available resources funds at a time of economic crisis. In this framework, benefit-cost analyses (BCA) are carried out to support the decision making process and alternative measures are ranked according to their expected benefit and benefit-cost ratio calculated using a Safety Performance Function (SPF) and Crash Modification Factors (CMFs) as predictor of future safety performances. Due to the variance of CMFs and crash frequency we are uncertain what the benefits of some future actions will be. The chance of making a wrong decision depends on the size of the standard deviation of the probability distribution of CMFs and SPF, as well. To deal with the uncertainty inherent in the decision making process, a reliability based assessment of Benefits must be performed introducing a stochastic approach. In the paper the variance of the CMFs and SPFs are taken into account in a reliability based BCA to address improvements and issues of an accurate probabilistic approach when compared to the deterministic results or other approximated procedures. A case study is presented comparing different safety countermeasures selected to reduce crash frequency and severity on sharp curves in motorway. These measures include retrofitting of old safety barrier, delineation systems, shoulder rumble strips and their combinations. The methodology was applied using Monte Carlo simulations to calculate the probability of failure of BCA statements. Results and comparisons with alternative approaches, like that proposed in the HSM, are presented showing remarkable differences in the evaluation outcomes that can be achieved.

5 Crash Severity Prediction

Alfonso Montella, University of Naples Federico II

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

The subcommittee identified twenty-nine papers dealing with crash severity prediction. These papers are scattered across various sessions, with most papers presented at the poster sessions 540 Crash-Based Safety Analysis and Modeling (Tuesday, 8:30AM – 10:15AM) and 848 Pedestrian Safety and Operational Performance Measurement (Wednesday, 2:45PM – 4:30PM).

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

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

- Binomial logit model (Hassan et al., 15-3625; Ozturk et al., 15-4130, Yang et al., 15-0101);
- Multinomial logit model (Harvey and Aultman-Hall, 15-2942; Montella et al., 15-0123);
- Nested logit model (Poorfakhraei et al., 15-5352);
- Mixed logit model (Islam, 15-1300; Islam and Hernandez, 15-5439; Ma et al., 15-1709 ; Wu et al., 15-5476);
- Bayesian binomial logit model (Franke et al., 15-1833);
- Hierarchical Bayesian logit model (Chen et al., 15-5506); and
- Bivariate Probit model (Hassan et al., 15-3625).

The following ordered regression modeling approaches were used:

- Ordered logit model (Cunto and Ferreira, 15-4503);
- Generalized ordered logit model (Michalaki et al., 15-3885);
- Mixed ordered logit model (Quddus, 15-3874);
- Bayesian ordered logit model (Lee et al., 15-0434);
- Ordered probit model (Forbes and Habib, 15-5962; Hassan et al., 15-0572; Stakleff et al., 15-3356; Wang et al., 15-4253);
- Hierarchical ordered probit model (Forbes and Habib, 15-5962); and
- Random parameter spatial ordered probit model (Zou et al., 15-4249).

Other papers used different approaches, such as classification trees (Iragavarapu et al., 15-2916; Lee and Li, 15-3606), boosted regression trees (Lee and Li, 15-3606), latent class cluster analysis (Sasidharan et al., 15-3208), decision tables (Chen et al., 15-5491), naïve

Bayes hybrid classifier (Chen et al., 15-5491), multiple correspondence analysis (Das and Sun, 15-2535), random forests (Lee and Li, 15-3606), and structural equation modeling (Hassan et al., 15-0572). Metha et al. (15-5229) used a multivariate extension of the Conway-Maxwell Poisson Distribution. Wang et al. (15-4253) used a copula based model to jointly estimate injury severity and vehicle damage.

From an application point of view, the papers addressed:

- Environmental factors (Chen et al., 15-5491; Cunto and Ferreira, 15-4503; Das and Sun, 15-2535; Forbes and Habib, 15-5962; Iragavarapu et al., 15-2916; Islam, 15-1300; Montella et al., 15-0123; Michalaki et al., 15-3885; Poorfakhraei et al., 15-5352 ; Sasidharan et al., 15-3208 ; Wu et al., 15-5476; Yang et al., 15-0101);
- Highway characteristics (Chen et al., 15-5491; Cunto and Ferreira, 15-4503; Das and Sun, 15-2535; Forbes and Habib, 15-5962; Harvey and Aultman-Hall, 15-2942; Hassan et al., 15-0572; Islam and Hernandez, 15-5439; Lee et al., 15-0434; Ma et al., 15-1709; Montella et al., 15-0123; Quddus, 15-3874; Yang et al., 15-0101);
- Road users' characteristics (Cunto and Ferreira, 15-4503; Forbes and Habib, 15-5962; Franke et al., 15-1833 ; Islam, 15-1300; Islam and Hernandez, 15-5439; Hassan et al., 15-0572; Lee and Li, 15-3606; Montella et al., 15-0123; Michalaki et al., 15-3885; Poorfakhraei et al., 15-5352; Quddus, 15-3874);
- Roadside features (Montella et al., 15-0123);
- Traffic characteristics (Lee and Li, 15-3606; Michalaki et al., 15-3885; Sasidharan et al., 15-3208); and
- Vehicle characteristics (Hassan et al., 15-0572 ; Iragavarapu et al., 15-2916; Islam and Hernandez, 15-5439 ; Lee and Li, 15-3606; Montella et al., 15-0123; Michalaki et al., 15-3885; Poorfakhraei et al., 15-5352 ; Sasidharan et al., 15-3208; Wu et al., 15-5476; Yang et al., 15-0101).

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

- Cyclists (Islam, 15-1300)
- Motorcyclits (Cunto and Ferreira, 15-4503; Stakleff et al., 15-3356);
- Pedestrians (Das and Sun, 15-2535; Forbes and Habib, 15-5962; Iragavarapu et al., 15-2916; Islam, 15-1300; Poorfakhraei et al., 15-5352);

Furthermore, Ferreira et al. (15-4373) assessed the under-reporting and misclassification of the traffic injury severity reported by the police.

Authors	Hong Yang, New York University Kaan Mehmet Ali Ozbay, New York University Kun Xie, New York University
Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	790
Session Title	Truck and Bus Safety
Paper Number	15-0101
Paper Title	Impact of Truck-Auto Separation on Crash Severity
Abstract	Truck traffic has significant impact on traffic operations and safety. Especially, safety concerns due to truck traffic continue to draw increasing attention of transportation engineers and policy makers who are proposing a number of practical strategies such as lane restrictions and exclusive facilities. The key aspect of all these strategies lies in separating trucks from cars to create more homogeneous traffic conditions. Earlier research demonstrated merits of these strategies whereas very limited findings on their safety impacts have been reported so far. The objective of this study is to examine the impact of truck-auto separation on highway crash severity. Specifically, the safety impact of separation through dual-dual roadways, a system that simultaneously provide separated car-only lanes and mixed traffic flow lanes, is of great interest since this kind of system was barely studied in the past. In order to achieve this goal, a detailed crash data set from a major highway section with dual-dual roadways for several years was examined. Comparative analyses were conducted and a statistical model have been developed. The results of this study show that the deployment of the dual-dual roadways with car-only lanes has statistically significant impact on crash severity. The model results show higher risk of having injury crashes in dual-dual lanes (both inner and outer lanes) compared with regular mix traffic lanes. This finding suggests that other than considering crash frequency as a measure of safety, crash severity should also be considered to fully assess the performance of the truck-auto separation strategies similar to the one studied in this paper. However, other than the impact of the truck-auto separation, these findings can be (partially) changed due to other factors that are not accounted for by the model, such as the actual operational speed when crash occurred, trucks being loaded or empty, etc. In short, due to the unavailability of detailed data, current results need to be considered with great care and should be considered preliminary at best. More research with better and more detailed data is needed to be able to make any final conclusion and recommendation.

Authors	Alfonso Montella, University of Naples Federico II, Italy Lella Liana Imbriani, University of Naples Federico II, Italy Filomena Mauriello, University of Naples Federico II, Italy Mariano Pernetti, Second University of Naples, Italy
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0123
Paper Title	Factors Contributing to Run-Off-the-Road Severe Crashes
Abstract	In the paper, results from in-depth investigation of 2,750 run-off-the-road (ROR) crashes on the motorway A16 (Italy) are presented. The research is aimed at pointing out risk factors that can address highway agencies and designers towards the selection of safety countermeasures aimed at reducing ROR crashes severity. Crash data were collected through the analysis of police crash reports and relate to the period 2001-2011. Crash severity was assessed in three categories (property damage only, slight injury, and severe injury/fatal) basing on police and hospital reports. Effects on crash severity were estimated through a multinomial logit model. The investigated factors included crash dynamics, number of crash events, day type, weather conditions, lighting conditions, cross-section characteristics, alignment, pavement conditions, most harmful impacted object, point of first impact, safety barrier performance, involved vehicles, driver's gender, driver's age, driver's behavior, presence of passengers, passenger gender, passenger age, and seat belt use. Factors significantly contributing to an increase of crash severity were crash dynamics, alignment, most harmful impacted object, point of first impact, safety barrier performance, driver's gender, driver's behavior, and seat belt use.

Authors	Jaeyoung Lee, University of Central Florida BooHyun Nam, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	AFD90, Investigation of Effect of Pavement Conditions on Crash Injury Severity
Session Number	443
Session Title	Pavement Surface Characteristics
Paper Number	15-0434
Paper Title	Investigation of Effect of Pavement Conditions on Crash Injury Severity
Abstract	Improving road safety through proper pavement maintenance is one of the goals of pavement management. Many studies have found that pavement conditions significantly influence traffic safety. Although several studies have explored the relationship between pavement conditions and crash occurrence, the effect of poor pavement conditions on crash severity levels has not been investigated, especially by using a discrete model that can handle ordered data. This paper focuses on the development of the relationship between poor pavement conditions and crash severity levels using a series of Bayesian ordered logistic models for low/medium/high speed roads and single/multiple collision cases. The Bayesian ordered logistic regression models indicated that the poor pavement condition decreases the severity of single-vehicle collisions on low-speed roads whereas it increases their severity on high-speed roads. On the other hand, the poor pavement condition increases the severity of multiple-vehicle crashes on all roads. Findings of this study can assist transportation agencies at the Federal, State, and local levels to select appropriate pavement maintenance and rehabilitation strategies to reduce traffic crash severity levels.

Authors	Hany M. Hassan, Ain Shams University, Egypt Nuha M. Albusaeedi, Abu Dhabi Traffic Police, United Arab Emirates Atef M. Garib, Abu Dhabi Traffic Police, United Arab Emirates Hussain Al-Harthei, Abu Dhabi Traffic Police, United Arab Emirates
Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	790
Session Title	Truck and Bus Safety
Paper Number	15-0572
Paper Title	Exploring the Nature and Severity of Heavy-Truck Crashes in Abu Dhabi, United Arab Emirates
Abstract	Traffic crashes involving large or heavy trucks have long been a major concern in the field of traffic safety due to their great impact on accidents' severity in terms of increasing the numbers of vehicles, injuries, and fatalities involving in these types of crashes. The Emirate of Abu Dhabi (the capital of United Arab Emirates) has a unique situation as it has several roads that were designed mainly for trucks movement. Although, those roads have been constructed about ten years ago to decrease the severity of trucks related crashes, no prior studies have examined their effects on improving traffic safety. Therefore, this study aims to provide a better understanding regarding the nature, characteristics and causes of heavy trucks crashes occurring in Abu Dhabi. Also, it aims to identify the factors associated with the severity of those crashes and to examine the probability of having fatal trucks crashes on trucks roads compared to other mixed roads. To achieve these goals, data from a sample of 1426 reported fatal and injury heavy trucks related-crashes that occurred in Abu Dhabi during the period 2007-2013 were analyzed. First, conditional distributions, two-way analysis and odds ratio were conducted. Second, ordered probit model and structural equation modeling were developed. The results indicated that the likelihood of having fatal crash on trucks roads is 35% higher than mixed roads. In addition, the findings showed that human errors, drivers' education, location, road type and road speed were the significant variables affecting the severity of heavy trucks related crashes. Finally, practical suggestions on how to reduce the number of heavy trucks related crashes in Abu Dhabi were presented and discussed.

Author	Samantha Islam, University of South Alabama
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	751
Session Title	Exploring Safety and Risk of Nonmotorized Vehicles
Paper Number	15-1300
Paper Title	Comparative Analysis of Injury Severity Resulting from Pedestrian- and Bicycle-Motor Vehicle Crashes on Roadways in Alabama
Abstract	This paper provides a comparison between the influence of a variety of variables on the injury severities resulting from pedestrian-motor vehicle and bicycle-motor vehicle accidents in Alabama incorporating the effects of randomness across the observations. Given the occurrence of a crash, random parameter logit models of injury severity (with possible outcomes of fatal, major, minor, and possible or no injury) were estimated. The estimated models identified a variety of statistically significant factors influencing the pedestrian and bicyclist injury severities. According to these models, some variables were found to be significant only in one model (pedestrian or bicycle) but not in the other one. For example, variables such as roadway crossing, accidents on Saturdays and accidents on private roadways were found significant only in the pedestrian model. On the other hand, variables such as the use of retro-reflective clothing, accidents during evening rush hour and accidents in summer were found significant only in the bicyclist model. In addition, some variables (such as, old pedestrians/bicyclists, dark roadway, low speed roadway, etc.) were found significant in both models. Also, estimation findings showed that three parameters (between 12 A.M. and 7 A.M, clear weather, and at intersections) in the pedestrian model and two parameters (level grade on tangent and clear weather) in the bicycle model could be modeled as random parameters indicating their varying influences on the injury severity. Based on the results obtained, this paper discusses the effects of different variables on pedestrian and bicyclist injury severities and their possible explanations.

Authors	Xiaoxiang Ma, Colorado State University Feng Chen, Tongji University, China Suren Chen, Colorado State University
Sponsoring Committee	ANB20, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-1709
Paper Title	Empirical Analysis of Driver-Injury Severity on Mountainous and Non-Mountainous Interstate Highways: A Comparative Study
Abstract	Mountainous highways usually exhibit complex geometry features such as steep gradients or sharp curves, which can cause considerably different driver behavior and vehicle performance as compared to non-mountainous highways. In addition, mountainous highways are more vulnerable to adverse weather conditions. Therefore, a uniform traffic safety performance function for both mountainous and non-mountainous highways across the same region may not be sufficient. One major interstate highway with typical mountainous (MT) characteristics and another one with non-mountainous (NM) characteristics in Colorado have been selected for this study. A comparative investigation about the impact on injury severity from mountainous and non-mountainous highways is conducted. Separate mixed logit models are estimated for both highways with four-year detailed crash data. Some new findings about injury severity are made possible for the first time. Incorporating two major interstate highways from the same region into the comparative study offers some unique strength on investigating the impacts. As a result, the study provides better insights about contributing factors and associated mechanism for injury severity on mountainous highways. Substantial differences in the magnitude and direction of the influence of contributing factors between MT and NM models are observed. Differences in a comprehensive set of contributing factors of injury severity such as roadway characteristics, temporal and environmental characteristics, driver characteristics, accident characteristics, and vehicle characteristics are summarized. The findings in this study provide scientific guidance to potentially improve the current highway design and traffic management policy on thousands of miles of mountainous highways.

Authors	Rebecca Franke, Montana Department of Transportation Debbie Sue Shinstine, University of Wyoming Mohamed M. Ahmed, University of Wyoming Khaled Ksaibati, University of Wyoming
Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	790
Session Title	Truck and Bus Safety
Paper Number	15-1833
Paper Title	Effects of Truck Traffic on Crash Injury Severity on Rural Highways in Wyoming Using Bayesian Binary Logit Models
Abstract	Roadway crashes involving large trucks tend to have greater ramifications than most other vehicle crashes. A major use of the highway system is the transport of goods. The United States has experienced constant growth in the amount of freight transported by truck in the last few years. The state of Wyoming is experiencing a large increase in truck traffic on some of its local and county roads due to an increase in oil and gas production. This study addresses the effect that large truck traffic is having on the safety of various road classifications. Many studies have been done on the factors involved in and the causation of heavy truck crashes, but few address the causation and effect the truck crashes have on different roadway classifications. Answers to this question may give transportation engineers guidelines on how to address truck safety as it relates to the different classifications. A descriptive analysis of statewide crash data in Wyoming was performed to identify trends in truck crashes. Binary Logit Models (BLM) with Bayesian inferences were utilized to classify heavy truck involvement in severe and non-severe crashes using ten years (2002-2011) of historical crash data in the State of Wyoming. The results from the study indicated that truck crashes had fifty percent more fatalities than non-truck crashes. Truck involved crashes occurred more often when there was ice or frost on the roadway. Safety belt use was higher and alcohol and drug use was lower than that of drivers of other vehicles. Providing advanced warning systems such as installing monitors at truck stops, restaurants and gas stations can provide real time visual information on the existing weather and road conditions. The trucking industry has done well to train their drivers on the dangers of drug and alcohol use and the importance of seatbelt use. They could expand their training targeting the risks of driving during severe weather conditions. Improved roadway safety can be realized and fatal crashes involving trucks can be reduced.

Authors	Subasish Das, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ANF10, Pedestrians
Session Number	848
Session Title	Pedestrian Safety and Operational Performance Measurement
Paper Number	15-2535
Paper Title	Factor Association Using Multiple Correspondence Analysis in Vehicle-Pedestrian Crashes
Abstract	In the U.S., around 14% of the total traffic crash fatalities are pedestrian related. In 2011, 4,432 pedestrians were killed and 69,000 pedestrians were injured in vehicle-pedestrian crashes in the U.S. Vehicle-pedestrian crashes have become a key concern in Louisiana due to the high percentage of fatalities in recent years. In 2012, pedestrians were accounted for 17% of the total fatalities due to traffic crashes in the state. This research uses Multiple Correspondence Analysis (MCA), an exploratory data analysis method used for detecting and representing underlying structures in a categorical data set, to analyze eight years (2004-2011) of vehicle-pedestrian crashes in Louisiana. As pedestrian crash data is best represented as transactions of multiple categorical variables, MCA would be a unique choice to determine the relationship of the variables and their significance. The findings indicated several non-trivial focus groups such as drivers with high occupancy vehicles, female drivers in bad weather conditions, and drivers distracted by mobile phone use. Other key associated factors were hillcrest roadways, dip/hump aligned roadways, roadways with multiple lanes, and roadways with no lighting at night. Male drivers were seen to be more inclined towards severe and moderate injury crashes. Fatal pedestrian crashes were correlated to two-lane roadways with no lighting at night. This method helped to measure significant contributing factors and degrees of association between the factors by analyzing the systematic patterns of variations with categorical datasets of pedestrian crashes. The findings from this study will be helpful for the transportation professionals to improve the strategy of countermeasure selection.

Authors	Vichika Iragavarapu, Texas A&M Transportation Institute Dominique Lord, Texas A&M University Kay Fitzpatrick, Texas A&M Transportation Institute
Sponsoring Committee	ANF10, Pedestrians
Session Number	848
Session Title	Pedestrian Safety and Operational Performance Measurement
Paper Number	15-2926
Paper Title	Analysis of Injury Severity in Pedestrian Crashes Using Classification Regression Trees
Abstract	Texas is considered to be an "opportunity" state by the Federal Highway Administration (FHWA), due to the high number of pedestrian crashes. Data from the Fatality Analysis Reporting System (FARS) show that the number of pedestrian fatal crashes in Texas is the third highest in the U.S and is significantly higher than the national average. The research team explored the Texas Department of Transportation (TxDOT) Crash Record Information System (CRIS) database to identify characteristics of crashes involving pedestrians in Texas. A Classification and Regression Tree (CRT) analysis of all pedestrian crashes was conducted to find the significant factors influencing the severity of crashes involving pedestrians in Texas. The classification tree identified that light condition, road class, traffic control, right shoulder width, involvement of a commercial vehicle, pedestrian age, and the collision manner, have the most influence on the severity of pedestrian crashes.

Authors	Chester W. Harvey, University of Vermont Lisa Aultman-Hall, University of Vermont
Sponsoring Committees	ABE30, Transportation Issues in Major U.S. Cities ANB20, Safety Data, Analysis and Evaluation ANF10, Pedestrians
Session Number	476
Session Title	Livable Arterials: Urban Elixir or Oxymoron?
Paper Number	15-2942
Paper Title	Urban Streetscape Design and Crash Severity
Abstract	Streetscape design is increasingly acknowledged as a tool for improving traffic safety and livability in urban settings. While traditional highway safety engineering promotes widening and removing obstacles from roadside "clear zones" to reduce collision potential, a contrasting framework proposes that smaller, more enclosed streetscapes may incentivize slower, less risky driving and therefore improve both livability and safety outcomes. Such a strategy may have particular relevance along urban arterials, where large clear zones may be impractical due to complex adjacent land uses and promotion of livable spaces is an increasing focus. This study examined streetscape design and traffic safety in urban settings by assessing relationships between crash severity and streetscape design variables in New York City. A GIS-based method was used to precisely capture streetscape design measurements at the locations of more than 240,000 crashes. Logistic regression models indicated that crashes on smaller, more enclosed streetscapes were less likely to result in injury or death compared with those on larger, more open streetscapes. These results point to infill development and street tree planting as safety countermeasures that are consistent with additional livability goals such as walkability, high quality public realm design, and provision of natural amenities.

Authors	Lekshmi Sasidharan, Swiss Federal Institute of Technology, Zurich Kun-Feng Wu, National Chiao Tung University, Taiwan Monica Menendez, Swiss Federal Institute of Technology, Zurich
Sponsoring Committee	ANF10, Pedestrians
Session Number	848
Session Title	Pedestrian Safety and Operational Performance Measurement
Paper Number	15-3208
Paper Title	Exploring Application of Latent Class Cluster Analysis for Investigating Pedestrian Crash Injury Severity in Switzerland
Abstract	One of the major challenges in traffic safety analyses is the heterogeneous nature of safety data, due to the sundry factors involved in it. This heterogeneity often leads to difficulties in interpreting results and conclusions due to unrevealed relationships. Understanding the underlying relationship between injury severities and influential factors is critical for the selection of appropriate safety countermeasures. A method commonly employed to address systematic heterogeneity is to focus on any subgroup of data based on the research purpose. However, this need not ensure homogeneity in the data. In this paper, latent class cluster analysis is applied to identify homogenous subgroups for a specific crash type-pedestrian crash. The manuscript employs data form police reported pedestrian (2009-2012) crashes in Switzerland. The analyses demonstrate that dividing pedestrian severity data into seven clusters helps in reducing the systematic heterogeneity of the data and to understand the hidden relationships between crash severity levels and socio-demographic, environmental, vehicle, temporal, traffic factors, and main reason for the crash. The pedestrian crash injury severity models were developed for the whole data and individual clusters, and were compared using receiver operating characteristics curve, for which results favored clustering. Overall, the study suggests that latent class clustered regression approach is suitable for reducing heterogeneity and revealing important hidden relationships in traffic safety analyses.

Authors	Brandon A. Stakleff, University of Akron William A. Holik, University of Akron Alexander R. Maistros, University of Akron William Henry Schneider, University of Akron
Sponsoring Committee	ANF30, Motorcycles and Mopeds
Session Number	222
Session Title	Exploring Factors in Motorcycle Crashes, Injuries, and Fatalities
Paper Number	15-3356
Paper Title	Contributing Factors to Fatal Single Unit Motorcycle Crashes
Abstract	There are many hazards presented to motorcyclists on the roadway. This study probes into the contributing factors which have a significant impact on the fatalities in which the operator had used alcohol, been speeding, and crashed on a curved roadway. These factors are examined through an analysis, using a multivariate probit model, of single vehicle motorcycle fatalities from the Fatality Analysis Reporting System (FARS) for the years 2010 through 2012. The results indicate that fatal crashes in which high risk behaviors, such as not wearing a helmet or having a suspended license, occur are more likely to be alcohol related. Similarly, slightly less risky behaviors, such as having a harmful moving conviction or a previous crash, are more likely to be speed related. The correlation between the use of alcohol, speeding, and crashing on a curved roadway is positive indicating a link between the contributing factors within each of the models. This reveals a relationship of how motorcyclists who are speeding or impaired by alcohol have a reduced judgment in their ability to properly manage traveling through a curved roadway.

Authors	Chris Lee, University of Windsor, Canada Xuancheng Li, University of Windsor, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-3606
Paper Title	Predicting Driver's Severe Injury in Single-Vehicle and Two-Vehicle Crashes Using Boosted Regression Trees
Abstract	The boosted regression trees model (BRT) is an emerging non-parametric tree-based model which can capture nonlinear effects of both discrete and continuous variables without post-processing of data. The BRT is particularly advantageous in prediction of severe injuries which are more difficult to be classified due to a smaller number compared to non-severe injuries. However, the BRT has not been extensively applied to prediction of injury severity for both single- and two-vehicle crashes in the past. Thus, the objectives of this study are to investigate driver's injury severity using the BRT and other non-parametric models - the classification and regression tree (CART) and random forests - and evaluate the performance of the BRT based on the comparison with the CART. The study identified important factors affecting injury severity and their effects on severe injury using 5-year crash records for provincial highways in Ontario, Canada. The results of the BRT show that ejection from vehicles and head-on collisions commonly have strong association with driver's severe injury. The results also show that the marginal effects of continuous variables including truck percentage, AADT, driver's age and vehicle age on severe injury were nonlinear. In particular, their effects on heavy truck driver's injury had different patterns compared to passenger car and light truck drivers – the risk of heavy truck driver's severe injury increases as truck percentage and AADT increase and driver's age decreases. It was also found that the BRT predicted driver's injury severity more accurately than the CART for both single-vehicle and two-vehicle crashes. Thus, it is recommended that the BRT is applied using separate data sets for single-vehicle crashes and different types of two-vehicle crashes for more accurate prediction of crash injury severity.

Authors	Hany M. Hassan, Ain Shams University, Egypt Mohamed Shawky, Ain Shams University, Egypt Atef M. Garib, Abu Dhabi Traffic Police, United Arab Emirates Hussain Al-Harthei, Abu Dhabi Traffic Police, United Arab Emirates
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-3625
Paper Title	Examining Differences Between Contributing Factors Affecting Severity of Single- and Multivehicle Crashes
Abstract	During the last two decades, the factors affecting the severity of traffic crashes have been extensively examined in many prior studies. However, the studies that addressed the differences between the factors affecting the occurrence and severity of single-vehicle (SV) and multi-vehicle (MV) crashes are relatively low. In the Emirate of Abu Dhabi (AD), the capital of United Arab Emirates, about 41% of severe traffic crashes is SV crashes. In addition, AD has a unique composition of population and licensed drivers as about 87% of licensed drivers are non-Emiratis. Despite these facts and the uniqueness of licensed drivers' composition in AD, the factors affecting the occurrences and severity of SV and MV crashed in AD have not been explicitly addressed in any previous studies. Therefore, this paper aims to contribute to the literature by providing a better understanding regarding the differences between the contributing factors (i.e., driver, vehicle, road and environment factors) affecting the occurrences and severity of SV and MV crashes in AD. Also, it aims to examine the influence of crash type (single or multi-vehicle crash) on the crash severity in AD. The results indicated that males, young and low educated contribute in both SV and MV crashes more than females, old and high educated. However, several contributing factors (driver, vehicle, road and environment factors) that affect the severity of SV and MV crashes in AD are relatively different. Also, it was found that having MV crash increases the likelihood of fatal crash compared to SV crash. Practical suggestions on how to improve traffic safety of SV and MV crashes are also provided and discussed.

Authors	Mohammed A. Quddus, Loughborough University, United Kingdom
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-3874
Paper Title	Effects of geodemographic profiles of drivers on their injury severity from traffic crashes using a multilevel mixed-effects ordered logit model
Abstract	The purpose of this paper is to examine various geodemographic factors on driver injury severity using a statistical model. A driver's geodemographic profile with respect to traffic crash occurrence consists of variables from multiple hierarchical levels such as drivers who are nested within crashes and crashes that are clustered within areas. Geodemographic profiles of a driver therefore contain factors such as age, gender, residence of driver and its land-use characteristics, social deprivation, and the distance from home to crash locations (at the driver-level); crash location in terms of land-use patterns, casualties per crash and vehicles involved in the crash (at the crash- level); and vehicles per 1,000 population, population density and roadway density (at the area-level). This implies that driver-level observations are correlated rather than independent as assumed in many injury severity modelling. In order to capture within-group and between-group correlations among observations a multilevel mixed-effects ordered logit model has been employed in this research. Mixed-effects allows some variables to vary by observations (i.e. random parameters). The analysis is based on UK national traffic crash data between 2009 to 2011 consisting of 271,654 drivers from 217,523 traffic crashes occurring across 27,773 different census areas. Data on area deprivation, Census, and land-use patterns were collected from multiple sources and integrated using a GIS framework. The results indicate that the severity of injuries sustained by urban drivers involved in crashes increases if they travel to rural areas; the level of driver injury severity also increases if traffic crashes occur in areas with high car ownership per capita; and drivers from more disadvantaged areas would sustain, ceteris paribus, more severe injuries. The findings from this study would be useful to the Department for Transport and Local Authorities in formulating safety policies aimed at enhancing driver education, training and licensing programmes.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-3885
Paper Title	Exploring Factors Affecting Motorway Accident Severity Using Generalized Ordered Logistic Regression Model
Abstract	This paper examines the most important factors affecting the severity of motorway accidents, using data from the United Kingdom. The accidents are grouped into two categories according to the location on the motorway where the first impact happened: hard-shoulder (HS) and main carriageway (MC) accidents. The proposed model is the generalized ordered logistic regression and two separate models for the two groups of accidents are estimated. The factors examined include accident and vehicle characteristics, traffic and environment conditions, as well as other behavioral factors. Results suggest that the factors increasing the accident severity include the number of vehicles, peak traffic time and low visibility. Differences between HS and MC accidents are identified, with the most important being the involvement of HGVs and driver fatigue which are more crucial in increasing the severity of HS accidents.

Authors	Ozgur Ozturk, Izmir Institute of Technology Kaan Mehmet Ali Ozbay, New York University Hong Yang, New York University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-4130
Paper Title	Investigating the Impact of Work Zones on Crash Severity by Comparative Analysis
Abstract	Work zone safety has received much attention in recent years due to numerous highway construction projects that have resulted in many work zone crashes. To minimize the impact of work zones on roadway safety, the contributing potential factors that influence these risks need to be investigated. This can be done by identifying the possible causal factors in terms of crash severity and implementing countermeasures to ensure the motorist's safety. In this paper, the impacts of the work zone presence on crash severity were identified by using descriptive analysis and then statistical modeling methods. Statistically robust models were developed by incorporating enhanced datasets that could be used to identify significant factors affecting crash severity. A major contribution of this study is that severity modeling parameters for work zone crashes were compared to non-work zone crash severity parameters to better distinguish work zone specific parameters. Logistic regression technique was applied to examine the best model or set of variables to correlate crash severity and possible causative factors for binary level outcomes. Modeling results were interpreted for both work zone and non-work zone conditions individually based on odds-ratio values. Comparison of the significant factors for work zone and non-work zone crash severity models, key findings and recommendation were also provided. Agencies can use these models and recommendations to improve safety at work zone locations by developing relevant countermeasures.

Authors	Wei Zou, Rensselaer Polytechnic Institute Xiaokun (Cara) Wang, Rensselaer Polytechnic Institute Dapeng Zhang, Rensselaer Polytechnic Institute
Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	790
Session Title	Truck and Bus Safety
Paper Number	15-4249
Paper Title	Truck Accident Severity in New York City: Investigation of Spatiotemporal Effects and Vehicle Weight
Abstract	This paper uses a flexible econometric structure for truck injury severity analysis in New York City, accounting for both spatial dependency, time of day effect, and the heterogeneous effect of truck weight. The results show that heterogeneity does exist in the truck weight, but crash severity for individual crashes are spatially isolated events. The time of day effect, after other environmental factors are controlled, is also insignificant.

Authors	Kai Wang, University of Connecticut Shamsunnahar Yasmin, McGill University, Canada Karthik Charan Konduri, University of Connecticut Naveen Eluru, University of Central Florida John N. Ivan, University of Connecticut
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-4253
Paper Title	A Copula Based Joint Model of Injury Severity and Vehicle Damage in Two-Vehicle Crashes
Abstract	In the transportation safety arena, in an effort to improve safety, statistical models are developed to identify different factors that contribute to crashes, as well as various factors that affect injury severity in the unfortunate event of a crash. Our study contributes to the literature on severity analysis. Injury severity and vehicle damage are two important indicators of assessing severity in crashes. Typically injury severity and vehicle damage indicators are modeled independently. However, there are common observed and unobserved factors affecting the two crash indicators leading to potential interrelationships between them. Failing to account for the interrelationships of the indicators may lead to biased coefficient estimates in crash severity prediction models. The focus of this study is to explore the interrelationships between the crash severity indicators: injury severity and vehicle damage, and also identify the nature of these correlations across different types of crashes. A copula based methodology that can simultaneously model injury severity and vehicle damage while also accounting for the interrelationships between the two indicators was employed in this study. Furthermore, parameterization of the copula structure was used to represent the interrelationships between the crash indicators as a function of the crash characteristics. In this study, six different specifications of the copula model including Gaussian, Farlie-Gumbel-Morgenstern (FGM), Frank, Clayton, Joe and Gumbel were developed. Based on goodness-of-fit statistics, the Gaussian copula model was found to outperform the other copula based model specifications. The results indicate that the interrelationships between injury severity and vehicle damage varied with different crash characteristics including manners of collision and collision types.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4373
Paper Title	Quality of Injury Severity Classification by Police: Important Step for Reliable Assessment
Abstract	This study aims to assess the under-reporting and misclassification of the traffic injury severity reported by the police for the first time in Portugal. The non-fatality traffic injuries classified by the police are compared with the information recorded by the hospitals using linked data. The underreporting in the police data was found to be of 29%. Therefore, a significant number of road traffic casualties admitted in the hospitals were not known by the police. Taking advantage of the linked information on accident injuries, the misclassification in the police reports is assessed considering two criteria: the length of hospital stay (LS) and the maximum abbreviated injury scale (MAIS). The latter criterion corresponds to the common definition recently established by the European Commission, which has the advantage of representing the medical conditions of the casualty. The comparison between police classification and LS indicates that a discrepancy between the police reports and the established police definition exists maybe because no systematic communication between the police and the hospitals is established. Notably, the police classification shows inferior levels of misclassification regarding the MAIS when compared to the LS, with a tendency to overclassified the injury severity. A remarkable proportion of severe injuries reported by the police are, in fact, slight injuries. Additionally, using univariate and multivariate analyses, factors contributing to the misclassification of casualties by the police are identified. Finally, similarly to the fatality adjustment coefficient used in Portugal and in other European countries in the past, non-fatality adjustment coefficients were computed to estimate the total casualties taking into account the under-reporting and misclassification phenomena.

Authors	Flavio Jose Craveiro Cunto, Universidade Federal do Ceará, Brazil Sara Pinho Ferreira, University of Porto, Portugal
Sponsoring Committee	ANF30, Motorcycles and Mopeds
Session Number	478
Session Title	Modelling Traffic Flow for Motorcycles and Mopeds
Paper Number	15-4503
Paper Title	Motorcycle Crash Injury Severity In Brazil: An Analysis Using Mixed Ordered Response Models
Abstract	Brazilian traffic environment has experienced a disproportionate growth in motorcycle use over the last 15 years. Unfortunately the same trend has been observed for crash frequency and severity in the category in part by their relative exposure as well as vulnerability. This study investigates factors that influence the severity of motorcycle accidents in urban streets of Fortaleza. Traditional and mixed orderd logit models were calibrated using a sample of 3,232 observations of traffic accidents from 2004 to 2011. Physical levels of injury inflicted to motorcyclists were grouped as "no apparent injury" (17.3%), "slight injury" (68.2%), "serious injury" (13.1%) and "fatal injury" (1.4%). The models were developed using variables related to helmet usage, time of the day, day of the week, road surface conditions at the time of the crash, type of motorcycle usage, age and gender of drivers. Results suggested that motorcyclists using helmets reduced by 9% their chances of suffering severe and fatal injuries after the crash. Accidents during the daylight as well as on weekdays presented lower risk of resulting in fatal injuries than during night time and weekends and crashes involving motorcyclists above 61 years old have 22% more probability of resulting in severe and fatal injuries as compared to young riders (18 to 40 years old). Most of these findings can be associated w commonly reported risky behavior from motorcyclists which includes speeding, DUI, improper lane changes, red light running and unsafe longitudinal and transversal headway.

Authors	Sungyop Kim, University of Missouri, Kansas City Cheol Oh, Hanyang University, South Korea
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5297
Paper Title	Analysis of Freeway Crashes Involving Drowsy Driving: Prevalence, Characteristics, and Crash Severity in Korea
Abstract	Drowsy driving is a major cause of freeway crashes. From 2006-2012, 22.5 percent of all crashes and 33.3 percent of fatal crashes in Korea were attributed to drowsy driving. This study examines driver and vehicle characteristics, road geometry, and spatial and temporal factors associated with drowsy-driving crashes. More male drivers were involved in the crashes. However, unlike in the U.S. and other Western countries, the majority of drowsy-driving crashes were caused by drivers in their 30s, 40s, and 50s. The multinomial logit model results showed that older drivers aged 60+, male drivers, and vans are more likely to be involved in fatal crashes involving drowsy driving. Also, the fatal crashes were more likely to occur during nighttime and late summer in work zones and on freeway segments with concrete barriers and no shoulder. Areas of future research and recommendations to reduce the prevalence of drowsy driving are discussed.

Authors	Gaurav Mehta, University of Alabama Yingyan Lou, Arizona State University Steven Lee Jones, University of Alabama
Sponsoring Committee	ANB20, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-5229
Paper Title	A Bayesian Analysis of Crash Severities with Multivariate Conway-Maxwell Poisson Distribution
Abstract	Numerous efforts have been devoted to understand the relationship between crash severities and roadways using different statistical techniques. Most efforts have resulted in univariate count models for individual crash severity, with a few exceptions of Multivariate Poisson Lognormal model, Ordered Probit and Logit choice models. Although, such models have been proved to perform well with over-dispersed datasets, they are not as effective for under-dispersed datasets. This paper offers a multivariate extension of the Conway-Maxwell Poisson Distribution, a very flexible distribution that has been shown to perform well with both over- and under-dispersion. The multivariate extension accounts for correlation among different crash severities that can exist because of missing variables or unobserved information. The parameters of this model are estimated using Bayesian paradigm as conventional techniques can be inefficient. A component-wise Monte Carlo Markov Chain (MCMC) simulation with Gibbs and Metropolis Hastings samplers is developed and coded in Matlab to estimate the parameters. The algorithm is validated using a simulated data set. The convergence of the MCMC simulation is verified using trace plots and running mean plots. An application of the proposed model on a real-world dataset is provided to demonstrate the use of the model along with its interpretation.

Authors	Amir Poorfakhraei, University of New Mexico Amir Samimi, Sharif University of Technology, Iran Alireza Ermagun, University of Minnesota, Twin Cities
Sponsoring Committee	ANF10, Pedestrians
Session Number	848
Session Title	Pedestrian Safety and Operational Performance Measurement
Paper Number	15-5352
Paper Title	Effect of Model Specification on Results of Pedestrian Injury Analysis
Abstract	Analytical models have been widely used in the field of pedestrian safety analysis. They are usually developed to measure the effectiveness of different safety improvement strategies and play a pivotal role in policy making process. Inappropriate model specifications affect the results of models, introducing inaccuracy, and bias in them. Since decisions and policies which are made based on inaccurate and biased results might lead to worsened safety issues, it is really important to correctly specify the models. In this study, several specifications of discrete-choice models are compared to find out the extent to which change in model specification can affect the results of pedestrian injury severity analysis in motor-vehicle crashes. Models are then evaluated based on their advantages and limitations to find the most appropriate specification. Police-reported crash data between 2008 and 2011 from the State of North Carolina are used to develop various models. Estimates of applied models suggest several factors including pedestrian age, alcohol consumption, speed violation, lightening, and vehicle type affect pedestrian injury severity in accidents. A comparison of models indicates that the magnitude of effect of exogenous variables on injury severity is significantly different across diverse models. The differences prove the significant effect of model specification on the results of analysis. Evaluation of models suggests that a three-level nested logit analytical framework is the most appropriate model among developed models to be used in pedestrian injury severity analysis.

Authors	Mouyid Islam, CH2M Hill, Inc. Salvador Hernandez, Oregon State University
Sponsoring Committee	ANB70, Truck and Bus Safety
Session Number	790
Session Title	Truck and Bus Safety
Paper Number	15-5439
Paper Title	Analysis of Injury Outcomes of Crashes Involving Large Trucks by Time of Day in Urban Areas in Texas
Abstract	Mixed logit models were used to analyze injury outcomes of crashes involving large trucks on urban interstate systems in Texas. Split subsets of the Texas crash database – Crash Records Information System were used in this discrete outcome random parameter modeling study to explore the relationship between three different time periods of a day and injury severity by accounting possible unobserved heterogeneity related to human, vehicle, road-environment in the database. Using separate models for each of the five injury levels of a traditional KABCO scale, this study estimated the likelihood of each injury level occurring during AM (6 to 9 AM), PM (4 to 7 PM), and off-peak periods and identified the factors contributing to the different severity levels. Estimated model results indicated that contributing factors are driver demographics, driving behavior, roadway geometrics, traffic characteristics, weather characteristics, temporal characteristics, and crash dynamics. This study highlights these factors that vary according to the time of day, as does injury outcome of crashes.

Authors	Qiong Wu, University of New Mexico Feng Chen, Tongji University, China Guohui Zhang, University of New Mexico Xiaoyue (Cathy) Liu, University of Utah Hua Wang, Harbin Institute of Technology, China Susan Bogus, University of New Mexico
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5476
Paper Title	Analysis of Driver Injury Severities in Single-Vehicle and Multivehicle Crashes on Rural Two-Lane Highway
Abstract	Crashes occurring on rural two-lane highways are more likely to result in severe driver incapacitating injuries and fatalities. In this study, mixed logit models are developed to analyze driver injury severities in Single-Vehicle (SV) and Multi-Vehicle (MV) crashes on rural two-lane highways in New Mexico from 2010 to 2011. A series of significant contributing factors are identified and their impacts on injury severities are quantified for these two types of crashes, respectively. Elasticity analyses and transferability tests were conducted to better understand the models' specification and generality. The research findings indicate that there are significant differences in causal attributes determining driver injury severities between SV and MV crashes. For example, more severe driver injuries and fatalities can be observed in MV crashes when motorcycles or trucks are involved. Dark lighting conditions and dusty weather conditions are found to significantly increase MV crash injury severities. However, SV crashes demonstrate different characteristics influencing driver injury severities. For example, the probability of having severe injury outcomes is higher when vans are identified in SV crashes. Drivers' overtaking actions will significantly increase SV crash injury severities. Although some common attributes are significant in both SV and MV crash severity models, their effects on different injury outcomes vary substantially. This study provides a better understanding of similarities and differences in contributing factors and their impacts on driver injury severities between SV and MV crashes on rural two-lane highways. It is also helpful to develop cost-effective solutions for rural SV and MV crashes.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5491
Paper Title	Prediction of Driver Injury Severity in Rear-End Crashes Decision Table and Naive Bayes Classification Approach
Abstract	Rear-end crash is a major type of traffic crashes in the U.S. inducing significant life and economic losses. A comprehensive examination of its mechanism resulting in injuries and fatalities is of practical importance. Decision tables and naïve Bayes methods have been widely used separately for solving classification problems in multiple areas except for traffic safety research. Based on a two-year rear-end crash dataset, this paper applies a decision table/naïve Bayes(DTNB) hybrid classifier to select deterministic attributes for driver injury severities in rear-end crashes and investigate decision rules for injury prediction with these selected attributes. The test results show that the hybrid classifier performs reasonably well, indicated by several performance evaluation measurements, such as accuracy, F-measure, ROC curve and AUC. Fifteen attributes are found to be significant in predicting driver injury severities, including weather, lighting condition, road geometry characteristics, driver behavior information, etc. The extracted decision rules demonstrate that heavy vehicle involvement, comfortable traffic environment, inferior lighting condition, two-lane rural roadways, vehicle disabled damage, and two-vehicle crashes would increase the likelihood of driver fatal injuries. The research limitations on data size, data structure and result presentation are also summarized. The applied methodology and estimation results provide insights for developing effective countermeasures to alleviate rear-end crash injury severities and improve traffic system safety performance.

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Sponsoring Committee	ANB20, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-5506
Paper Title	Examining Driver Injury Severity on Rural Interstate Highways Using a Hierarchical Bayesian Approach
Abstract	Rural interstate highways are major corridors carrying a significant portion of high speed traffic and have high risks for crashes with severe injuries and fatalities. Hierarchical Bayesian models incorporate between-crash variance and within-crash correlations into hierarchical traffic data modeling and therefore outperform ordinary regression models in traffic safety analysis. This paper applies a hierarchical Bayesian logistic model to examine the significant factors at crash and vehicle/driver levels and their influence on driver injury severity in rural interstate crashes. The intra-class correlation (ICC) and deviance information criterion (DIC) are summarized to illustrate the suitability of the proposed model. The research results demonstrate that the major portion of the total variance is resulted from between-crash variance, indicating the appropriateness of using hierarchical modeling. Two crash-level variables and four vehicle/driver-level variables are identified to be significant based on the 95% Bayesian credible interval (BCI) of odds ratio: the number of vehicles in a crash, wet road surface, vehicle type, driver age, gender and driver alcohol or drug involvement. Single-vehicle crashes, female drivers, senior drivers, motorcycles and driver alcohol or drug involvement tend to increase the odds of drivers being incapably injured or killed in rural interstate crashes. Wet road surface and male drivers are more likely to decrease the probability of severe driver injuries. It is also indicated that the potential interactive effects among demographic variables and other crash-related variables should be further examined. The results provide insightful understanding of rural interstate crashes to develop effective countermeasures for rural interstate crash prevention.

Authors	Justin Forbes, Dalhousie University, Canada Ahsan Habib, Dalhousie University, Canada
Sponsoring Committee	ANF10, Pedestrians
Session Number	848
Session Title	Pedestrian Safety and Operational Performance Measurement
Paper Number	15-5962
Paper Title	Pedestrian Injury Severity Levels in Halifax Regional Municipality, Canada: Hierarchical Ordered Probit Modeling Approach
Abstract	Pedestrians are particularly vulnerable road users within the urban environment. Many studies have examined the factors contributing to the frequency and severity of collisions, but limited research has examined the influence of the built environment on pedestrian injury severity. This paper used the Halifax Regional Municipality as a case study to examine the effect of the built environment on injury severity of pedestrians using two ordered response models; first, a conventional ordered probit model, and then, a hierarchical ordered probit (HOPIT) model, which accommodates unobserved heterogeneity by allowing the thresholds to vary across observations. In the HOPIT model fit in this study, the threshold covariates vary with whether or not the collision occurred at an intersection and with the number of walking commuters in the neighborhood. In this study, built environment contributing factors include a variety of street pattern classifications, land use types, transit supply, and demographic characteristics and are examined together with other variables including pedestrian and driver characteristics, collision characteristics, and environmental conditions. We utilized Nova Scotia Collision Record Database (NSCRD) data for the years 2007-2011 to develop the ordered response models of injury severity of pedestrians. The results found gender and age, time of day, as well as weather conditions to be significant in explaining injury severity of pedestrians. The analysis also suggests that vehicle interaction, road design, and pedestrian action and location are important variables influencing pedestrian injury severity. Additionally, we found built environment characteristics including land use type, presence of activity centers, and demographic attributes to influence injury severity outcomes. The results may help inform policy development aimed at improving pedestrian safety in Nova Scotia.

6 Crash Mofification Factors

Tarek Sayed, University of British Columbia

The Subcommittee identified twenty-nine papers dealing with crash modification factors and crash modification functions. The majority of these papers employed the empirical Bayes approach (Kay et al. 15-0179, Choi et al. 15-0503, Ahmed et al. 15-0830, Abuzwidah et al. 15-2700, Wu et al. 15-3001, Ma et al. 15-3472, Persaud et al. 15-4996) while the Full Bayes approach was employed in six studies (Wang et al. 15-0952, Park et al. 15-1036, Park et al. 15-1252, Buddhavarapu et al. 15-2314, Islam et al. 15-2342, Islam et al. 15-2350). Cross-sectional regression methods were employed in six studies (Banihashemi 15-1783, Aldemir-Bektas et al. 15-2378, Wu et al. 15-2433, Dias et al. 15-0339, Butsick et al. 15-0797, Qi et al. 15-1271). Other evaluation techniques were also proposed. The safety impact of countermeasures was generally represented by changes in crash frequency and/or crash severity. However, some studies evaluated simulated traffic conflicts as a surrogate measure (e.g. Dias et al. 15-0339 and Pin et al. 15-0827). Several studies proposed crash modification functions.

The evaluated countermeasures included geometric elements (Kay et al. 15-0179, Choi et al. 15-0503, Butsick et al. 15-0797, Ahmed et al. 15-0830, Park et al. 15-1038, Park et al. 15-1252, Qi et al. 15-1271, Banihashemi 15-1783, Wu et al. 15-2433, Wu et al. 15-3001, de Leur et al. 15-3440, Persaud et al. 15-4996), signal visibility (Dias et al. 15-0339) and pavement condition (Buddhavarapu et al. 15-2314), traffic control elements (Wang et al. 15-0952, Simpson et al. 15-1593, Fink et al. 15-3076, Ma et al. 15-3472), pavement marking retro-reflectivity (Aldemir-Bektas et al. 15-2378), toll plazas (Abuzwidah et al. 15-2700), speed limit reduction (Islam et al. 15-2342, Islam et al. 15-2350, Elbassuoni et al. 15-5844), rail crossings (Abdel-Rahim et al. 15-2439), and pedestrian countermeasures (Pin et al. 15-0827, Guo et al. 15-1202).

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-0797
Paper Title	Modeling Safety Effects of Geometric Design Consistency on Two-Lane Rural Roads Using Mixed Effects Negative Binomial Regression
Abstract	Previous research has examined the relationship between roadway safety and design consistency using measures such as the difference between design and operating speeds and changes to driver workload. While such measures have proven effective in identifying inconsistences in the roadway, they do not directly identify the conditions associated with safety performance. The purpose of this research was to directly quantify the effects of geometric design consistency on roadway safety using measures that can be linked to specific geometric elements. Using mixed effects negative binomial modeling, two safety performance functions (SPFs) were developed. The first contains typical roadway parameters that are suggested for use by several contemporary safety management tools, while the second contains additional geometric design consistency parameters. After Empirical Bayes adjustments were performed on 5 years of crash data from over 2,100 fixed-length (2.5 miles) segments of two-lane rural roadway, the sites with potential (SWiPs) were identified. The disparity between SWiPs identified by the two SPFs was evident; 40 unique sites were identified by each model out of the top 220 sites identified. Along with a marked shift of rankings, this constitutes a 19 percent change in the top 10 percent of sites.

Authors	Yi Qi, Texas Southern University Xumei Chen, Beijing Jiaotong University, China Jie Liu, Texas Southern University
Sponsoring Committee	AHB65, Operational Effects of Geometrics
Session Number	472
Session Title	Operational and Safety Effects of Geometric Designs
Paper Number	15-1271
Paper Title	Safety Performance of Freeway Weaving Sections
Abstract	The intensive lane change maneuvers at weaving sections on freeways often result in safety and operational problems. Various factors, including the design of ramps, the use of auxiliary lanes, and the continuity of lanes have significant effects on the level of service and safety performance of weaving sections. The objectives of this study were to investigate the safety performance of freeway weaving sections and to develop a quantitative model for predicting the safety impacts of different types of geometric treatments for a freeway weaving section. The results of this study showed that longer weaving sections had lower crash frequencies per 1000 ft. Three other significant findings resulted from the study, i.e., 1) the number of crashes in the freeway's weaving section was directly related to the number of lane changes that were required for the vehicles to diverge; 2) increasing the merging traffic volume in the weaving sections reduced the crash risk in these sections; and 3) increasing the volume of diverging traffic in the weaving sections will increase the crash risk in these sections. In this study, crash modification factors (CMFs) were also derived based on the developed crash prediction model for estimating the safety impacts of different geometric treatments for freeway weaving sections.

Authors	Salvatore Cafiso, University of Catania, Italy Carmelo D'Agostino, University of Catania, Italy
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2226
Paper Title	Reliability-based assessment of Benefits in roadway safety management
Abstract	Road Agencies set quantitative targets and adopt related road safety strategies within the priorities and the available resources funds at a time of economic crisis. In this framework, benefit-cost analyses (BCA) are carried out to support the decision making process and alternative measures are ranked according to their expected benefit and benefit-cost ratio calculated using a Safety Performance Function (SPF) and Crash Modification Factors (CMFs) as predictor of future safety performances. Due to the variance of CMFs and crash frequency we are uncertain what the benefits of some future actions will be. The chance of making a wrong decisions depends on the size of the standard deviation of the probability distribution of CMFs and SPF, as well. To deal with the uncertainty inherent in the decision making process, a reliability based assessment of Benefits must be performed introducing a stochastic approach. In the paper the variance of the CMFs and SPFs are taken into account in a reliability based BCA to address improvements and issues of an accurate probabilistic approach when compared to the deterministic results or other approximated procedures. A case study is presented comparing different safety countermeasures selected to reduce crash frequency and severity on sharp curves in motorway. These measures include retrofitting of old safety barrier, delineation systems, shoulder rumble strips and their combinations. The methodology was applied using Monte Carlo simulations to calculate the probability of failure of BCA statements. Results and comparisons with alternative approaches, like that proposed in the HSM, are presented showing remarkable differences in the evaluation outcomes that can be achieved.

Authors	Md Tazul Islam, University of Alberta, Canada Karim El-Basyouny, University of Alberta, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2350
Paper Title	Full Bayesian Mixed-Effect Intervention Model for Before-After Speed Data Analysis
Abstract	Analysing the before-after speed data to evaluate the effectiveness of any safety intervention is often limited to non-model-based comparison of various speed-related indicators. Moreover, modelling the speed data often does not take into account the nested nature of the data. To this end, the objective of the current study was to quantify the effect of posted speed limit (PSL) reduction in an urban residential context by employing a mixed-effect intervention model, which can address the limitations of existing methodologies. To model the mean free-flow speed and probability of speed below or equal to various thresholds, mixed-effect normal regression and binomial logistic regression models were used, respectively. The use of a comprehensive, unique, and disaggregated dataset enabled not only the before-after evaluation of the PSL reduction, but also exploration of the effects of various temporal, traffic, and road geometry factors on speed behaviour. Results demonstrated the appropriateness of using the mixed-effect model for the speed data. The parameter estimations showed that night-time, weekends, the high proportion of vans/buses/trucks, evening peak periods, collector roads (as opposed to local roads), and lower hourly traffic volume were all associated with an increase in mean free-flow speed and a decrease in the probability of speed below or equal to various speed thresholds. The evaluation results showed that the mean free-flow speed reduced by 3.85 km/h in the after period, while speeds below or equal to 50 km/h, 60 km/h, 70 km/h, and 80 km/h increased by 20.0%, 9.2%, 2.8%, and 0.9%, respectively. All the improvements were statistically significant, implying the effectiveness of the PSL reduction in influencing vehicle speed behaviour.

Authors	Hui Wu, University of Texas, Austin Zhe Han, University of Texas, Austin Mike Murphy, University of Texas, Austin Zhanmin Zhang, University of Texas, Austin
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-3001
Paper Title	Empirical Bayes Before-After Study on Safety Effect of Narrow Pavement Widening Projects in Texas
Abstract	Texas has approximately 40,000 lane miles (64,000 km) of two-lane farm-to-market (FM) and ranch-to-market (RM) roads with total paved widths of 18 to 22 ft (5.5 to 6.7 m), most of which are in rural areas. Narrow pavement widening in Texas typically involves adding a total of 1- to 9-ft (0.3- to 2.4-m) lane width and/or a narrow shoulder to each direction of a narrow FM/RM road. The main reasons for roadway widening are usually to improve safety, increase structural capacity, and/or enhance pavement performance. The goal of this study is to investigate the safety effects of narrow pavement widening projects for rural two-lane FM/RM roads in Texas. A before-after comparison study was conducted using the empirical Bayes method to evaluate how wider lanes/shoulders impact crash occurrence by type and severity. Of the 22 studied projects, analysis showed a 31.5 percent reduction in total crashes; a 35.7 percent in run-off-the-road crashes; and a 55.4 percent reduction in head-on crashes after narrow widening projects were constructed. The projects were also effective in reducing fatal crashes and injuries by about 29.5 percent. These findings suggest that narrow pavement widening is an effective safety countermeasure on narrow two-lane FM/RM roads in rural areas.

Authors	Paul de Leur, Vancouver, Canada Michael Weightman, Insurance Corporation of British Columbia, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3440
Paper Title	The Effectiveness of The High Risk Corridor Program in British Columbia
Abstract	British Columbia's High-Risk Corridor (HRC) Program was created by recognizing that a safe roadway environment is a shared responsibility, involving several public agencies including the police, the road authority, and others. In BC, another public agency interested and responsible for road safety is the Insurance Corporation of BC (ICBC), which is a provincial agency responsible for vehicle insurance and driver licensing services. It was felt that coordinated and strategic efforts by public agencies responsible for road safety could yield greater safety benefits as compared to individual agency efforts that are undertaken in isolation. This paper provides an overview of British Columbia's HRC Program and presents a case study example to demonstrate the success of the program in reducing the frequency and severity of collisions on a high-risk corridor. The paper also describes the technical elements of the program, including how corridors are defined as high-risk, as well as the collision and infrastructure analysis used to guide the interventions deployed as part of the program. The details of the strategic efforts and coordination by the various agencies will be detailed to illustrate the range and integration of the road safety initiatives. Finally, the results from a robust, time-series evaluation are presented to show the significant and positive safety impact of the HRC Program, which has resulted in a large reduction in the frequency and severity of collisions.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-1038
Paper Title	A Study on Development and Comparison of Crash Modification Factors for Combining Multiple Treatments on Rural Multilane Roadways
Abstract	As multiple treatments (or countermeasures) are simultaneously applied to roadways, there is a need to assess their combined safety effects. Due to a lack of empirical Crash Modification Factors (CMFs) for multiple treatments, the Highway Safety Manual (HSM) and other related studies developed various methods of combining multiple CMFs for single treatments. However, the literature did not evaluate the accuracy of these methods using CMFs obtained from the same study area. Thus, the main objectives of this research are: 1) develop CMFs for two single treatments (shoulder rumble strips, widening shoulder width) and one combined treatment (shoulder rumble strips + widening shoulder width) using before-after and cross-sectional methods and 2) evaluate the accuracy of the combined CMFs for multiple treatments estimated by the existing methods based on actual evaluated combined CMFs. Data was collected for rural multi-lane highways in Florida and four safety performance functions (SPFs) were estimated using 360 reference sites for two crash types (all crashes and Single Vehicle Run-off Roadway (SVROR) crashes) and two severity levels (all severity (KABCO) and injury (KABC)). The results of both before-after and cross-sectional methods show that the two single treatments and the combined treatment produced safety improvement. It was found that safety effects were higher for the roadway segments with shoulder rumble strips and wider shoulder width. It was also found that the treatments were more safety effective (i.e. lower CMF) for the roadway segments with narrower original shoulder width in the before period. However, although CMFs for multiple treatments were generally lower than CMFs for single treatments, they were similar for the roadway segments with shoulder width of 8~12 feet. Among different methods of combining CMFs, the HSM, Systematic Reduction of Subsequent CMFs, Applying only the most effective CMF, and Weighted average of multiple CMFs (Meta-Analysis) showed good estimates of the combined CMFs for multiple treatments with 2.2% difference between actual and estimated CMFs. The findings suggest that the existing methods of combining multiple CMFs are generally valid but they need to be applied for different crash types and injury levels separately. Lastly, an average of the combined CMFs from the best two methods was closer to the actual CMF than the combined CMF from only one best method. This indicates that it is better not to rely on only one specific existing method of combining CMFs for predicting CMF for multiple treatments.

Authors	Lingtao Wu, Texas A&M University Dominique Lord, Texas A&M University Yajie Zou, University of Washington
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-1467
Paper Title	Validation of Crash Modification Factors Derived from Cross-Sectional Studies Using Regression Models
Abstract	Crash modification factors (CMFs) can be used to capture the safety effects of countermeasures and play significant roles in traffic safety management. As an alternative to the before-after study, the regression model method has been widely used for estimating CMFs. Although before-after studies are considered to be superior, the use of regression models for estimating CMFs has never been fully investigated. This paper consequently sought to examine the conditions in which regression models could be used for such purpose. CMFs for three variables, lane width, curve density and pavement friction, were assumed and used for generating random crash counts. Then, CMFs were derived from regression models using the simulated crash data for three different scenarios. The results were then compared with the assumed true value. The study results showed that (1) the CMFs derived from the regression models should be unbiased when all factors affecting traffic safety are identical in all segments, except those of interest; (2) if some factors having minor safety effects are omitted from the models, the accuracy of estimated CMFs can still be acceptable; (3) if some factors already known to have significant effects on crash risk are omitted, the CMFs derived from the regression models are generally unreliable. Thus, depending on the missing variables that are not included in the model, the transportation safety analyst can decide if the CMFs developed from the regression models should be used for highway safety applications.

Authors	Joshua Fink, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-3076
Paper Title	Impact of Adaptive Traffic Control Systems on Crash Frequency and Severity
Abstract	Despite seeing widespread usage worldwide, adaptive traffic control systems have experienced relatively little use in the United States. Of the systems used, the Sydney Coordinated Adaptive Traffic System (SCATS) is the most popular in America. Safety benefits of these systems are not as well understood nor as commonly documented. This study investigates the safety benefits of adaptive traffic control systems by using the large SCATS-based system in Oakland County, MI known as FAST-TRAC. This study uses data from FAST-TRAC-controlled intersections in Oakland County and compares a wide variety of geometric, traffic, and crash characteristics to similar intersections in metropolitan areas elsewhere in Michigan. Data from 498 signalized intersections are used to conduct a cross-sectional analysis. Negative binomial models are used to estimate models for three dependent crash variables. Multinomial logit models are used to estimate an injury severity model. A variable tracking the presence of FAST-TRAC controllers at intersections is used in all models to determine if a SCATS-based system has an impact on crash occurrences or crash severity. It is found to be statistically significant in 8 models. Estimates show angle crashes could be reduced by up to 19.3% at intersections with SCATS-based controllers. Severity results show a statistically significant increase in non-serious injuries, but not a significant reduction in incapacitating injuries or fatal accidents.

Authors	Sherief Elbassuoni, University of Idaho Michael Dixon, University of Idaho Ahmed Abdel-Rahim, University of Idaho
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	540
Session Title	Crash-Based Safety Analysis and Modeling
Paper Number	15-5844
Paper Title	Long-Term Impact of Differential Speed Limits on Rural Freeways in Idaho
Abstract	The main focus of this research is to evaluate the long-term operation and safety impact of Differential Speed Limits (DSL) on rural freeways in Idaho. The analysis of speed data covered three periods: period 1: January 1992 - April 1996 (Uniform Speed Limit (USL) of 65 mph); Period 2: April, 1996 - June, 1998 (with a USL of 75 mph); and Period 3: July, 1998 – December, 2011 (with a DSL of 75 mph for passenger cars and 65 mph for commercial truck vehicles). The analysis showed that since the implementation of the DSL policy, Idaho's speed trends have stabilized with no sizable change. The mean speed for trucks and passenger vehicles are very close to their respective posted speed limits. The 85th percentile speeds have also stabilized at about five mph above the respective speed limits. DSL implementation also visibly improved the compliance rate of truck speed limit. The considerable reduction in the 85th percentile and the pace speeds for trucks and the improved speed limit compliance rate indicate that the DSL policy favorably impact truck driver behavior by reducing the most extreme truck speeds. Implementation of the DSL policy has contributed to the improved safety conditions on rural freeways in Idaho. Crash rate analysis showed that DSL favorably affects safety. Crash rates for all crash types were highest during the period 1996 to 1998 with a USL of 75 mph. When DSL policy was implemented in 1998, the crash rates decreased considerably and continued to decline since then.

Authors	Carrie L. Simpson, North Carolina Department of Transportation Shawn Troy, North Carolina Department of Transportation
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	618
Session Title	Research on Flashing Traffic Control Devices
Paper Number	15-1593
Paper Title	Safety Effectiveness of Flashing Yellow Arrow: Evaluation of 222 Signalized Intersections in North Carolina
Abstract	The purpose of this project is to develop crash modification factors (CMFs) for the implementation of Flashing Yellow Arrow (FYA) based on the specific before and after period conditions of a signalized intersection. Although this countermeasure has been used for years in North Carolina and other States, none of the published studies to-date have provided CMFs for left turn crashes specific to the treated approaches, and none have provided CMFs for the three-section FYA for permissive only left turns. Crash data from 222 intersections in North Carolina with FYA-protected/permissive left turn (FYA-PPLT) and/or three-section FYA-permissive only left turn installations were used to provide CMFs for five Category types: Category 1 (Permissive Only to FYA-PPLT), Category 2 (Protected Only to FYA-PPLT), Category 2A (Protected Only to FYA-PPLT with Time of Day Operation), Category 3 (5-Section PPLT to FYA-PPLT), and Category 4 (Permissive Only to FYA-Permissive Only). A before and after crash analysis with consideration for traffic increase was used to determine the safety estimates. Safety performance functions were used to account for the effect of traffic volume trends. Readers may be most interested in Category 3 and 4, where the change is exclusive to the left turn display and not a change in phasing. All CMF results are statistically significant for Category 3, and target and injury CMF results are statistically significant for Category 4. Based on the results from our study sites, we find a statistically significant decrease in target left turn crashes and injury crashes when going from a solid green ball to a FYA for permissive left turns when phasing remains unchanged. This applies regardless of whether the left phasing is protected/permissive or fully permissive.

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Sponsoring Committee	AHB50, Traffic Control Devices AHB60, Highway/Rail Grade Crossings AHD55, Signing and Marking Materials AND40, Visibility
Session Number	754
Session Title	Research on Perception and Effectiveness of Visual Information and Safety Systems
Paper Number	15-4996
Paper Title	Safety Evaluation of Centerline Plus Shoulder Rumble Strips
Abstract	The combined application of centerline and shoulder rumble strips was selected for evaluation under the Federal Highway Administration (FHWA) Evaluation of Low-Cost Safety Improvements Pooled Fund Study. This strategy is intended to reduce the frequency of crashes by alerting drivers that they are about to leave the travelled lane. To date, this combination treatment has not been rigorously evaluated with a multistate database. Geometric, traffic, and crash data were obtained at treated two-lane rural road locations in Kentucky, Missouri, and Pennsylvania. To account for potential selection bias and regression-to-the-mean, an Empirical Bayes (EB) before-after analysis was conducted, utilizing reference groups of untreated two-lane rural roads with similar characteristics to the treated sites. The analysis also controlled for changes in traffic volumes and time trends in crash counts unrelated to the treatment. The combined results for all States indicate statistically significant crash reductions for all crash types analyzed. The crash type with the smallest crash modification factor (CMF) (i.e., the greatest crash reduction) is head-on with a CMF of 0.632. Run-off-road and sideswipe-opposite-direction crashes have estimated CMFs of 0.742 and 0.767, respectively. For all crash types combined, CMFs of 0.800 for all severities and 0.771 for fatal+injury were estimated. For run-off-road, head-on and sideswipe-opposite direction crashes combined (i.e., lane departure crashes), the estimated CMF is 0.733. Benefit-cost (B/C) ratios were estimated to range from 11.0 to 29.8, depending on the treatment cost and service life assumption, which varied by State.

Authors	Ishani Madurangi Dias, Kansas State University Sunanda Dissanayake, Kansas State University
Sponsoring Committee	AHB50, Traffic Control Devices AHB60, Highway/Rail Grade Crossings AHD55, Signing and Marking Materials AND40, Visibility
Session Number	754
Session Title	Research on Perception and Effectiveness of Visual Information and Safety Systems
Paper Number	15-0339
Paper Title	Effectiveness of Retroreflective Signal Back Plates as a Countermeasure to Reduce Red-Light-Running Violations
Abstract	When a vehicle enters an intersection after the onset of the red signal light indication, it is considered as a red light running (RLR) violation. According to FHWA, 97% of drivers feel that other drivers violating red lights are a main safety threat, which needs to be addressed. The objective of this study was to evaluate the effectiveness of retro-reflective signal backplates in reducing red light running as a low cost countermeasure. Two intersections from Topeka, KS were considered for a cross sectional study and four intersections from Manhattan, KS were considered for before-and-after study in order to evaluate retroreflective signal backplates. Before-and-after study showed a significant reduction in red-light-running violations in through and left turning traffic according to paired-t-test results. Cross-sectional study used two-sample-t test statistics and from that also, it was shown that reflective backplates are effective in reducing red light violations in the through and left turning traffic flows. Both analyses could not prove a significant impact on red light violations among the right turning vehicles. Violation modification factors were estimated using the before and after study and when RLR violation counts from both the treatment sites are considered, number of RLR violations becomes 0.74 times that from the before condition. Overall, this study can conclude that introducing retro-reflective backplates is a successful countermeasure to reduce RLR violations in through and left turning traffic at signalized intersections. Keywords: Red light running, Reflective backplates, Before-and-after study, Cross-sectional study.

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Sponsoring Committee	AHB50, Traffic Control Devices AHB60, Highway/Rail Grade Crossings AHD55, Signing and Marking Materials AND40, Visibility
Session Number	754
Session Title	Research on Perception and Effectiveness of Visual Information and Safety Systems
Paper Number	15-2378
Paper Title	Effects of Segmentation and Sampling of Pavement Marking Retroreflectivity on Crash Frequency Analyses
Abstract	This paper investigates the effects of segmentation and sampling on pavement marking retroreflectivity and safety analyses. Road data, crash data, pavement condition data, and pavement marking retroreflectivity data from Iowa DOT databases were acquired and spatially integrated. Data sets for one-, three-, and five mile segments were prepared to investigate the effect of segmentation. Additional data sets with imputed and measured retroreflectivity data were prepared for comparison. A series of negative binomial regression analyses were run to estimate the expected number of crashes on varying segment lengths and data subsets based on the two retroreflectivity collection methods. The findings show that statistical analyses on smaller segments and using datasets with measured retroreflectivity rather than datasets enriched with imputed values lead to results that are more significant to establish a relationship between retroreflectivity of longitudinal pavement markings and crash frequency. In addition, using measured retroreflectivity values versus imputed values proved more suitable, and corrected counterintuitive findings from data sets with imputed values. The findings suggest that keeping longitudinal pavement markings in good condition has significant positive effects on safety. The results further suggested a percentage reduction of 4.88%, and 9.52% in the annual number of expected crashes for two-lane roads and four-lane roads, respectively, if retroreflectivity increased by 50 mcd/m2/lux. In addition, a significant relationship between pavement condition (measured with IRI) and expected number of crashes was found for all data sets.

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Sponsoring Committee	AHB50, Traffic Control Devices AHB60, Highway/Rail Grade Crossings AHD55, Signing and Marking Materials AND40, Visibility
Session Number	754
Session Title	Research on Perception and Effectiveness of Visual Information and Safety Systems
Paper Number	15-2439
Paper Title	Benefits of IdaShield Signs at Highway-Rail Crossings in Idaho: Crash Analysis and Usability Assessment Survey
Abstract	This paper describes findings from a study aimed at assessing the safety impacts of IdaShield signs installed at 1,341 highway-rail crossings in Idaho. Specifically, our research assessed IdaShield effectiveness using two measures: 1) Before /After analysis of crash data preceding and following installation of the IdaShield, and 2) Usability assessment survey measuring users' understanding of the IdaShield and changes in users' response due to the IdaShield. Before/After analysis of crash data revealed a significant 38.6 percent improvement in safety after IdaShields were installed. A separate analysis using Wilcoxon signed rank tests found a significant 39.5 percent improvement in the daytime and 72.2 percent improvement in the nighttime, suggesting that IdaShield had an effect on improving safety during both daytime and nighttime conditions. The higher percentage of crash reduction for nighttime crashes indicates that some of the crash reduction of the IdaShield could be associated with improved sign reflectivity. In the usability assessment survey, Idaho drivers were randomly sampled and asked to complete an online web-based survey. In the survey, participants were given scenarios with accompanying pictures of approaching railroad crossings with just IdaShield signs and also IdaShield signs combined with YIELD or STOP signs. The results of the survey showed that users understood the purpose of the IdaShield, believed it enhanced intersection visibility, and would improve safety. Most significant, a majority of drivers (63%) who completed the web survey indicated they felt the IdaShield increased visibility of the railway crossings as well as overall safety at the crossing.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0830
Paper Title	Evaluation of the Safety Effectiveness of the Conversion of Two-Lane Roadways to Four-Lane Divided Roadways: Bayesian vs. Empirical Bayes
Abstract	This paper utilized various observational before-after analyses to evaluate the safety effectiveness of widening urban and rural two-lane to four-lane divided roadways. These methodologies ranged from simple (naïve) before-after, before-after with comparison group, Empirical Bayes (EB), and Bayesian approach. The EB method requires Safety Performance Functions (SPFs) to be calibrated; the simple AADT-based SPF is used widely. In this paper, two sets of Negative Binomial models were calibrated; 'full' SPF model that utilizes various explanatory covariates and 'simple' SPF using AADT only. The preliminary results from the calibrated models indicated that the SPF is pivotal in the EB method; the more accurate the models, the more pragmatic the evaluation of the safety effectiveness of a treatment. The proposed methodology of using the 'Full' SPF in EB method is recommended over the conventional EB observational before-after. In order to obtain more reliable estimates, Bayesian before-after approach was performed. The Bayesian Bivariate Poisson-Lognormal approach provided comparable results and might have several advantages over the EB technique. The results from this paper indicated that the conversion from two-lane roadways to four-lane divided roadways resulted in a notable reduction of more than 63 percent on urban roadways and 45 percent reduction on rural roadways for fatal and injury (F+I) crashes. Conversion to 4-lane divided roadway yielded a higher reduction in total and property damage only crashes in urban areas than in rural areas. Additionally, the safety effects of the conversion appear to be more effective on roadway segments with high AADT in urban areas.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0952
Paper Title	Estimating Safety Performance Trends over Time for Treatments at At-Grade Intersections in Florida
Abstract	Researchers have put great efforts in quantifying Crash Modification Factors (CMFs) for diversified treatment types. In the Highway Safety Manual (HSM), CMFs have been identified to predict safety effectiveness of converting a stop-controlled to a signal-controlled intersection (signalization) and installing Red Light Running Cameras (RLCs). Previous studies showed that both signalization and adding RLCs reduced angle crashes but increased rear-end crashes. However, some studies showed that CMFs varied over time after the treatment was implemented. Thus, the objective of this study is to investigate trends of CMFs for the signalization and adding RLCs over time. CMFs for the two treatments were measured in each month and 90- day moving windows respectively. The ARMA time series model was applied to predict trends of CMFs over time based on monthly variations in CMFs. The results of the signalization show that the CMFs for rear-end crashes were lower at the early phase after the signalization but gradually increased from the 9th month. On the other hand, the CMFs for angle crashes were higher at the early phase after adding RLCs but decreased after the 9th month and then became stable. It was also found that the CMFs for total and fatal/injury crashes after adding RLCs in the first 18 months were significantly greater than the CMFs in the following 18 months. This indicates that there was a lag effect of the treatments on safety performance. The results of the ARMA model show that the model can better predict trends of the CMFs for the signalization and adding RLCs when the CMFs are calculated in 90-day moving windows compared to the CMFs calculated in each month. In particular, the ARMA model predicted a significant safety effect of the signalization on reducing angle and left-turn crashes in the long term. Thus, it is recommended that the safety effects of the treatment be assessed using the ARMA model based on trends of CMFs in the long term after the implementation of the treatment.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2314
Paper Title	A Fully Bayesian Before-After Analysis of Permeable Friction Course (PFC) Pavement Wet Weather Safety
Abstract	Permeable friction course (PFC), open-graded hot-mix asphalt used in Texas, is typically applied to improve wet weather safety. This paper aims to quantify the effectiveness of PFC in terms of reducing wet weather crashes. The majority of the earlier literature on the safety effectiveness of porous mixes has been limited and inconclusive. This paper thoroughly evaluates the wet weather safety effectiveness of porous asphalt mixes using a fully Bayesian before-after safety analysis. A negative binomial count specification was employed to model the underlying reference and treatment population of crash counts. A computationally efficient procedure was utilized for fully Bayesian estimation of the proposed crash count model and to perform Bayesian inference on the safety effectiveness. Based on the the crash data from a pool of PFC and reference road segments across Texas, the hypothesis that PFC is effective in reducing wet weather crashes is rejected. It is interesting to note that the findings of this study are in agreement with most of the earlier literature on the safety benefits of porous surfaces. The study highlights the importance of the interaction between the road user's behavior and the safety infrastructure.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2342
Paper Title	Full Bayesian Evaluation of the Safety Effects of Reducing the Posted Speed Limit in Urban Residential Neighbourhoods
Abstract	Full Bayesian (FB) before-after evaluation is a newer approach than the empirical Bayesian (EB) evaluation in traffic safety research. While a number of earlier studies have conducted univariate and multivariate FB before-after safety evaluations and compared the results with the EB method, often contradictory conclusions have been drawn. To this end, the objectives of the current study were to i) perform before-after safety evaluation using both the univariate and multivariate FB methods in order to enhance our understanding of these methodologies, ii) perform the EB evaluation and compare the results with those of the FB methods, and iii) apply the FB and EB methods to evaluate the safety effects of reducing the urban residential posted speed limit (PSL) for policy recommendation. In addition to three years of crash data for both the before and after periods, traffic volume, road geometry, and other relevant data for both the treated and reference sites were collected and used. According to the model goodness-of-fit criteria, the current study found that the multivariate FB model for crash severities outperformed the univariate FB models. Moreover, in terms of statistical significance of the safety effects, the EB and FB methods led to opposite conclusions when the safety effects were relatively small with high standard deviation. Therefore, caution should be taken in drawing conclusions from the EB method. Based on the FB method, the PSL reduction was found effective in reducing crashes of all severities and thus is recommended for improving safety on urban residential collector roads.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2700
Paper Title	Safety Evaluation of All-Electronic Toll Collection System
Abstract	Traditional mainline toll plaza (TMTP) is considered the most high risk locations on the toll roads. Conversion from TMTP or Hybrid Mainline Toll Plaza (HMTP) to an All-Electronic Toll Collection (AETC) system has demonstrated measured improvements in traffic operations and environmental issues. However, there is a lack of research that quantifies the safety impacts of these new tolling systems. This study evaluated the safety effectiveness of conversion from TMTP or HMTP to AETC system. An extensive data collection was conducted that included a hundred mainline toll plazas located on more than 750 miles of the toll roads in Florida. Various observational before-after studies including the Empirical Bayes method were applied. The results indicated that the conversion from the TMTP to an AETC system resulted in an average crash reduction of 77, 76, and 67 percent for total, fatal-and-injury and Property Damage Only (PDO) crashes, respectively; for rear end and Lane Change Related (LCR) crashes the average reductions were 81 and 75 percent. The conversion from HMTP to AETC system enhanced traffic safety by reducing crashes by 23, 29 and 19 percent for total, fatal-and-injury, and PDO crashes; also, for rear end and LCR crashes, the average reductions were 15 and 21 percent, respectively. Overall, this paper provided an up-to-date safety impact of using different toll collection systems. The results proved that the AETC system significantly improved traffic safety for all crash categories; and changed toll plazas from the highest risk on Expressways to be similar to regular segments.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0503
Paper Title	Development of Crash Modification Factors of Alignment Elements and Safety Countermeasures for Korean Freeways
Abstract	Recently, many efforts have been devoted to improving the safety of freeways in Korea, as freeways are the most important roadways in the transportation network. As a part of these efforts, this research aims to develop crash modification factors (CMFs) of two alignment elements, as well as eight safety countermeasures for Korean freeways. To do this, we first developed classical safety performance functions (SPFs) for each freeway. To develop the CMFs of two alignment elements, horizontal curve and vertical grade, we also estimated inclusive SPFs that include the alignment elements together with traffic volume and segment length as independent variables. The CMFs of horizontal curve and vertical grade were calculated as the marginal effect of their coefficients on the inclusive SPFs. Then, we developed eight CMFs for safety countermeasures including delineator posts, automated speed enforcement cameras, rumble strips, chevron signs, roadside barriers, grooving, illumination and median barriers. We also corrected for regression-to-the-mean (RTM) bias, time trend of crash count, and effect of traffic volume change by using the empirical Bayes (EB) method. We compared the developed CMFs in this study with those from previous literature and discussed the findings from the comparison. The results from this study contribute to enhancing the safety of Korean freeways and act as a reference guide for other Korean roadways, as well as roadways in other countries.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-1252
Paper Title	Assessing Safety Effects of Widening Four-Lane to Six-Lane Roadways using a Nonlinearizing Link Function Accounting for Time Changes in Developing Crash Modification Functions
Abstract	Since a crash modification factor (CMF) represents the overall safety performance of specific treatments in a single fixed value, there is a need to explore the variation of CMFs with different roadway characteristics among treated sites over time. Therefore, in this study, we 1) evaluated the safety performance of a sample of urban four-lane roadway segments that have been widened with one through lane in each direction and 2) determined the relationship between safety effects and different roadway characteristics over time. Observational before-after analysis with the Empirical Bayes (EB) method was assessed in this study to evaluate the safety effects of widening urban four-lane roadways to six-lanes. Moreover, the nonlinearizing link function was utilized to achieve better performance of crash modification functions (CMFunctions). The full CMFunctions were developed using multivariate linear regression and Bayesian random parameter regression methods including the estimated nonlinearizing link function to incorporate changes in safety effects of treatment over time. Data was collected for urban arterials in Florida, and the Florida-specific full SPFs were developed and used for EB estimation. The results indicated that the conversion of four-lane roadways to six-lane roadways resulted in a crash reduction of 15 percent for total crashes, and 24 percent for fatal and injury crashes on urban roadways. The results show that the safety effects vary across the sites with different roadway characteristics. In particular, LOS changes, time changes, shoulder widths, paved shoulder types, and speed limits are significant parameters that affect the variation of CMFs. Moreover, it was found that narrowing shoulder and median widths to make space for an extra through lane shows negative safety impacts. It was also found that including the nonlinearizing link function in developing CMFunctions shows more reliable estimates, if the variation of CMFs with specific parameters has a nonlinear relationship. The findings provide insights into the selection of roadway sites for adding through lanes.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2433
Paper Title	Relationship of Lane Width to Safety for Urban Expressways
Abstract	Urban expressways served as the backbone of road traffic system in metropolitan cities. In order to increase the capacity of urban expressways in Shanghai, several cross-section reconstruction projects (the cross-section width remained the same) took place in past ten years. Site investigation found that the maximum lane width was 4.05m and the minimum lane was only 2.73m. To examine the safety influence of lane width on urban expressway, crash data and the corresponding traffic flow data from 2010 to 2013 were extracted from Shanghai Expressway Surveillance System for cross-sectional study. Negative binominal model (NB) was selected as the function form of the predicted crash frequency. Three datasets corresponding to undersized (average lane width ¡Ü 3.25m), standard-sized (average lane width ~ 3.45m), and oversized lanes (average lane width ¡Ý 3.75m) were collected for the development of crash modification factors (CMFs). Since lane width might exert different influence to different type of crash, different models were established by involved-vehicle number (two-vehicle crash and multi-vehicle crash) and traffic condition (congestion-flow crash and free-flow crash), and CMFs were developed respectively. The results showed that standard-sized lanes experienced the lowest crash frequency in all kind of crash. Specifically, the crash frequency of undersized lanes and oversized lanes would increase 190% and 134% compared with standard-sized lanes in total crash.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-1783
Paper Title	Is Horizontal Curvature a Significant Factor of Safety in Rural Multilane Highways?
Abstract	The Highway Safety Manual (HSM) crash prediction models estimate the expected number of crashes for different facility types. Models in Part C of the first edition of the HSM include crash prediction models for divided and undivided rural multilane highway segments. Each of the HSM crash prediction models for highway segments is comprised of a “Safety Performance Function” (SPF) that is a function of AADT and segment length plus, a series of “Crash Modification Factors” (CMFs). The SPF estimates the number of crashes for the site if the site features are of base condition. The effects of the other features of the site, if their values are different from base condition, are carried out through use of CMFs. The existing models for rural multilane segments do not have any CMF for horizontal curvature. The goal of this research is to investigate if the horizontal alignment has any significant effect on crashes on these types of facilities and if so, to develop a CMF for this feature. Washington State cross sectional data from the Highway Safety Information System (HSIS) lab is used in this research. Data from 2007 to 2009 is used to do the investigation. The 2010 and 2011 data is used to validate the results. As the results show the horizontal curvature has significant safety effect on rural multilane highways and using a CMF for horizontal curvature improves the prediction of crashes significantly, for both tangent and curve segments.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3472
Paper Title	Estimation of the Safety Effects of an Adaptive Traffic Signal Control System
Abstract	Adaptive traffic signal control (ATSC) is a traffic management strategy in which traffic signal timings change, or adapt, based on observed traffic demand. While ATSC can improve mobility, it also has the potential to reduce crashes since mainline stops are reduced. This paper aims to evaluate the safety effectiveness of ATSC using the Empirical Bayes method. This analysis examines 47 urban or suburban intersections where ATSC was deployed in Virginia using 235 site-years of before data and 66 site-years of after data. Installing ATSC was found to produce a crash modification factor (CMF) for total intersection crashes of 0.83 with a standard error of 0.05. This CMF was statistically significant at a 95 percent confidence level. Fatal and injury crashes did not change by a statistically significant amount. Analyses of ATSC safety effects on crash type proportion, by traffic volume level, and by operational improvement magnitude were also performed. All crash types were found to be reduced, but safety benefits vary from corridor to corridor and at different volume levels. It was concluded that ATSC installation can potentially reduce both total and FI crashes at highway intersections, and public agencies should consider both its safety and mobility benefits when justifying ATSC projects.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0179
Paper Title	Safety Impacts of a Statewide Centerline Rumble Strip Program
Abstract	Lane departure events result in the majority of all traffic fatalities in the United States, a problem that is particularly pronounced on high-speed undivided highways, which are prone to cross-centerline crashes. A common countermeasure to reduce such crashes involves the installation of centerline rumble strips (CLRS), which provide an audible and tactile warning to alert drivers of an impending lane departure event. This study assessed the safety impacts of a statewide CLRS implementation program conducted in Michigan between 2008 and 2010. This program included the installation of more than 5,000 miles of CLRS, covering the majority of the rural non-freeway highways maintained by MDOT. Shoulder rumble strips (SRS) were installed in combination with the CLRS at locations with paved shoulders of at least 6 ft in width. The empirical Bayes method was utilized to assess the effectiveness of more than 4,200 miles of centerline rumble strips that were installed along two-lane highways. CLRS were found to reduce target cross-centerline crashes by 27.3 percent and by 32.8 percent when used in combination with SRS. In addition to these overall reductions, rumble strips were also effective in reducing crashes under adverse pavement conditions, as well as crashes involving passing maneuvers and impaired driving. This study also provided important insights into the necessary methods for identification of correctable target crashes through a comprehensive manual review of over 72,000 crash report forms. This review found that approximately 10 percent of target crashes were misclassified in the statewide crash database due to coding errors.

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Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	849
Session Title	Bicycle Transportation, Part 2: Safety and Infrastructure
Paper Number	15-1036
Paper Title	Evaluation of Safety Effectiveness of Adding Bike Lane for Urban Arterials with Different Roadway and Socioeconomic Characteristics
Abstract	Although many researchers have estimated crash modification factors (CMFs) for specific treatments (or countermeasures), there is a lack of studies that explored the heterogeneous effects of roadway characteristics on crash frequency among treated sites. Generally, the CMF estimated by before-after studies represents overall safety effects of the treatment in a fixed value. However, as each treated site has different roadway characteristics, there is a need to assess the variation of CMFs among the treated sites with different roadway characteristics through crash modification functions (CMFunctions). The main objective of this research is to determine relationships between the safety effects of adding a bike lane and the roadway characteristics through 1) evaluation of CMFs for adding a bike lane using observational before-after with empirical Bayes (EB) and cross-sectional methods and 2) development of simple and full CMFunctions which are describe the CMF in a function of roadway characteristics of the sites. Data was collected for urban arterials in Florida, and the Florida-specific full SPFs were developed. Moreover, socio-economic parameters were collected and included in CMFunctions and SPFs 1) to capture the effects of the variables that represent volume of bicyclists and 2) to identify general relationship between the CMFs and these characteristics. In order to achieve better performance of CMFunctions, data mining techniques were used. The results of both before-after and cross-sectional methods show that adding a bike lane on urban arterials has positive safety effects (i.e. CMF < 1) for All crashes and bike crashes. It was found that adding a bike lane is more effective in reducing bike crashes than All crashes. It was also found that the CMFs vary across the sites with different roadway characteristics. In particular, Annual Average Daily Traffic (AADT), number of lanes, AADT per lane, median width and bike lane width are significant characteristics that affect the variation in safety effects of adding a bike lane. Some socio-economic characteristics such as bike commuter rate also have significant effect on the variation in CMFs. The findings suggest that full CMFunctions showed better model fit than simple CMFuncttions since they account for the heterogeneous effects of multiple roadway and socio-economic characteristics. The proposed CMFunctions provide insights into bike lane design and selection of sites for bike lane installation for reducing crashes.

Authors	Calvin Pin, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada Mohamed H. Zaki, University of British Columbia, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-0827
Paper Title	Assessing Safety Improvements of Pedestrian Crossing Using Automated Conflicts Analysis
Abstract	Surrogate safety measures such as the traffic conflict technique (TCT) have been promoted as an alternative or complementary approach to evaluate road safety from a broader perspective than collision statistics alone. One safety application that can significantly benefit from the use of surrogate safety measures is the before-and-after (BA) evaluation of safety treatments. This study demonstrates the use of automated traffic conflict analysis to conduct before-and-after (BA) safety evaluations. The objective is to conduct a time-series (before-to-after) safety evaluation for an intersection in the City of Surrey where several pedestrian related countermeasures were implemented. The treatments included one or more of the following: use of protected only turns for left turning vehicles; installing pedestrian countdown timers; crosswalk realignment; and the use of drop down sidewalks. The results indicated a significant decrease in both pedestrian conflicts frequency and severity at the intersection following the treatments. A greater reduction of conflicts was exhibited on the western portion of the intersection where several countermeasures including a protected left turn phase, dual drop down ramps, and shifting the crosswalk further west were implemented. This variation in conflict reduction along different segments of the same intersection gives a particularized view on the impact of the adopted countermeasures. The outcome of this research provides evidence that surrogate safety indicators can effectively be used to diagnose safety problems and evaluate countermeasures at intersections.

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Sponsoring Committee AND30, Simulation and Measurement of Vehicle and Operator Performance
ANF10, Pedestrians
Session Number 848
Session Title Pedestrian Safety and Operational Performance Measurement
Paper Number 15-1202

Paper Title Effects of Parallelogram-Shaped Pavement Markings on Vehicle Speeds and Safety of Pedestrian Crosswalks on Urban Roads in China

Abstract The primary objective of this study was to evaluate the effects of parallelogram-shaped pavement markings on vehicle speeds and crashes in vicinity of urban pedestrian crosswalks. The research team measured speed data at seven locations, and crash data at eleven locations. Observational cross-sectional studies were conducted to identify if the effects of parallelogram-shaped pavement markings on vehicle speeds and speed violations were statistically significant. The results showed that parallelogram-shaped pavement markings significantly reduced vehicle speeds and speed violations in vicinity of pedestrian crosswalks. More specifically, the speed reduction effects varied from 2.4 km/hr to 4.2 km/hr with a mean of 3.3 km/hr. The reduction in the 85th percentile speed varied from 2.7 to 5.0 km/hr with a mean of 3.7 km/hr. The proportion of drivers exceeding speed limit declines by 9.4% to 15.6% with an average of 11.5%. The results of crash data analysis suggested that the use of parallelogram-shaped pavement markings reduced both the frequency and severity of crashes at pedestrian crosswalks. According to the crash model developed in this study, the presence of parallelogram-shaped pavement markings reduces crash frequency at pedestrian crosswalks by 24.87%, given that other factors remain constant.

7 Surrogate Measures of Safety

Andrew Tarko, Tomas Hall, and Yaotian Zou, Purdue University

The subcommittee identified forty-eight papers dealing with surrogate measures of safety. 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 surrogate safefety assessment models as complementary techniques. Seventeen papers have this methodological focus (Essa and Sayed, 15-0707; Fernandes et al., 15-1526; Jeong et al., 15-0533; Jeong et al., 15-1756; Kuang et al., 15-3871; Li et al., 15-4892; Lorion and Persaud, 15-5028; Mohamed and Saunier, 15-6018; Moreno et al., 15-1767; Mousavi et al., 15-4431; Roach et al., 15-5207; Saulino et al., 15-4968; So et al., 15-4002; Songchitruksa and Zha, 15-1309; St-Aubin et al., 15-4629; Tageldin et al., 15-4371; Vedagiri and Killi, 15-4161). The research on proactively estimated risk is examined in five papers (Gaca and Kiec, 15-3393; Lorion and Persaud, 15-5028; Mousavi et al., 15-4431; Sahukara and Vedagiri, 15-2238; Saulino et al., 15-4968). An important and challenging topic of estimating the potential crash severity from traffic conflicts is represented by three papers (Ni and Wang, 15-3010; Pin et al., 15-0827; Yue et al., 15-2978). 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. Twenty-nine are associated with **conflicts** (Azab et al., 15-1849; Bai et al., 15-0845; Essa and Sayed, 15-0707; Hajiseyedjavadi et al., 15-3480; Hutton et al., 15-4794; Kassim et al., 15-5319; Li et al., 15-4892; Lorion and Persaud, 15-5028; Lund et al., 15-1599; Ni and Wang, 15-3010; Osama et al., 15-2461; Pin et al., 15-0827; Roach et al., 15-5207; Sacchi and Sayed, 15-0622; Sadeq and Sayed, 15-2686; Sahukara and Vedagiri, 15-2238; Saulino et al., 15-4968; So et al., 15-4002; St-Aubin et al., 15-4629; St-Aubin et al., 15-5317; Stipancic and Miranda-Moreno, 15-1340; Tageldin et al., 15-4371; Tang et al., 15-0408; Tao et al., 15-3635; Vedagiri and Killi, 15-4161; Wang and Stamatiadis, 15-2628; Xu et al., 15-2993; Yue et al., 15-2978; Zangenehpour et al., 15-4903). In addition, there are nine papers related to **speed** (Fernandes et al., 15-1526; Gaca and Kiec, 15-3393; Hall et al., 15-4277; Kuang et al., 15-3871; Mousavi et al., 15-4431; Munehiro et al., 15-1468; St-Aubin et al., 15-5317; Stipancic and Miranda-Moreno, 15-1340; Tageldin et al., 15-4371).

Time-to-collision and **post-encroachment time** are the most frequently used indicators of traffic conflicts (Essa and Sayed, 15-0707; Hutton et al., 15-4794; Kassim et al., 15-5319; Li et al., 15-4892; Osama et al., 15-2461; Roach et al., 15-5207; Sahukara and Vedagiri, 15-2238; St-Aubin et al., 15-4629; St-Aubin et al., 15-5317; Stipancic et al., 15-1339; Stipancic and Miranda-Moreno, 15-1340; Tageldin et al., 15-4371; Tang et al., 15-0408; Vedagiri and Killi,

15-4161; Yue et al., 15-2978; Zangenehpour et al., 15-4903). Another criterion used is **deceleration** or **jerk** (Gaca and Kiec, 15-3393; Kuang et al., 15-3871; Mousavi et al., 15-4431; Tageldin et al., 15-4371). Three papers considered the frequency or risk of **red light running** in relation to safety evaluation or identification of troublesome locations (Jahangiri et al., 15-2910; Park et al., 15-3059; Sun et al., 15-3723). **Lane-keeping** was also used (Mehta et al., 15-2150).

In terms of data sources and techniques, multiple methods were utilized. **Field observations**, which included video-based observations in many cases, were used in thirty-two papers (Azab et al., 15-1849; Bai et al., 15-0845; Brewer et al., 15-1292; Essa and Sayed, 15-0707; Gaca and Kiec, 15-3393; Hajiseyedjavadi et al., 15-3480; Hall et al., 15-4277; Jahangiri et al., 15-2910; Jeong et al., 15-0533; Kassim et al., 15-5319; Kuang et al., 15-3871; Li et al., 15-4892; Lund et al., 15-1599; Mehta et al., 15-2150; Mohamed and Saunier, 15-6018; Osama et al., 15-2461; Park et al., 15-3059; Pin et al., 15-0827; Roach et al., 15-5207; Sacchi and Sayed, 15-0622; Sadeq and Sayed, 15-2686; St-Aubin et al., 15-4629; St-Aubin et al., 15-5317; Stipancic et al., 15-1339; Sun et al., 15-3723; Tageldin et al., 15-4371; Tang et al., 15-0408; Tao et al., 15-3635; Wang and Stamatiadis, 15-2628; Xu et al., 15-2993; Yue et al., 15-2978; Zangenehpour et al., 15-4903). Also popular were **simulation**-related tools, utilized in twelve papers (Essa and Sayed, 15-0707; Fernandes et al., 15-1526; Hajiseyedjavadi et al., 15-3480; Jeong et al., 15-1756; Moreno et al., 15-1767; Park et al., 15-3059; Roach et al., 15-5207; Saulino et al., 15-4968; So et al., 15-4002; Songchitruksa and Zha, 15-1309; Tao et al., 15-3635; Xu et al., 15-2993). **Naturalistic driving**-related data were important in two papers (Hutton et al., 15-4794; Mousavi et al., 15-4431) and **driver simulators** (Thapa et al., 15-1291), **survey** (Lund et al., 15-1599), and other methods (Munehiro et al., 15-1468) for one paper each.

Certain topics particularly stand out among this year's papers. Twenty-nine papers dealt with **intersection safety** (Azab et al., 15-1849; Bai et al., 15-0845; Essa and Sayed, 15-0707; Hall et al., 15-4277; Hutton et al., 15-4794; Jahangiri et al., 15-2910; Kassim et al., 15-5319; Lorion and Persaud, 15-5028; Lund et al., 15-1599; Mohamed and Saunier, 15-6018; Munehiro et al., 15-1468; Ni and Wang, 15-3010; Park et al., 15-3059; Pin et al., 15-0827; Roach et al., 15-5207; Sacchi and Sayed, 15-0622; Sadeq and Sayed, 15-2686; Sahukara and Vedagiri, 15-2238; Saulino et al., 15-4968; So et al., 15-4002; Songchitruksa and Zha, 15-1309; St-Aubin et al., 15-5317; Stipancic et al., 15-1339; Sun et al., 15-3723; Tageldin et al., 15-4371; Tang et al., 15-0408; Vedagiri and Killi, 15-4161; Yue et al., 15-2978; Zangenehpour et al., 15-4903). Fourteen papers examined safety and safety factors for **pedestrian, cyclists, and motorcycles** using surrogate measures (Azab et al., 15-1849; Bai et al., 15-0845; Brewer et al., 15-1292; Fernandes et al., 15-1526; Gaca and Kiec, 15-3393; Kassim et al., 15-5319; Mehta et al., 15-2150; Ni and Wang, 15-3010; Pin et al., 15-0827; Stipancic et al., 15-1339; Tageldin et al., 15-4371; Xu et al.,15-2993; Yue et al., 15-2978; Zangenehpour et al., 15-4903). The safety impact and other safety-related aspects of **signage and control devices** were studied with methods involving surrogates measures in nine papers (Brewer et al., 15-

1292; Hajiseyedjavadi et al., 15-3480; Lund et al., 15-1599; Montella et al., 15-0811; Moreno et al., 15-1767; Park et al., 15-3059; Tao et al., 15-3635; Xu et al., 15-2993; Zangenehpour et al., 15-4903), while reduction in **speed** as an indirect indicator of safety improvement was studied or used in four papers (Montella et al., 15-0811; Stipancic and Miranda-Moreno, 15-1340; Sahukara and Vedagiri, 15-2238; Yue et al., 15-2978).

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Sponsoring Committee	AHB40, Highway Capacity and Quality of Service
Session Number	592
Session Title	Highway Capacity Analysis for Interrupted Facilities
Paper Number	15-0408
Paper Title	Risk-Taking Behavior of Left-Turners in Gap Acceptance and Its Effects on Capacity Estimation at Signalized Intersections
Abstract	Capacity of signalized intersections with the permissive left-turn phase is influenced significantly by the gap acceptance of left-turners. Risk perception of left-turners when deciding to accept a gap or not is of great importance for understanding such type of driver behavior and developing intersection improvement countermeasures. The objective of this study is thus to model the tradeoff relationship between the perceived risk and the time-saving benefit in the gap acceptance for left-turners at signalized intersections in China. In the proposed model, the perceived risk is measured by the Post Encroachment Time (PET) of the left-turn vehicle and the gap-ending through vehicle at the conflict, and the time-saving benefit is indicated by the potential time to wait for the next acceptable gap. A gap acceptance model that incorporates both of the variables was then developed and validated using the data collected at two intersections in Shanghai. The acceptable risk level of left-turners can then be defined as the ratio of the estimated model coefficients of those two variables. Results indicate that the time-to-wait significantly affects the gap acceptance and the critical gap decreases as the acceptable risk level rises. In addition, it was found that the acceptable risk level appeared to be approximately 60 at the observed intersections. Based on the results, impacts of the acceptable risk level on the capacity of permissive left-turn traffic were then investigated through a numerical study. The findings reveal that the capacity of permissive left-turn traffic could be stochastic in nature rather than constant, due to the random traffic flow characteristics as well as the different risk perceptions of drivers.

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Sponsoring Committee	ABJ50, Information Systems and Technology ABJ60, Geographic Information Science and Applications
Session Number	377
Session Title	Information Technology Applications in Transportation 2015
Paper Number	15-0533
Paper Title	Real-Time Road Safety Information System Based on Monitoring Individual Vehicle Maneuverings: Methodology and Field Demonstration
Abstract	This study proposes a novel framework to evaluate the real-time level of road safety based on connected vehicle technologies including in-vehicle sensors, and vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communication. An integrated safety monitoring index (ISMI) that incorporates a crash risk estimation model and a method to analyze hazardous driving events using individual vehicle maneuvering data are developed. The methodology and field implementation presented in this study have potential value to highway traffic agencies for monitoring and evaluating traffic streams with a focus on road traffic safety. The outcomes of the proposed system can be used to analyze traffic conditions before or after a crash, and this analysis can inform effective countermeasures for preventing crash occurrences. In addition, ISMI data stored on a database in the traffic management center can be archived and further analyzed using reported crash data. Another possible application outcome would be to use the data as a resource to identify crash-prone locations in a more active manner, rather than waiting until after actual crashes occur.

Authors	Emanuele Sacchi, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada
Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-0622
Paper Title	Bayesian Estimation of Conflict-Based Safety Performance Functions
Abstract	Most of the current research on road safety relies on the analysis of collision data which is challenged by well-recognized availability and quality issues. Therefore, the use of surrogate safety measures such as traffic conflicts has been gaining acceptance as an alternative or complementary approach to analyze traffic safety from a broader perspective than collision data alone. However, there is a need to develop statistical techniques to analyze conflict data to support various road safety applications. This paper discusses the development of conflict-based safety performance functions (SPFs) within the framework of Bayesian statistics. The Bayesian approach was selected as it represents the state-of-the-art technique in the statistical analysis of collisions. In particular, SPFs were developed to predict the number of rear-end conflicts at different intersection approaches. The functions were validated using posterior predictive checking indicators. Data for traffic conflict observations were automatically extracted with computer vision techniques at several urban and suburban intersections in British Columbia (Canada). The results indicate that the models developed have a good fit of the observed conflict data and can offer a useful tool for conducting safety analysis.

Authors	Mohamed Ahmed Essa, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-0707
Paper Title	Simulated Traffic Conflicts: Do They Accurately Represent Field-Measured Conflicts?
Abstract	Recently, there has been a growing interest in using micro-simulation models for the safety assessment of road facilities by analyzing vehicle trajectories and estimating conflict indicators. Using micro-simulation in safety studies can have several advantages. However, concerns have been raised about the ability of these models to realistically represent unsafe vehicle interactions and near misses and the need for a rigorous model calibration. The main objective of this study is to investigate the relationship between field-measured and simulated conflicts at an urban signalized intersection in Surrey, BC. Sixty hours of recorded traffic data in two days were collected and used in the conflict analysis. Automated video-based computer vision techniques were used to extract vehicle trajectories and identify conflicts on all four approaches of the intersection. Conflict measures (e.g. time-to-collision (TTC)) and location were determined and compared with simulated conflicts from a microscopic simulation model (VISSIM) using the Surrogate Safety Assessment Model (SSAM). A two-step calibration procedure was proposed to enhance the correlation between simulated and field-measured conflicts. The first calibration step consists of matching actual field conditions (desired speed and arrival type) to ensure that VISSIM gives real average delay values. The second step was to use sensitivity analysis followed by a Genetic Algorithm (GA) procedure to calibrate VISSIM parameters which have the biggest effect on the simulated conflicts. Finally, conflict heat maps were provided to compare field measured and simulated conflict locations. The results highlighted the importance of model calibration and identified several limitations of the SSAM.

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Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	471
Session Title	Impacts of Traffic Control Devices on Speed and Road User Behavior
Paper Number	15-0811
Paper Title	Effects of traffic control devices on rural curves driving behaviour
Abstract	The paper investigates by means of a dynamic driving simulator experiment drivers' behaviour at curves of rural two-lane highways in relation to different advance warning signs, perceptual measures, and delineation treatments. The tested treatments were intended to alert drivers of the presence of low radius curves and to affect their behaviour both in the curve approach as well as along the curve. Study results showed that the advance warning signs, the perceptual measures, and the delineation treatments tested in the driving simulator experiment produced significant effects on drivers' behaviour. The perceptual treatments, i.e. the coloured transverse strips, the dragon teeth markings, and the coloured median island, were the most effective since they produced significant speed reductions both in the approach tangent as well as inside the curve. Furthermore, the deceleration behaviour in the curve approach was significantly affected by the presence of the treatments that helped the drivers to detect the curve earlier providing more time to perform deceleration manoeuvres with lower rates. The study results strongly support the real world implementation of the coloured transverse strips, the dragon teeth markings, and the coloured median island. Implementation of the tested measures should be conducted on similar rural highways to validate the generalization of the results of this study to other regions.

Authors	Calvin Pin, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada Mohamed H. Zaki, University of British Columbia, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	476
Session Title	Prevention and Modeling of Severe Crashes
Paper Number	15-0827
Paper Title	Assessing Safety Improvements of Pedestrian Crossing Using Automated Conflicts Analysis
Abstract	Surrogate safety measures such as the traffic conflict technique (TCT) have been promoted as an alternative or complementary approach to evaluate road safety from a broader perspective than collision statistics alone. One safety application that can significantly benefit from the use of surrogate safety measures is the before-and-after (BA) evaluation of safety treatments. This study demonstrates the use of automated traffic conflict analysis to conduct before-and-after (BA) safety evaluations. The objective is to conduct a time-series (before-to-after) safety evaluation for an intersection in the City of Surrey where several pedestrian related countermeasures were implemented. The treatments included one or more of the following: use of protected only turns for left turning vehicles; installing pedestrian countdown timers; crosswalk realignment; and the use of drop down sidewalks. The results indicated a significant decrease in both pedestrian conflicts frequency and severity at the intersection following the treatments. A greater reduction of conflicts was exhibited on the western portion of the intersection where several countermeasures including a protected left turn phase, dual drop down ramps, and shifting the crosswalk further west were implemented. This variation in conflict reduction along different segments of the same intersection gives a particularized view on the impact of the adopted countermeasures. The outcome of this research provides evidence that surrogate safety indicators can effectively be used to diagnose safety problems and evaluate countermeasures at intersections.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-0845
Paper Title	Understanding Factors Affecting Frequency of Traffic Conflicts between Electric Bicycles and Motorized Vehicles at Signalized Intersections
Abstract	The primary objective of the study was to identify the influence factors to traffic conflicts between electric bicycles and motorized vehicles at signalized intersections. Data were collected at twenty sites in the Kunming area in China. Three predominant types of traffic conflicts, which accounted for more than 75% of the total conflicts at the selected sites, were identified. Conflict models were developed to relate the frequency of traffic conflicts to various explanatory variables. Three types of models were compared, including the fixed-effect, the random-effect and the random-parameter generalized linear regressions models. It was found that the random-parameter models provided the best goodness-of-fit to field data. By analyzing the elasticity of the explanatory variables, it was concluded that motorized vehicles played a more important role on conflict occurrences at signalized intersections than two-wheeled vehicles do. The presence of e-scooters had a considerably negative influence on the safety of signalized intersections, while the presence of e-bikes had a minor effect on the safety of signalized intersections. The present of traffic channelization and barrier between motorized vehicles and bicycle lanes significantly reduces traffic conflicts between two-wheeled and motorized vehicles at signalized intersections.

Authors	Raju Thapa, Louisiana State University Julius Atta Codjoe, Louisiana State University Sherif Ishak, Louisiana State University Kevin S. McCarter, Louisiana State University
Sponsoring Committee	AND10, Vehicle User Characteristics
Session Number	541
Session Title	Distracted Driving: Methods, Patterns, and Impact
Paper Number	15-1291
Paper Title	Investigating Protracted Effect of Cell Phone Use on Distracted Driving
Abstract	A number of studies have been done in the field of driver distraction, specifically on the use of cell phone for either conversation or texting while driving. However, till now, researchers have focused on the driving performance of drivers when they were actually engaged in the task. The primary objective of this paper is to analyze the post event effect of cell phone usage (texting and conversation) in order to verify whether the distracting effect lingers on after the actual event had ceased. It utilizes a driving simulator study of thirty-six participants to test whether a significant decrease in driver performance occurs during cell phone usage and after the usage. Surrogate measures used to represent lateral and longitudinal control of the vehicle were standard deviation (SD) of Lane Position and Mean Velocity respectively. Results suggest there were no significant decrease in driver performance (both lateral and longitudinal control) during and after the cell phone conversation. For the texting event, there were significant decreases in driver performance in both the longitudinal and lateral control of the vehicle during the actual texting task. The diminished longitudinal control ceased immediately after the texting event but the diminished lateral control lingered on for an average of 3.38 seconds. The result indicates that the distraction and subsequent elevated crash risk of texting while driving linger on even after the texting event has ceased. Such finding has safety and policy implications in the fight to reduce distracted driving.

Authors	Marcus A. Brewer, Texas A&M Transportation Institute Kay Fitzpatrick, Texas A&M Transportation Institute Raul E. Avelar, Texas A&M Transportation Institute
Sponsoring Committee	ANF10, Pedestrians
Session Number	625
Session Title	Evaluation of Innovative Pedestrian Crossing Treatments
Paper Number	15-1292
Paper Title	Pedestrian and Driver Behavior Before and After Installation of Rectangular Rapid Flashing Beacons or Pedestrian Hybrid Beacons
Abstract	As part of a recent research project on countermeasures for pedestrian crashes in Texas, researchers conducted a before-and-after field study at four sites with rectangular rapid-flashing beacons (RRFBs) and one site with a pedestrian hybrid beacon (PHB) to identify changes in driver yielding and selected pedestrian behaviors resulting from installing these treatments at previously untreated crosswalks. The installations resulted in noticeable improvement in the proportion of yielding vehicles, with increases of 35 to 80 percentage points, at the study sites. Most (94 percent) of the non-staged pedestrians activated the treatment at treated sites. An increase in the number of non-staged pedestrian crossings was observed after the PHB was installed at the study site. Near-side yielding rates were higher for non-staged pedestrians who waited at the edge of the travel lane than those waiting at the top of the curb ramp. Pedestrian searching behavior for crossings not controlled by a crossing guard was common, with 92 percent looking at least one direction, and 68 percent looking in both directions at least once.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-1309
Paper Title	Assessment of Safety Performance Monitoring at Signalized Intersections Using Connected-Vehicle Vehicle-to-Infrastructure Data
Abstract	This study assesses the viability and effectiveness of long-term safety performance monitoring application via vehicle-to-infrastructure data within a connected vehicle platform. As limited saturation of on-board equipment (OBE) is expected in the near-term evolution, this study focuses on a connected vehicle application that can process data elements from vehicle-to-infrastructure (V2I) communications using standard dedicated short-range communications (DSRC) message sets for safety evaluation purposes. This paper first describes an algorithm for extracting surrogate safety indicators from V2I message sets. To evaluate the algorithm's performance, we created a signalized intersection test bed in VISSIM microscopic simulation while using Car-to-Devices (C2X) Application Programming Interface (API) to model wireless communications capability. Then, we analyzed the effectiveness of the monitoring application in detecting the changes in safety performance of the signal operation with respect to varying market penetration rates and observation periods. Sensitivity analysis showed that at least 40% penetration rate is desirable for reliable safety deficiency detection under light to moderate traffic volume condition. The observation period can be extended to compensate for low sample size under low OBE market penetrations. The required observation periods vary with the types of safety indicators being collected and the levels of OBE saturation.

Authors	Joshua Stipancic, McGill University, Canada Sohail Zangenehpour, McGill University, Canada Luis Fernando Miranda-Moreno, McGill University, Canada
Sponsoring Committee	ABE30, Transportation Issues in Major U.S. Cities ABE70, Women's Issues in Transportation ANF20, Bicycle Transportation
Session Number	527
Session Title	Understanding the Gender Gap in Urban Biking, Part 1 (Part 2, 735)
Paper Number	15-1339
Paper Title	Segmented Ordered Logit Analysis of Gender and Bicycle-Vehicle Conflict Occurrence at Urban Intersections
Abstract	The relative lack of safety for cyclists in North America demands attention from transportation professionals. Traffic crash modelling is one tool for evaluating the factors that contribute to cyclist risk, though traditional safety models calibrated with crash data require crashes to occur before causes can be identified and countermeasures can be implemented. Although surrogate safety measures have diminished reliance on crash data, surrogate techniques have yet to be integrated with traffic crash models. The purpose of this study is to estimate a segmented ordered logit model for bicycle-vehicle conflict occurrence to evaluate the impact of gender on cyclist risk at urban intersections with cycle tracks.Video data was collected at two sites in Montreal, Canada. Road users were extracted, classified, and filtered using open-source computer vision software to yield 762 interactions for analysis. Creation of the discrete choice variable was achieved by dividing post-encroachment time (the chosen surrogate measure) into normal interaction, conflict, and dangerous conflict. Independent variables reflecting attributes of the cyclist, vehicle, and environment were extracted by both automated and manual techniques. Results indicated that an ordered model is appropriate for analyzing traffic conflicts. Furthermore, segmentation was beneficial in comparing different segments of the population within a single model. Male cyclists, with all else being equal, were less likely than female cyclists to be involved in conflicts and dangerous conflicts at the studied intersections. These results will contribute to and further the understanding of gender differences in cycling within North America.

Authors	Joshua Stipancic, McGill University, Canada Luis Fernando Miranda-Moreno, McGill University, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-1340
Paper Title	Traffic Parameter Methods for Surrogate Safety Comparative Study of Three Mobile Sensor Technologies
Abstract	Although maintaining adequate levels of safety is a universal requirement for modern road networks, the preferred techniques for defining and quantifying safety remain debated. Traditional studies have frequently relied on crash data as a method for assessing safety, though crash-based methods are reactive, requiring crashes to occur before causes can be identified and countermeasures can be implemented. In response, surrogate safety measures, non-crash measures that are physically and predictably related to motor vehicle crashes, have become popular. Existing work has predominantly focused on traffic parameter data collected by loop detectors, without comparison of surrogate measures reported by different detection technologies. The purpose of this paper is to evaluate how three mobile traffic sensors, microwave radar, plate magnetometer, and video-based devices, report safety surrogate measures. The surrogates considered included conflicts (measured by time-to-collision, TTC), temporal speed variation (measured by the coefficient of variation of speed, CVS), and lateral speed variation (measured by the average difference in speed, ΔS). For rear-end TTC, the video-based sensor reported relatively more conflicts than the radar and magnetometer, which performed similarly. CVS calculated from radar data was consistently higher than for the video. These measures are largely influenced by the overestimation bias in speed measurement present in video-based data. Utilizing the average difference in speed across lanes to quantify lateral speed variation is independent of mean speed, the overestimation bias of the video is inconsequential, and the results from the radar and video detectors are similar as expected.

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Sponsoring Committee	ANB75, Roundabouts
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-1468
Paper Title	Driving Behavior and Travel Path of Semi-trailers on Roundabouts
Abstract	In planning at local levels roundabouts have been promoted strongly on local Japanese roads. As future development, planning and dissemination of a high-standard highway is expected, but the safety verification of large vehicles traveling on them is required. A compact single-lane roundabout was placed in Tomakomai-Test Track of Hokkaido, the present study reports the experiment results of the behavior and travel path during driving, in 2012 and 2013. The outer diameter of the roundabout, was varied in the range of 26 ~ 40m. Road surface conditions were dry surface and compacted-snow road surface. The semi-trailer was equipped with high-precision GPS devices; the travel paths were measured. The experimental results from the compact single-lane roundabout of outer diameter in the range of 26 ~ 40m with dry surface, confrimed that the tractor unit with speed of approximately 15km/h exhibited a satisfactory speed inhibitory effect and, with trailer unit at approximately 10km/h. Considering the maximum transverse acceleration of the semi-trailer, a higher variation of 0.10 ~ 0.29G was observed with outer diameter of 26m, but a smaller variation of 0.16 ~ 0.22G was observed with outer diameter of 40m. In addition, the travel paths of the semi-trailer on the roundabout were able to be measured from high precision GPS data.

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Sponsoring Committee	ANB75, Roundabouts
Session Number	419
Session Title	Examining Roundabouts: A Closer Look at Access Management, Crosswalks and Trucks
Paper Number	15-1526
Paper Title	Multi-criteria Assessment Of Crosswalk Location In Urban Roundabout Corridors
Abstract	Mid-block pedestrian crossing areas between closely-spaced roundabouts can have an effect on traffic operations and could result in a trade-off among capacity, environment, and safety. Although research on the impacts of traffic performance on pedestrian crosswalks located at isolated roundabouts has been conducted, very few studies have focused on how traffic operations are impacted by pedestrian crosswalks between adjacent roundabouts in close proximity. This study examined the integrated effect of a pedestrian crosswalk at different locations between closely-spaced two-lane roundabouts on traffic delay, CO2 emissions and relative speed between vehicles and pedestrians by using a microsimulation approach. The main purpose of the research was to develop a simulation platform of traffic (VISSIM), emissions (Vehicle Specific Power - VSP) and safety (Surrogate Safety Assessment Methodology - SSAM) in order to optimize such variables. The Fast Non-Dominated Sorting Genetic Algorithm (NSGA-II) was mobilized to identify a set of optimized pedestrian crosswalk locations for the roundabout exit section along the mid-block segment. The results indicated that locating the crosswalk at 15, 20 and 30 meters from the exit section seemed to be an acceptable solution, providing a good balance among traffic performance, emissions and pedestrians' safety. It was also observed that even at low pedestrian demands, the effectiveness of the crosswalk, in terms of capacity and environment, gradually decreased when located near the circulatory ring delimitation (<10 meters). The findings suggested that crosswalks at mid-block segment (55/60 meters from the exit section) must be also taken into account, especially under high traffic demands.

Authors	Victor Lund, St. Louis County Public Works Taek Mu Kwon, University of Minnesota, Duluth Husam Ibraim Ismail, University of Minnesota Duluth
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	593
Session Title	Traffic Control Device Research
Paper Number	15-1599
Paper Title	Evaluation of the ALERT System, a Rural Intersection Conflict Warning System
Abstract	Rural, two-way stop-controlled intersections account for a significant portion of serious crashes on the rural highway system. The risk of crashes for this type of intersection is elevated when there is restricted intersection sight distance due to highway geometrics. This paper presents the findings of the second phase of the study on the development of a new rural intersection conflict warning system referred to as the Advanced LED Warning System for Rural Intersections (ALERT). The ALERT System consists of solar powered vehicle detectors and LED blinker warning signs on both the major and minor approaches that warn drivers of a potential conflict at the intersection. Driver behavior before and after the system was installed was observed through video data. The ALERT System in this second phase (ALERT 2) was able to replicate the surrogate traffic safety benefits of the ALERT System of the first phase (ALERT 1). There were also two additional key findings from the second phase of this study. First, the ALERT 2 System maintained its operations throughout the entire northern Minnesota winter where temperatures are regularly below 0° Fahrenheit and there is limited sun light. Second, the observed effect of drivers treating this system like a de-facto traffic signal was mitigated by adding blinker STOP signs to the minor approaches. And finally, the results of a survey of local residents suggest most drivers understand the system and believe it has improved safety.

Authors	Eunbi Jeong, Hanyang University, South Korea Cheol Oh, Hanyang University, South Korea
Sponsoring Committee	AHB30, Vehicle-Highway Automation AL040, Emerging Technology Law
Session Number	469
Session Title	Recent Progress in Vehicle-Highway Automation
Paper Number	15-1756
Paper Title	Evaluating the Effectiveness of Integrated Active Vehicle Safety Systems
Abstract	Advanced vehicle safety systems have been widely introduced in transportation systems and are expected to enhance traffic safety. However, these technologies mainly focus on assisting individual vehicles that are equipped with them, and less effort has been made to identify the effect of vehicular technologies on the traffic stream. This study proposed a methodology to assess the effectiveness of active vehicle safety systems (AVSSs), which represent a promising technology to prevent traffic crashes and mitigate injury severity. An integrated AVSS, which consists of an adaptive cruise control (ACC), an automatic emergency braking system (AEBS), and a blind-spot detection system (BSDS), was evaluated based on the proposed technology in terms of crash potential reduction and congestion mitigation. A microscopic traffic simulator, VISSIM, was used to simulate freeway traffic stream and collect vehicle-maneuvering data. In addition, an external application program interface, VISSIMi¯s COM-interface, was used to implement the integrated AVSS. A surrogate safety assessment model (SSAM) was used to derive indirect safety measures to evaluate the effectiveness of the integrated AVSS. For the non-incident conditions, the rear-end and lane-change conflicts were reduced by 78.8% and 17.3%, respectively, under the level of service (LOS) D traffic conditions. In addition, the average delay was reduced by 55.5%. However, the systemi¯s effectiveness was weakened in the LOS A-C categories. Under incident traffic conditions, the number of rear-end conflicts was reduced by approximately 9.7%. Vehicle delays were reduced by approximately 43.9% with 100% MPR. These results imply that from the perspective of traffic operations and control to address the safety and congestion issues of a traffic stream, smarter management strategies that consider both traffic conditions and MPR are required to fully exploit the effectiveness of the integrated AVSS in the field.

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Sponsoring Committee	AHB65, Operational Effects of Geometrics
Session Number	472
Session Title	Operational and Safety Effects of Geometric Designs
Paper Number	15-1767
Paper Title	Minimum Passing Zone Length Design Criteria Considering Operational and Safety Impacts
Abstract	Passing zones are provided to improve operational efficiency of two-lane highways where passes can be performed safely. Minimum passing zone lengths of 120 m were established in MUTCD and Green Book, although some studies indicate a potential need to increase them. However, no changes have been recommended pending further research on the safety of short passing zones. The objective of this study is to develop design and marking criteria for minimum passing zone lengths considering their operational efficiency and safety. On one hand, a traffic microsimulation was carried out with Aimsun software. The calibration and validation included the observation of 1,750 passing maneuvers in Spain. The results indicate that passing zones shorter than 250 m add very little to operational efficiency. On the other hand, a reliability analysis was applied. It quantified the probability that a passing maneuver was completed beyond the end of the passing zone (non-compliant passing maneuvers). Afterwards, the number of non-compliant passing maneuvers was calculated. It depended on traffic flow as well as passing zone length. The minimum passing zone length should be increased at least to 300 m, for high traffic volumes, 350 m for medium traffic volumes and 400 m for low traffic volumes. From this length, the number of non-compliant passing maneuvers decreases. The marginal increase in the minimum length of passing zones can potentially improve safety without reducing much operational efficiency. The results can be directly used by practitioners to establish the minimum passing zone length based on the range of hourly volumes and the level of risk willing to assume.

Authors	Mohamed Hussein Azab, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada Passant Reyad, University of British Columbia Lee Kim, AKRF Inc
Sponsoring Committee	ANF10, Pedestrians
Session Number	513
Session Title	Pedestrian Safety Evaluation and Measurement
Paper Number	15-1849
Paper Title	Automated Pedestrian Safety Diagnosis and Behavioural Study at a Signalized Intersection in New York City
Abstract	Automated Computer vision video analysis techniques were used to analyze two hours of video data collected at a major signalized intersection in New York City. The main objectives of this study were to: 1) diagnose pedestrian safety issues and identify contributing factors at the intersection; and 2) demonstrate the feasibility of the automatic extraction of pedestrian data required for pedestrian behaviour analysis—mainly pedestrian speed and gait parameters. The safety study was conducted using the traffic conflict techniques (TCT). It was observed that the main factor that contributes to the high number of pedestrian-vehicle conflicts is pedestrian violations, mainly temporal violation where pedestrians cross the street during “Flashing Don’t Walk” or “Don’t Walk” phase. During the two hours analyzed, about one-third of pedestrians were non-compliant with the signal timing or crosswalk boundary: 17.9% were spatial violations and 15.3% were temporal violations. Furthermore, the pedestrian speed, step frequency, and step length were automatically extracted for 333 pedestrians. These three parameters were found to follow the normal distribution with 95% confidence with mean and standard deviation (1.47 ± 0.27 m/s), (1.96 ± 0.17 Hz), and (0.75 ± 0.14 m), respectively. Gait analysis shows that the walking speed for single pedestrians is 9% higher than those who walk in groups. Males tend to be slightly faster than females with higher step length but lower step frequency. Violators tend to have higher walking speed compared to non-violators and the difference in speed is dependent on step length but not on step frequency.

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Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	817
Session Title	Bicycling Perspective on Roadway Design and Operations
Paper Number	15-2150
Paper Title	Analysis of Lateral Distance Between Motorized Vehicles and Cyclists During Overtaking Maneuvers
Abstract	This paper evaluates the influence of on-street bike lanes on the lateral separation between motor-vehicles and cyclists at the time the vehicle overtakes the cyclist and investigates the relationship between the passing behavior and traffic conditions. A bike was instrumented with a sensor array consisting of an ultrasonic sensor, a GPS receiver, and a video camera, and a total of 5,227 passing events were recorded across different categories of urban arterials. The results show that the facilities with on-street bike lanes provide greater separation between bicycles and motor-vehicles. Passing maneuvers with lateral separation of less than 1,000 mm (3.30 ft), were observed less frequently on the facilities with on-street bike lanes. Furthermore, it was found that in the absence of bike lanes a higher proportion of passing vehicles moved laterally to their left and encroached on the adjacent lane. The analysis showed that for arterial roadways without on-street bike lanes, drivers tend to attempt to provide increased lateral clearance by either changing lanes or encroaching on the adjacent lane. However, their ability to do either of these maneuvers may be restricted by surrounding vehicles.

Authors	Shekhar Babu Sahukara, College of Military Engineering, India Perumal Vedagiri, Indian Institute of Technology, Bombay
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-2238
Paper Title	Proactive Safety Evaluation of Unsignalized Intersection Using Surrogate Measures
Abstract	Road traffic safety is emerging as an area of increased attention and concern in many countries including India. Several countermeasures are being practiced across the world to improve traffic safety. To evaluate the impact of these measures on safety many predictive methods are suggested by several researchers. Safety evaluation by conflict technique using surrogate safety measures is a faster and resource effective method. This does not require any accident data, hence is a proactive method of safety evaluation. Safety evaluation can be made using any surrogate measure like Post Encroachment Time (PET). Post Encroachment Time is defined as the time lag between the passages of offending vehicle and conflicting vehicle on a conflict zone. The critical conflicts are determined based on certain threshold value of PET. Many researchers have used different threshold values for these indicators ranging from 1s to 5s. There is no specific value defined which can be used to determine critical conflicts. In the present study safety evaluation of an unsignallised intersection is carried out determining Post Encroachment Time (PET) and the speed of conflicting vehicle. Determination of critical conflicts is made based on PET values, the speeds of conflicting vehicles and corresponding critical speed. A term critical speed is proposed in this study which is determined by using braking distance concept. The concept and logic of evaluation of safety using PET as surrogate safety indicator, speed of conflicting vehicles and the critical speed are described in the paper. Using the above concept the safety evaluation of an unsignallised intersection in Thane city has been carried out. The results show that there are significant percent of conflicts which are critical and hence there is high probability of accidents at the intersection. As the crossing maneuver depends on the acceleration and speed of vehicle, the effect of type of vehicle has also been studied. The results show that the crossing TW is at higher risk at the intersection. Thus safety evaluation of any unsignallised intersection may be carried out using the above concept.

Authors	Ahmed Osama, University of British Columbia Tarek Sayed, University of British Columbia, Canada Mohamed H. Zaki, University of British Columbia, Canada Khaled Shaaban, Qatar University
Sponsoring Committee	ANB75, Roundabouts
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-2461
Paper Title	Automated Approach for a Comprehensive Safety Assessment of Roundabouts
Abstract	This paper provides a framework for analyzing safety issues at roundabouts. An automated safety analysis approach is used to detect different types of traffic conflicts, as well as the inappropriate negotiations and the gap acceptance behavior of drivers. To test the validity of the proposed method, a case study is used for a roundabout in Doha, Qatar. Seven types of traffic conflicts are studied and their severity identified using the time to collision measure. Four common types of driver inappropriate negotiations behavior are also investigated. The analysis shows that most of the inappropriate negotiations and traffic conflicts are due to drivers' poor lane discipline which can be partially attributed to the poor lane marking. Gap acceptance behavior is also studied by identifying lead, lag and total gaps. The traffic conflicts, inappropriate negotiations, and gap acceptance results are validated by comparison with manual observations. The results of the validation process show the viability of the automated approach which produces acceptable results with less time and effort. Moreover, the data gathered using this approach provides further insights on roundabouts safety evaluation and has the potential for the assessment of roundabout design.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-2628
Paper Title	Sensitivity Analysis of New Simulation-Based Conflict Metrics
Abstract	The Conflict Propensity Metric (CPM) and the Aggregate Conflict Propensity Metric (ACPM) are two simulation-based conflict metrics recently proposed as surrogate safety measures. CPM is able to quantify crash probabilities of conflicts and ACPM captures relative safety levels of traffic facilities or treatments. The two metrics are derived through a stochastic process incorporating distributions of driver reaction time (RT) and vehicle maximum braking rates (MABR). This paper presents sensitivity analyses on the two metrics, by altering the parameters (i.e. mean and standard deviation) of RT distributions. Both RT mean and standard deviation affect the estimates of CPM for the three conflict types examined here (i.e. crossing, rear-end and lane change), and the impacts vary by conflict types, indicating the need of carefully evaluating and considering RT distributions and conflict types when developing simulation-based conflict metrics. A sensitivity analysis based on field data showed that different RT distributions have an impact on ACPM and could affect the reliability of ACPM in identifying relative safety as well as its correlation with actual crashes. The analysis here identified the "realistic" RT distributions for different conflict types and the suggested values are considered reasonable or consistent with prior findings. ACPM has proved to have potential to further improve its accuracy using more suitable RT distributions. However, dedicated RT distributions for different conflict types are lacking, impeding the improvement of ACPM. In general, sensitivity analyses have shown the validity of the process of deriving CPM and ACPM.

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Sponsoring Committee	ANB75, Roundabouts
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-2686
Paper Title	Automated Roundabout Safety Analysis: Diagnosis and Remedy of Safety Issues
Abstract	The use of roundabouts is gaining popularity in North America for their safety, capacity and environmental benefits. Studies have shown that roundabouts can significantly reduce injury collisions compared to stop controlled and signalized intersections. As more roundabouts are constructed, there will be an increased need for a detailed analysis of their safety performance. Traditional road safety analysis of roundabouts has relied on the use of historical collision records. This approach offers less complete understanding of roundabout safety issues and their effects on the behaviour of drivers, pedestrians and cyclists. This paper presents a case study where automated video-based traffic conflict analysis techniques are used to diagnose safety issues at a roundabout in Vancouver, British Columbia. Traffic conflicts are automatically identified and analyzed to develop an in-depth understanding of the behaviour of road users and the causes of traffic conflicts. Conflicts contributing factors were identified and several safety countermeasures were presented.

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Sponsoring Committee	ABJ70, Artificial Intelligence and Advanced Computing Applications
Session Number	234
Session Title	Artificial Intelligence and Advanced Computing Applications
Paper Number	15-2910
Paper Title	Predicting Red-light Running Violations at Signalized Intersections using Machine Learning Techniques
Abstract	Statistics demonstrate that a large number of crashes occur at signalized intersections due to traffic violations, specifically red light running (RLR). In order to prevent/mitigate intersection-related crashes, these violations need to be identified before they occur, so appropriate warnings can be issued. Several factors influence the drivers' behavior when approaching intersections. These include the vehicle speed, Time to Intersection (TTI), Distance to Intersection (DTI), age, gender, etc. However, the driver-related factors (i.e. age, gender) are more difficult to obtain in practice. On the other hand, kinetic factors (e.g. speed, acceleration) can be obtained by monitoring the movement of vehicles through video cameras installed on the infrastructure or through on-board devices installed on the vehicles. Hence, the problem of interest is to develop models to predict red light running (RLR) violations using kinetic information of individual drivers/vehicles. Machine learning techniques, namely Support Vector Machine (SVM) and Random Forest (RF), were adopted to develop prediction models. The minimum Redundancy Maximum Relevance (mRMR) feature selection technique was used to identify the most important factors for model development. To evaluate the performance of the models the K-fold cross-validation and out-of-bag (OOB) errors were used for the SVM and RF models, which contributed to high prediction accuracies of 96.7 and 94.2 percent, respectively. It was shown that other than the critical instant at which the traffic signal changes to yellow, an appropriate time window with respect to the yellow onset can provide additional useful information ensuring that the driver decision occurs during that time window.

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Sponsoring Committee	ANF30, Motorcycles and Mopeds
Session Number	478
Session Title	Modelling Traffic Flow for Motorcycles and Mopeds
Paper Number	15-2978
Paper Title	Characteristics of Moped Conflict with Other Vehicles at Intersections
Abstract	The conflict involved the moped at intersections has become a main problem for traffic safety in China. Previous researches mostly focus on the moped conflict frequency and the factors attribute to it, while this study concentrated on the typical moped conflict types and their characteristics. Moped conflicts can be divided by the conflict traffic direction, the conflict nature and the type of vehicles involved in conflict. The conflict characteristics include conflicting speed, distance-to-collision and time-to-collision. The research is based on 169 conflict samples extracted from 445 minutes of video recorded at 5 intersections in Shanghai. Firstly the research summarized the 4 main types of moped conflicts divided by the conflicting traffic direction and their characteristics. Significant differences exist in both distance-to-collision and time-to-collision between different conflict types. Results represent 3 types of conflicts is typical, the relationship between distance-to-collision and conflicting speed can be fitted by quadratic function. Secondly the comparison of moped conflicts with different nature reveals that there¡¯s no significant difference in conflict severity between conflicts caused by violation behaviors and normal conflicts caused by phase shared. Further analysis shows that there¡¯s no obvious change in riding characteristics of illegal riding mopeds and normal riding mopeds. Thirdly the vehicle types have great influence on moped conflicts: the distance-to-collision of moped-moped conflict is far shorter than that of moped-car conflict. Besides, the severity of the former is much worse than the latter. Countermeasures about the moped safety management at intersections are proposed.

Authors	Xin Xu, Southeast Universtiy, China Pan Liu, Southeast University, China Zhao Yang, Southeast University, China Wei Wang, Southeast University, China
Sponsoring Committee	ANF10, Pedestrians
Session Number	755
Session Title	Characteristics of Pedestrian Interactive Behaviors under the Different Level of Service on Walkways
Paper Number	15-2993
Paper Title	Multiobjective Evaluation of Midblock Crosswalks on Urban Streets Based on TOPSIS and Entropy
Abstract	This study presents a procedure for evaluating different treatments of mid-block crosswalks on urban streets considering multiple performance measures, including traffic operations, safety, environmental impacts and costs. Data were collected at sixteen mid-block crosswalks in the Nanjing area in China. VISSIM simulation models were developed and calibrated to evaluate the operational and environmental impacts of various mid-block crosswalk treatments. For a particular treatment the operational impacts was measured using the total control delay to vehicles on the major streets and pedestrians. Similarly, the environmental impacts were measured using vehicle emissions and fuel consumptions. The frequency of traffic conflicts at the influence area of crosswalks was considered the safety performance measure. The TOPSIS entropy evaluation method was then used to rank the performance of various treatments of crosswalks considering multiple performance measures. It was found that combining multiple objectives in decision making one may obtain different results with regard to the optimum treatments of crosswalks. The research results can be directly used by traffic engineers to select crosswalk treatments given traffic flow conditions and geometric design characteristics. The framework implemented in the study can also be used to estimate the impacts of other traffic projects considering multi-objective evaluation.

Authors	Ying Ni, Tongji University, China Menglong Wang, Tongji University, China
Sponsoring Committee	ANF10, Pedestrians
Session Number	284
Session Title	Pedestrian and Driver Behavioral Influences on Pedestrian Safety
Paper Number	15-3010
Paper Title	Behavior-based Method on Pedestrian-Vehicle Conflict Analysis at Intersections
Abstract	Pedestrians are the most vulnerable road users, and pedestrian safety has become a major research concern in recent years. Collision statistics alone provide insufficient information for pedestrian safety study because of data quality and quantity issues. To address this problem, surrogate safety measures were developed for pedestrian conflict analysis. However, conflict situations between pedestrians and vehicles are complex due to various interactions, and most existing research focused on solo or combined conflict indicators and set corresponding fixed thresholds, which are incapable of capturing all interactions accurately. This paper presents a new method for analyzing pedestrian-vehicle conflicts based on road user trajectories. A behavior-based methodology has been developed which combines conflict indictors with interactions to capture conflicts and identify conflict severity. Pedestrian-vehicle interactions are then classified into three types according to behavior features and dynamic changes in conflict indicators. Conflict detection rules and binary logistic models were developed to identify conflict severity in related to each behavior type. The methodology was applied to analysis of conflicts between pedestrians and turning vehicles at an intersection crosswalk under both good and poor visibility for pedestrians. The analysis found a close relationship among visibility conditions, interaction types, and conflict severity levels. The calculations exhibited good conformity with observation results, and the methodology has proven capable of revealing greater detail about traffic events while capturing conflicts and identifying conflict severity with high accuracy. The proposed methodology is compatible with existing automated pedestrian conflict analysis systems. A combination with automated trajectory analysis is currently under research.

Authors	Sung Yoon Park, University of Maryland, College Park Liu Xu, University of Maryland, College Park Gang-Len Chang, University of Maryland, College Park
Sponsoring Committee	AHB50, Traffic Control Devices
Session Number	593
Session Title	Traffic Control Device Research
Paper Number	15-3059
Paper Title	Design and Evaluation of an Advanced Dilemma Zone Protection System: Advanced Warning Sign and All-red Extension
Abstract	This paper presents the evaluation results for an intelligent dilemma zone protection system that integrates advanced warning signs with all-red extension strategies to reduce the number of red-light running vehicles and also to provide extra time to clear the intersection. To realistically reflect the driversj¯ response to the yellow phase, a behavioral model has been developed and calibrated with field data from six intersections. The calibrated behavioral model has been incorporated in VISSIM to generate the simulation platform for experimental analysis. Based on the well-calibrated simulation network, the study has conducted extensive simulation experiments and compared the proposed systemj¯s performance with other two designs based on the number of red-light runners and remaining all-red time for those running on red. The results indicate that the proposed system offers the best protections on safety measures. Sensitivity analyses have also been conducted to assess the impact on the number of red-light running vehicles if different locations are selected for the advanced warning sign and under the different traffic volumes.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	751
Session Title	Exploring Safety and Risk of Nonmotorized Vehicles
Paper Number	15-3393
Paper Title	Assessment of Pedestrian Risk at Crossing Using Kinematic-Probabilistic Model
Abstract	One of the primary road safety problems in Poland are accidents involving pedestrians. Accident statistics indicate a significant, 26.5% share of pedestrians in accidents and their effects, i.e. the number of the injured and killed pedestrians exceeds 1/3 of all accident fatalities. Many factors affect accidents involving pedestrians, such as those related to the road characteristics, speed or traffic volume. This paper presents a method with a surrogate safety measure, allowing assessment of the influence of various pedestrian crossings on road safety. The authors used surrogate measures of road safety risk assessment which included speed change when approaching a crossing. This assessment was carried out by applying kinematic modeling taking into account the fatality risk as a function of impact speed for pedestrians struck by the front of a passenger car and the initial vehicle speed. Initial speed was analyzed in relation to vehicle speeds recorded when approaching various pedestrian crossings with different signs and location. The analysis method allowed comparison of road safety on several different pedestrian crossings while taking into account a number of variables: lighting and surface conditions and distance, at which pedestrians are noticed in the moment when braking begins. Basing on the research results, levels of hazard caused by sudden pedestrian appearance on the road, depending on the type of infrastructure were evaluated. Values of ratio of probability of lack of road accident at compared types of pedestrian crossings were evaluated, as well as the probability of fatalities caused by intrusion on the pedestrian crossing.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3480
Paper Title	Application of Microsimulation to Model the Safety of Varied Lane Configurations at Toll Plazas
Abstract	Different configurations of electronic toll collection (ETC) lanes and cash lanes in toll plazas affect drivers' behavior. ETC arrangements predicate lane changing behavior, path decision making and toll plaza comprehension in addition to the overall safety of the toll plaza. The objective of this research was to evaluate the effect of toll plaza lane configuration on safety. A secondary objective was to validate the feasibility of using microsimulation safety analyses in a toll plaza environment. Field video data was captured and subsequently a microsimulation study was conducted using VISSIM. Conflicts and events that were captured from the video were used as the source of further surrogate safety analyses. Surrogate Safety Assessment Model (SSAM) provided by Federal Highway Administration was used as supplementary software. Vehicle trajectories from a simulated network in VISSIM were integrated into the SSAM software to generate surrogate safety measures. Distribution of traffic volumes, stop delays at cash lanes and reduced speed distribution at ETC lanes were used as calibration variables. The number of conflicts was used as a validation parameter to verify the model's accuracy. The effect on safety of different lane configurations was studied under five scenarios using the toll plaza that connects Interstate 90 to Interstate 91 and Route 5 in West Springfield, Massachusetts as a case study scenario. The results identified the safest lane configuration was the one consisting of only ETC lanes; when ETC was not present in all lanes, the safest configurations were ones that separated ETC lanes from other lanes.

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Sponsoring Committee	AHB65, Operational Effects of Geometrics
Session Number	472
Session Title	Operational and Safety Effects of Geometric Designs
Paper Number	15-3635
Paper Title	A Two-step Microscopic Traffic Safety Evaluation Model of Reserved Lanes Facilities: An Arterial Case Study
Abstract	This study investigates the safety and operations of reserved lane facilities, with multiple interactions between vehicles. Currently, there are few studies that attempted to evaluate the impact on operations along the reserved lane with respect to the various geometric designs that allow for frequent locations of merging/diverging and crossing maneuvers. In this study, a VISSIM simulation model has been developed for a particular bus-lane arterial in Montreal area. The model was used to evaluate the safety and traffic operations along the corridor considering the status quo and some alternative design and prevailing traffic conditions scenarios, including different length of weaving sections and a modified geometric designed of the entire bus-lane section. The simulation model was calibrated with real-world vehicle headways and its vehicle trajectories output were used in the Surrogate Safety Assessment Model (SSAM). In addition, an improvement of the SSAM model was achieved via a binary matrix calibration methodology in order to identify the vehicle conflicts more accurately. This improvement helps traffic analysts in properly identifying the potential traffic operations measures that contribute to a reduction of vehicular conflicts along the urban arterial. A comparison analysis has been conducted using a nearly one-kilometer bus-lane segment along the investigated arterial. The results show that traffic operations along the arterial, including the bus-lane, can be significantly improved if a different geometric alignment is deployed to reduce the number of interaction opportunities. For example, it is shown that establishing a 30-meter weaving section can significantly improve the vehicles travel time as well as improve the safety performance.

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Sponsoring Committee	ANB70, Truck and Bus SafetY
Session Number	790
Session Title	Truck and Bus Safety
Paper Number	15-3723
Paper Title	Comparison of Dilemma Zone and Driver Behavior of Trucks and Passenger Cars at High-Speed Signalized Intersections
Abstract	Trucks have different dynamic performance and stronger willing of passing the intersection during the yellow light comparing with passenger cars. These differences can result in different behaviors conflicts and high safety risks at high-speed intersections. This paper investigates the driver behavior and dilemma zone of trucks and passenger cars at three high-speed signalized intersections in Shanghai. We use statistical methodology considering both type I dilemma zone and type II dilemma zone. Based on the field observation, it is found that there are significant differences in both type I dilemma zone, type II dilemma zone and red light running behavior between trucks and passenger cars. According to the stop/go decision of field observation, a calibration of parameters of type I dilemma zone is conducted based on vehicle types. The differences mentioned above can lead to both serious right-angle and rear-end conflicts. Thus an all-red extension strategy based on truck exclusive-approach lane was proposed to provide additional protection for trucks. The quantitative simulation evaluation shows that it can reduce the vehicle conflicts significantly and reduce the intersection delay as well.

Authors	Yan Kuang, Griffith University, Australia Xiaobo Qu, Griffith University, Australia Weng Jinxian, Beijing Jiaotong University, China Xu Wang, Griffith University, Australia
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-3871
Paper Title	Impact Analysis of Driver's Perception-Reaction Time on Performance of Crash Surrogate Indicators for Motorway Traffic
Abstract	Due to the enormous losses to society, researchers have been seeking capable solutions to improve traffic safety for decades. As an alternative to the traditional crash data models, the crash surrogate indicators are proposed and applied to evaluate the traffic safety in various situations. The driver's perception-reaction time (PRT), which is an important parameter in traffic safety and infrastructure design, has not been taken into account by several widely used surrogate indicators. In this regard, this paper aims to examine whether or not the performances of surrogate indicators can be improved by incorporating the impact of the PRT. In this study, we firstly modify surrogate indicators by involving the PRT into the crash mechanism. The crash and trajectory data collected on the Pacific Motorway are used to validate the modified surrogate indicators. The results show that the modified surrogate indicators outperform the existing ones.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4002
Paper Title	Exploring Traffic Conflict-Based Surrogate Approach for Safety Assessment of Highway Facilities
Abstract	This study explored potential use of the traffic conflict-based surrogate safety assessment method as an alternative way of evaluating safety performance of roads and identifying potential sites for safety improvement. While the statistical modeling method based on historical crash data (i.e., crash-based method) has been widely used in safety studies, it is limited when crash data are not available or sufficiently enough to perform reliable statistical analysis. On the other hand, the traffic conflict-based method using traffic conflicts estimated by microscopic traffic simulation models has been recently gaining attentions for safety studies as an alternative to the crash-based method. This study compared these two major safety assessment streams in assessing a crash risk to investigate the performance of the traffic conflict-based method as an alternative of the crash-based method in identifying hot-spots. The empirical Bayes (EB) method coupled with the safety performance function (SPF), called the EB-SPF method, was used as a benchmark and the conventional crash frequency (CF) method was used as a comparison supplement: these two methods are viewed as the crash-based methods in that they rely on crash data. The traffic conflicts were estimated using the microscopic traffic simulation model, VISSIM. The safety evaluation was performed separately for 24 signalized intersections and 86 segments in Tysons Corner area, Virginia. The estimated safety measures from the three methods (i.e., EB-SPF, CF, traffic conflicts) were compared using Pearson correlation analysis, and hot-spot identification results were compared using the rank-based mean absolute error values. As for the intersections, the conflict-based method was found to have a fairly high correlation with a coefficient of 0.71 with the EB-SPF method in resulting outcomes and performed better than the crash frequency method in identifying hot-spots. As for the segments, the conflict-based method outperformed the crash frequency method in terms of correlation coefficients as well as the MAE values. Thus, the conflict-based method can serve as a viable option for safety performance evaluation and hot-spot identification, especially when sufficient crash data are not obtainable.

Authors	Perumal Vedagiri, Indian Institute of Technology, Bombay Deepak V. Killi, Indian Institute of Technology, Bombay
Sponsoring Committee	ABE90, Transportation in the Developing Countries
Session Number	797
Session Title	Traffic Safety and Traffic Management in Developing Countries
Paper Number	15-4161
Paper Title	Traffic Safety Evaluation of Uncontrolled Intersections Using Surrogate Safety Measures Under Mixed Traffic Conditions
Abstract	In the developing world, with the increase in population, the number of vehicles is increasing tremendously. Hence, traffic safety on road has become a major concern even with advancements in technology and infrastructure. Traffic safety assessment and prediction related work is based on accidental data from the past, which is reactive in nature. It has known drawbacks related to the reliability of the accident data, especially in developing countries like India with large populations. It is however unethical to wait for accidents to occur before being able to draw statistically accurate conclusions regarding safety impact. To overcome this, there is a need to develop accurate models based on Surrogate Safety Measures (SSMs) for an effective safety evaluation. The main advantage associated with the use of these proactive models is that they occur considerably more frequently than accidents, thereby implying an efficient and more statistically reliable proximal measure of traffic safety. The objective of this study is to study the impact of management measures on traffic safety at a 3-arm uncontrolled intersection using micro-simulation modeling under mixed traffic condition by developing a unique methodology of measuring one of SSMs, Post Encroachment Time (PET), The main contribution of the paper is the improvement in the accuracy of the predictions by proposing a new methodology to calculate the safety indicator Post Encroachment Time (PET).

Authors	Thomas Mark Hall, Purdue University Andrew P. Tarko, Purdue University Mario Alfonso Romero, Purdue University Cristhian Guillermo Lizarazo, Universidad Nacional de Colombia
Sponsoring Committee	ANB75, Roundabouts
Session Number	419
Session Title	Examining Roundabouts: A Closer Look at Access Management, Crosswalks and Trucks
Paper Number	15-4277
Paper Title	The Effect Of Roundabout Circulatory Superelevation On Heavy Vehicle Rollover Risk
Abstract	There is a recent trend of building roundabouts on high-speed roads, often with significant heavy vehicle traffic. With the increased presence of trucks on roundabouts, the issue of rollover has become a considerable concern. Geometric features that allow excessive speed on the approach and entry have been connected to rollover, as well as sudden changes in cross fall and radius. However, the effect on the rollover threshold of changing the roundabout's circulatory superelevation is not fully understood. This paper describes a rollover model more generalized than those previously used for design considerations. It accounts for the intricacies of semi-trailers and other heavy vehicles by incorporating both complex trailer paths that do not conform to the road alignment and the resulting vehicle tilt. The proposed model is applied to determine whether inward circulatory superelevation may provide considerable safety benefits over the typically used outward design. This is done by introducing Δv - the difference between the critical rollover speed determined from the model and the actual speed. The study revealed that the 2% inward superelevation scenario produces a statistically significant and one mile per hour higher Δv than 2% outward. As expected, the difference becomes more significant (1.2 mph) when the inward superelevation is increased to 3%. However, these differences are too weak to recommend the inward design given its other shortcomings. The results confirm the model's usefulness and introduce it as tool for future research.

Authors	Ahmed Tageldin, University of British Columbia, Canada Tarek Sayed, University of British Columbia, Canada Xuesong Wang, Tongji University
Sponsoring Committee	ANF30, Motorcycles and Mopeds
Session Number	626
Session Title	The Role of Technology in Motorcycle and Moped Safety
Paper Number	15-4371
Paper Title	Can Time Proximity Measured Be Used As Safety Indicators In All Driving Cultures? A Case Study Of Motorcycle Safety In China
Abstract	Limitations associated with traditional collision-based safety analysis techniques led to a growing interest in the use of surrogate safety measures such as the traffic conflict technique. This interest has been facilitated by advances in automated video-based data collection methods that are helping to overcome the reliability issues associated with manual traffic conflict data collection. Various objective conflict indicators are available to measure the severity of traffic events which measure various spatial and temporal aspects of user proximity. These time proximity conflict measures assume that proximity is a surrogate for conflict severity. However, this assumption may not be valid in many driving environments. The objective of this paper is to investigate whether time-proximity conflict measures can be a good indicator of safety in less organized traffic environments with a high mix of road users. A case study of motorcycle conflicts in a highly congested shared intersection in Shanghai, China is used as a case study. Traffic conflicts are analysed with the use of automated video-based analysis techniques. Several traffic conflict indicators based on detecting evasive actions such as deceleration, jerk, and yaw-rate are recommended to better measure traffic conflicts in such traffic environments. The results showed that evasive action based indicators have higher potential to identify motorcycle conflicts in high mix, less organized traffic environments than time proximity measures such as the time to collision.

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Sponsoring Committee	ANB20, Safety Data, Analysis and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-4431
Paper Title	Forecasting Long-Term Crash Patterns on Interrupted-Flow Roadways Using Naturalistic Driving Data
Abstract	The state-of-the-practice for most municipal traffic agencies in identifying high risk road segments has been the use of historic traffic collision data. While the use of this data has proven to be a valuable tool in improving roadway safety, it is a not a proactive measure. Researchers have developed new methods to identify abnormal driving events which may be indicative of collision avoidance maneuvers and/or near-collision events. In general, these near-collision events are more frequent (than crashes), potentially enabling high risk locations to be identified significantly sooner. Naturalistic driving data collected with global positioning system (GPS) sensors was divided into trips and linearly referenced to LA 42, a divided four-lane interrupted flow highway in Baton Rouge, Louisiana. This data was used to calculate the driver's acceleration and rate of change of acceleration (jerk). A correlation analysis revealed that long-term collision rates were significantly related to rate of high magnitude jerk events while decelerating. In a negative binomial modeling framework, the percentage of high magnitude jerks observed in each segment (jerk-rate) was found to be statistically significant in the crash frequency model for LA 42 segments. This was in contrast to roadway characteristics identified in the Highway Safety Manual (HSM) used to estimate Safety Performance Functions, such as ADT and geometric curves, both of which were statistically insignificant in the crash frequency model. This research is unique in that for the first time ever, high magnitude jerk events were correlated to the collision rate on interrupted flow highways. Previously, this had only been established for uninterrupted flow freeway (US 101 in San Luis Obispo, California). In fact, a stronger correlation was discovered to exist between the jerk events and collision rate on LA 42 (highway with interrupted flow) in Baton Rouge (Louisiana) than US 101 (uninterrupted flow freeway) in San Luis Obispo (California).

Authors	Paul St-Aubin, Polytechnique Montreal, Canada Nicolas Saunier, Polytechnique Montreal, Canada Luis Fernando Miranda-Moreno, McGill University, Canada
Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-4629
Paper Title	Comparison of Various Time-to-Collision Prediction and Aggregation Methods for Surrogate Safety Analysis
Abstract	Surrogate safety analysis is the practice of diagnosing road safety by observation of ordinary traffic behaviour instead of rare traffic accidents. While this proactive approach was first proposed in the 60's, issues of subjectivity, transferability, and validity impeded the technique's maturity. However, it has recently gained some renewed traction with the advent of sophisticated, large-scale, microscopic data acquisition techniques solving some of the issues of objectivity, though the tasks of improving model transferability and validity remain, with the exception of speed indicators, which benefit from a large body of evidence linking them to road safety, especially collision severity. While trajectory measurement techniques have improved, the interpretation and definition of dangerous traffic events still lags. Various competing safety indicators have been proposed and tried, some more precise, objective, or context-sensitive than others. This paper examines and reviews the definition and interpretations of time-to-collision, one of the most ubiquitous and least context-specific surrogate safety indicators, for its suitability as an indicator of dangerous traffic events. An important emphasis is put on motion prediction methodology when defining time-to-collision, as well as aggregation methods of instantaneous time-to-collision exposure. This analysis is performed using one of the largest trajectory data sets collected to date for the purpose of surrogate safety analysis. The study recommends the aggregation of instantaneous time-to-collision indicators by 15th percentile over the use of minimum values, highlights the context-dependency of constant velocity motion prediction (particularly regarding car-following), recommends the use of motion pattern prediction using trajectory learning, and examines sensitivity to traffic event ranking by collision probability threshold.

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Sponsoring Committee	ANB25, Highway Safety Performance
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-4794
Paper Title	Evaluation of Left-Turn Lane Offset Using the Naturalistic Driving Study Data
Abstract	The SHRP 2 Naturalistic Driving Study (NDS) data were used to evaluate the gap acceptance behavior of drivers at left-turn lanes with offsets ranging from –29 ft to 6 ft. The study included 3,350 gaps evaluated (accepted or rejected) by 145 NDS drivers and 275 non-NDS drivers (whose turns were visible from the in-vehicle camera of an NDS driver) at 14 two-way stop-controlled intersections and 44 signalized opposing left-turn pairs. Logistic regression was used to model the critical gap length for drivers as a function of offset, under conditions when their view was either blocked by an opposing left-turning driver or not. The analysis found that the critical gap was longer for negative offsets than for zero or positive offsets, and also longer when sight distance was blocked by an opposing left-turning driver than when it was not. These longer gap lengths can result in decreased operational efficiency of an intersection. Sight distance was much more likely to be restricted by an opposing left-turning driver at negative-offset intersections than at zero- or positive-offset intersections, and drivers at negative-offset intersections were less likely to accept a gap when an opposing left-turn driver was present. An analysis of the shortest post-encroachment times showed that while drivers making left-turns at negative-offset left-turn lanes wait to accept longer gaps, they are, on average, also more likely to leave the shortest amount of time between their turn and the arrival of the next opposing through vehicle, which may present a potential safety concern.

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Sponsoring Committee	ABJ50, Information Systems and Technology ABJ60, Geographic Information Science and Applications
Session Number	377
Session Title	Information Technology Applications in Transportation 2015
Paper Number	15-4892
Paper Title	Automated Region-Based Vehicle Conflict Detection Using Computer Vision Techniques
Abstract	We present an approach for vehicle conflict analysis based on computer vision techniques. Techniques for quantitative conflict measurement often use a point trajectory representation for vehicles. More accurate conflict measurement can be facilitated by instead utilizing a region-based vehicle representation. This paper describes a computer vision approach for extracting vehicle trajectories from video sequences. The method relies on a fusion of background subtraction and feature based tracking to provide a 3D cuboid representation of the vehicle. Standard conflict indicators, including time to collision and post encroachment time, are computed utilizing the 3D cuboid vehicle representations. We demonstrate the use of these conflict measures on a challenging dataset of video footage. The results showed that the region-based representation can provide more precise calculation of traffic conflict indicators compared to approaches based on a point representation.

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Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	817
Session Title	Bicycling Perspective on Roadway Design and Operations
Paper Number	15-4903
Paper Title	Are Intersections with Cycle Tracks Safer? Control Case Study Based on Automated Surrogate Safety Analysis Using Video Data
Abstract	In recent years, cities in North America have been building cycle tracks with the intention of providing cyclists with a safer alternative to biking in the street. These facilities have been built and expanded but very little research has been done to investigate the safety impact of cycle tracks, in particular at intersections, where cyclists interact with turning-motor-vehicles. Some of the safety research has looked at observed injuries, finding some positive safety impacts of cycle tracks. The objective of this work is to investigate the safety effects of cycle tracks at intersections using a control-case study. For this purpose, a video-based method is proposed for analysing the post-encroachment time as a surrogate measure of the conflicts between cyclists and turning-vehicles traveling in the same direction. Using the city of Montreal as the case study, a sample of intersections with and without cycle tracks on the right and left sides were carefully selected accounting for intersection geometry and traffic volumes. A total of 90 hours of video were collected and processed in order to obtain cyclist and motor-vehicle trajectories and interactions. After cyclist and motor-vehicle interactions were defined, ordered logit models with random effects were developed to evaluate the safety effects of cycle tracks on conflicts at intersections. Among other results, it was found that intersection approaches with cycle tracks on the right are safer than intersection approaches with no cycle track; however, intersections with cycle tracks on the left compared to no cycle tracks were not found to have be significantly safer. As part of the contributions of this work, one can mention the extraction and use of disaggregate bicycle and vehicle flows in short time intervals such as 10 seconds intervals. The results identify that the likelihood of a cyclist being involved in a dangerous conflict increases with increasing turning-vehicle flow and decreases with cyclist group arrival.

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Sponsoring Committee	ANB75, Roundabouts
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-4968
Paper Title	Calibration And Application Of Crash Prediction Models For Safety Assessment Of Roundabouts Based On Simulated Conflicts
Abstract	There has been significant interest in recent research in evaluating road safety by means of surrogate measures. This paper contributes to that research by investigating the use of simulated conflicts as a possible surrogate safety measure for roundabouts, for which it has proven difficult to relate crashes to geometric characteristics. The evaluation of the capability of conflicts to predict crashes at a roundabout approach was carried out by seeking a formal link between these two safety measures. The idea is that the relative safety of roundabouts with different designs or various designs for the same roundabout can be evaluated by examining differences in conflicts estimated through simulation and relating those differences to changes in crash frequency. The microsimulation package VISSIM was applied to estimate the number of peak hour conflicts for roundabout approaches using a micro simulation software package and a database of U.S. roundabouts. For this, roundabout design characteristics were considered directly by graphically replicating the roundabout in the simulation, and indirectly though their effect on speed measures required as a simulation input. Conflict prediction models and several approach-level crash-conflict prediction models were successfully calibrated, suggesting that simulated conflicts could be considered as a surrogate measure for crashes at roundabouts.

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Sponsoring Committee	ANB20, Safety Data, Analysis, and Evaluation
Session Number	752
Session Title	Is It Safe to Use Surrogate Measures of Safety?
Paper Number	15-5028
Paper Title	Investigation of Surrogate Measures for Safety Assessment of Urban Two-Way Stop-Controlled Intersections
Abstract	Crash prediction models used to estimate safety of highway segments and intersections are traditionally developed using various traffic volume measures. There are issues with this approach and surrogate safety measures such as conflicts and delays have been proposed to overcome them. This study investigates the relationships between crash frequencies and traffic volume, intersection delay, and simulated conflicts to explore and compare the viability of these models for estimating safety at urban two-way stop controlled intersections. The database used includes 78 three leg and 55 four leg intersections within the Greater Toronto Area. Crash prediction models were developed and evaluated based on various goodness-of-fit measures. With the developed models, an alternate approach to crash based evaluations of intersection improvements is presented. A case study is developed to investigate and demonstrate the use of the models for estimating the safety impact of implementing a left turn lane on a major approach of an urban three leg stop controlled intersection.

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Sponsoring Committee	ANB75, Roundabouts
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-5207
Paper Title	Evaluating the Applicability of SSAM for Modeling the Safety of Roundabouts
Abstract	The number of roundabouts in the United States continues to increase due in large part to the safety related benefits associated with the design. Safety remains an ongoing national priority, and roundabouts decrease crash rates and severity compared to other intersection designs including signalized intersections and stop sign controlled intersections. However, safety evaluation of transportation designs with the use of field data is not always feasible due to high costs and the fact that one cannot always evaluate alternative designs unless the changes are actually implemented. The Federal Highway Administration developed the Surrogate Safety Assessment Model (SSAM) that can read micro-simulation vehicle trajectory files and estimate the number of conflicts based on several safety surrogate measures including time to collision, post encroachment time, vehicle speed differential, and collision angle. The objective of this research was to evaluate the applicability for SSAM as a means for estimating the number of conflicts at a roundabout. As part of the analysis video data was collected and used to calibrate and validate a micro-simulation model integrating SSAM. Although the predicted and actual number of conflicts was low, the relative match of the predicted and observed models was encouraging, and provided evidence to suggest the appropriateness of using SSAM to model the safety of roundabouts.

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Sponsoring Committee	ANB75, Roundabouts
Session Number	791
Session Title	All About Roundabouts
Paper Number	15-5317
Paper Title	Large-Scale Microscopic Traffic Behaviour and Safety Analysis of Québec Roundabout Design
Abstract	Roundabouts are a staple of European road design with many international studies demonstrating important reductions in collision severity and, to a lesser extent, frequency, among other benefits. With the promise of better safety, roundabouts have recently proliferated across across North America as well. However, regional adoption has not been smooth and questions still remain regarding roundabout design and suitability in the context of North American driving culture. Indeed, driving behaviour is a vital component of a well functioning roundabout as all movements within are managed entirely by driving etiquette. To obtain a better understanding of how roundabout design affects driving behaviour at Québec roundabouts, a study of 37 instrumented weaving zones across 20 roundabouts throughout the province of Québec was conducted. The instrumentation captured continuous, high-resolution, microscopic movements and speeds fifteen times per second (trajectories) of over 80,000 individual vehicles over a combined 9,500 veh-km, one of the largest studies of its kind to date. This study looks at the effects of several geometric design and built-environment factors on the behaviour and safety indicators of speed and time-to-collision. Among the major findings, roundabout conversions from traffic circles consistently scored the highest speeds and lowest (most dangerous) time-to-collisions, the number of roundabout lanes was negatively correlated with speed in the weaving zone, and mixed flow ratios between the roundabout lanes and the approach lanes produced the lowest time-to-collisions.

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Sponsoring Committee	ANF20, Bicycle Transportation
Session Number	849
Session Title	Bicycle Transportation, Part 2: Safety and Infrastructure
Paper Number	15-5319
Paper Title	Do Pedestrians Protect Cyclists? Investigation of Effect of Pedestrian Volume on Cyclist-Vehicle Interactions
Abstract	The purpose of this paper is to examine the effect of variability in pedestrian volume on cyclist-vehicle interactions after accounting for the effect of cyclist and vehicle volumes. Interactions between cyclists and motor vehicles at six signalized intersection were identified in this study using an objective conflict indicator; Post-Encroachment Time (PET). A total of 83 videos were reviewed and 465 interaction events were identified. A total of 3,688 through cyclist movements, 6,522 right-turn vehicle movements and 23,512 individual pedestrian crossings were recorded. A threshold of 3 seconds was used to identify interaction events based on measured PET. The results showed that the pedestrian volume was found to be associated with a positive (desirable) impact on cyclist safety when vehicles yielded to the cyclists while making a right turn movement across the cyclist path. This was statistically significant for PET proximity levels (0, 2] and (0, 3] seconds. However, when motorists failed to yield to cyclists, the effect was not significant. Furthermore, the variability in pedestrian volume was not associated with vehicles blocking cyclist path while making a right-turn movement. It may be argued that the increased presence of pedestrians may promote safer crossing of cyclists across right-turn vehicles when motorists yield to cyclists.

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Sponsoring Committee	ABJ70, Artificial Intelligence and Advanced Computing Applications
Session Number	234
Session Title	Artificial Intelligence and Advanced Computing Applications
Paper Number	15-6018
Paper Title	Behaviour Analysis Using A Multi-Level Motion Pattern Learning Framework
Abstract	The increasing availability of video data, through existing traffic cameras or dedicated field data collection, paves the way for the collection of massive datasets about the microscopic behaviour of road users using computer vision techniques. Analysis of such datasets helps to understand the normal road user behaviour, and it can be used for realistic prediction of future motion and computing surrogate safety indicators. A multi-level motion pattern learning framework is developed that enables automated scene interpretation, anomalous behaviour detection and surrogate safety analysis. Firstly, Points of interest (POI) are learnt based on Gaussian Mixture Model and the Expectation Maximization algorithm and then used to form activity paths (APs). Secondly, motion patterns, represented by trajectory prototypes, are learnt from road users' trajectories in each AP using a two-stage trajectory clustering method based on spatial then temporal (speed) information. Finally, motion prediction relies on matching at each instant partial trajectories to the learnt prototypes to evaluate the potential for collision by computing indicators. An intersection case study demonstrates the framework ability in many ways: it helps to reduce the computation cost up to 90 %, clean trajectories dataset from tracking outliers, use actual trajectories as prototypes without any pre- and post-processing and predict future motion realistically to compute surrogate safety indicators.

8 Applications of the Highway Safety Manual

Francesca La Torre

Authors	P. Alluri, D. Saha, A. Gan
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-2257
Paper Title	Prioritization of Highway Safety Manual (HSM) Data Variables Using Random Forest Algorithm
Abstract	The Highway Safety Manual (HSM) recommends using the empirical Bayes (EB) method with locally derived calibration factors to predict an agency's safety performance. However, the data needs for deriving these local calibration factors are significant, requiring very detailed roadway characteristics information. Many of these data variables are currently unavailable in Florida's roadway inventory databases. Since it is not economically feasible to collect and maintain all the HSM data variables that are currently missing in the Florida Department of Transportation (FDOT) databases, FDOT is interested in a prioritized list of variables that could help to identify influential variables for which data could be collected and maintained for continued updates. As such, a major effort of this study was to collect data for the missing variables for analysis. Data were collected on over 7,000 miles of segments and over 1,000 intersections across Florida. Random Forest algorithm, which works well with highly-correlated data and data with many interactions, was applied to prioritize data variables based on their impacts on safety predictions. For segment and intersection facility types in rural two-lane roads, rural multilane highways, and urban and suburban arterials, the variables were ranked based on the increase in node purity 16 (IncNodePurity) values.

Authors	K. Al Kaaf, M. Abdel-Ati
Sponsoring Committee	ANB25
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-3054
Paper Title	Transferability and Calibration of Highway Safety Manual Performance Functions and Development of New Models for Urban Four-Lane Divided Roads in Riyadh
Abstract	The first edition of the Highway Safety Manual (HSM) provides a number of safety performance functions (SPFs), which can be used to predict severe collisions on a roadway network. This paper examined the calibration of the HSM SPFs for Urban Four-lane divided roadway segments (U4D) with angle parking in Riyadh, Kingdom of Saudi Arabia (KSA) and the development of new SPFs. This study first calibrates the HSM SPFs using HSM default Crash Modification Factors (CMFs), then new local CMFs are proposed, which adjust the estimation of calibration factors using fatal and injury crash data. In addition, new forms for specific SPFs are further evaluated to identify the best model using the Poisson-Gamma regression technique. It was found that the jurisdiction-specific SPFs provided the best fit of the data used in this study, and would be the best SPFs for predicting severe collisions in the City of Riyadh. The best fatal and injury model describes the mean crash frequency as a function of natural logarithm of the annual average daily traffic, segment length, speed limit, and driveway density. The study finds that the HSM calibration using Riyadh local CMFs outperforms the calibration method using HSM default values. Based on these results, potential countermeasures were proposed to reduce severe crashes on Riyadh urban roads, and the potential for HSM application in KSA are addressed.

Authors	H-S. Shin, J. Whon, S. Dadvar, Y-J. Lee
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-4639
Paper Title	Statistical Evaluation of Different Sample Sizes for Local Calibration Process in the Highway Safety

	Manual
Abstract	An approach to determine a statistically reliable sample size for developing local calibration factors (LCFs) was proposed to complement the Highway Safety Manual (HSM)'s sampling guidance. The HSM suggests a minimum sample size of 30 to 50 sites per facility type with at least 100 annual crashes. However, it fails to provide clear guidance on how to determine a minimum sample size to assure the statistical reliability of LCFs. The proposed approach based on the finite population correction (FPC) factor determined minimum sample sizes by considering trade-offs among the desired error levels of the estimated LCFs, confidence levels, and sample standard deviations. The sample sizes by facility types were drawn based on various statistical assumptions; then they were assured by the comparisons between FPC-based samples and the HSM-based samples. LCF values estimated from the HSM-based sample sizes yielded inconsistent reliabilities depending on the facility types. In contrast, those from the samples by the FPC-based approach satisfied the desired reliabilities of the LCFs for all facility types.

Authors	H-S. Shin, S. Dadvar, Y-J. Lee
Sponsoring Committee	ANB25
Session Number	510
Session Title	Advancing the Science of Highway Safety Performance
Paper Number	15-4643
Paper Title	Results and Lessons from Local Calibration Process of Highway Safety Manual for the State of Maryland
Abstract	The paper discusses Maryland's experience in developing local calibration factors (LCFs) in the application of the Highway Safety Manual (HSM), which is the required process for adjusting predicted crashes estimated by the HSM's safety performance functions (SPFs) to local jurisdictions. LCFs for 18 facility types were calculated using data for the years 2008 to 2010. Additional variables were gathered by alternative data collection methods. Due to the difference with HSM's crash proportion, Maryland's crash proportion was used to predict crash frequency and calculate LCFs. Maryland in general had fewer crashes than predicted crash frequency generated by the HSM's SPFs. LCFs for 15 out of 18 facility types were less than 1.0. Especially, intersection LCFs were extremely low. Due to potential issues with unreported minor and property damage-only crashes, the authors recommend using LCFs for fatal and injuries crashes where available. The pair-wise comparison of Maryland LCFs with LCFs of nine case studies showed statistically significant differences among states, providing grounds for jurisdiction-specific LCF development.

Authors	D. Troyer, K. Bradbury, C. Juliano
Sponsoring Committee	ANB25
Session Number	789
Session Title	Highway Safety Performance
Paper Number	15-3093
Paper Title	Strength of the Variable: Calculating and Evaluating Safety Performance Function Calibration Factors for the State of Ohio
Abstract	The AASHTO Highway Safety Manual (HSM) provides methodologies for DOTs and other agencies to incorporate high-quality quantitative safety analyses into project development and decision-making. Taking full advantage of the HSM, though, requires states to collect and maintain more detailed and comprehensive data on their roadway system. Moreover, given that the methods in the HSM were based on research using select state databases, full use of the HSMrequires that states calibrate the models to their own databases and systems. Calibration is needed to account for differences in state reporting thresholds, terrain, driver demographics, climate, and other unique crash attributes. This paper outlines the efforts undertaken by the Ohio Department of Transportation (ODOT) to implement the HSM through data collection and calibration. Historically, ODOT has not collected data for all of the attributes included in the Part C predictive models. Over the past two years, ODOT collected additional data elements for their roadway system, including parking, driveways, and roadway curvature. ODOT staff also undertook calibration of the HSM Safety Performance Functions (SPFs) using the collected data, historic observed crashes, and specialized spreadsheet tools. In some cases, calibration factors cannot adequately adjust the HSM models, which may instead require the development of agency-specific SPFs. Cumulative Residual (CURE) plots were used to evaluate how closely calibrated SPFs predicted crash frequency compared to the observed frequency. ODOT determined that the calibration factors were currently sufficient to adjust the HSM models and the future development of Ohio-specific SPFs can be prioritized based on calibration evaluations..

9 Transportation Safety Management

Frank Gross, Vanasse, Hangen, Brustlin, Inc. (VHB)
Jake Kononov, DiExSys, LLC

Thirty two papers evaluating different aspects of safety management will be presented at the 2015 TRB Annual Meeting, some of them are briefly discussed below.

A number of papers examine the methodological aspects of managing safety; **Reliability-based Assessment of Benefits in Roadway Safety Management** by Cafiso and D'Agostino (15-2226) makes a compelling case that due to inherent uncertainty of SPF and CMF the outcomes of the benefit cost analysis can be highly divergent. **Full Bayesian Mixed-Effect Intervention Model for Before-After Speed Data Analysis by** Tazul Islam quantifies the effect of posted speed limit (PSL) reduction in an urban residential context by employing a mixed-effect intervention model, which can address the limitations of existing methodologies. **The Effectiveness Of The High Risk Corridor Program In British Columbia** by De Leur and Weightman show results from a robust, time-series evaluation demonstrating the significant and positive safety impact of the HRC Program, which has resulted in a large reduction in the frequency and severity of collisions. **Urban Sprawl as a Risk Factor in Motor Vehicle Crashes** by Ewing, Hamidi and Grace tests the relationship between sprawl and traffic crash rates using structural equation modeling. **Why have traffic fatalities dropped in the US?** by Noland and Sun observes that largest reductions in fatalities are generally associated with decreases in household median income while increasing the number of lanes on arterial and collector roads has increased fatalities. **Justifying Road Safety Investments for Locations Without Collisions by Quantifying Road Safety Risk** by De Leur and Hill examines the benefits of proactive approach to complement the program based on observed crashes in British Columbia.

Several papers address data challenges related to implementation of SafetyAnalyst and HSM; **Development of Comprehensive Database System for SafetyAnalyst** by Paz et al identifies many barriers to the implementation of SafetyAnalyst that currently exist and suggests strategies for overcoming them. **Comprehensive Assessment of Highway Inventory Data Collection Methods for Implementing Highway Safety Manual** by Jalayer et al. observes thatwidespread utilization of HSM faces significant barriers as many state Department of Transportations (DOTs) do not have sufficient HSM-required highway inventory data, this study evaluates existing highway inventory methods through a nationwide survey. **Preparing Input Data for SafetyAnalyst Implementation: Florida Experience** (Alluri, Gan and Liu) summarizes the Florida's efforts in implementing SafetyAnalyst for its state road network. It describes a major effort to collect the data variables that are required by SafetyAnalyst and are currently unavailable in Florida databases. A second major effort involved the conversion of local attribute codes to the standard codes required by SafetyAnalyst This paper is intended to provide assistance to the agencies contemplating deployment of SafetyAnalyst.

A paper by Shi and Abdel-Aty **How Traffic Crashes Affect Congestion on Urban Expressways** examines determining factors influencing duration of incidents and suggests the necessity to include real-time traffic data in emergency response strategies. **Rural Emergency Medical Service Needs Assessment** by Qin and He not only offer a comprehensive view of EMS from the geographic and temporal perspectives but also stresses key time- and distance-dependent factors such as response time, en-route time, on-scene time. **Exploring Road Safety Analysis and Stakeholder Engagement for Small and Medium-Sized Communities** by Rondier et al sheds light on the usefulness of combining qualitative and quantitative data in the identification of possible Accident Prone Locations (APL). The knowledge of the stakeholders gives an insight on the most important road safety issues, while the quantitative analyses tend to both confirm and nuance the APLs to be further investigated.

Authors	Salvatore Cafiso, University of Catania, Italy Carmelo D'Agostino, University of Catania, Italy
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2226
Paper Title	Reliability-based assessment of Benefits in roadway safety management
Abstract	Road Agencies set quantitative targets and adopt related road safety strategies within the priorities and the available resources funds at a time of economic crisis. In this framework, benefit-cost analyses (BCA) are carried out to support the decision making process and alternative measures are ranked according to their expected benefit and benefit-cost ratio calculated using a Safety Performance Function (SPF) and Crash Modification Factors (CMFs) as predictor of future safety performances. Due to the variance of CMFs and crash frequency we are uncertain what the benefits of some future actions will be. The chance of making a wrong decisions depends on the size of the standard deviation of the probability distribution of CMFs and SPF, as well. To deal with the uncertainty inherent in the decision making process, a reliability based assessment of Benefits must be performed introducing a stochastic approach. In the paper the variance of the CMFs and SPFs are taken into account in a reliability based BCA to address improvements and issues of an accurate probabilistic approach when compared to the deterministic results or other approximated procedures. A case study is presented comparing different safety countermeasures selected to reduce crash frequency and severity on sharp curves in motorway. These measures include retrofitting of old safety barrier, delineation systems, shoulder rumble strips and their combinations. The methodology was applied using Monte Carlo simulations to calculate the probability of failure of BCA statements. Results and comparisons with alternative approaches, like that proposed in the HSM, are presented showing remarkable differences in the evaluation outcomes that can be achieved.

Authors	Md Tazul Islam, University of Alberta, Canada Karim El-Basyouny, University of Alberta, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-2350
Paper Title	Full Bayesian Mixed-Effect Intervention Model for Before-After Speed Data Analysis
Abstract	Analysing the before-after speed data to evaluate the effectiveness of any safety intervention is often limited to non-model-based comparison of various speed-related indicators. Moreover, modelling the speed data often does not take into account the nested nature of the data. To this end, the objective of the current study was to quantify the effect of posted speed limit (PSL) reduction in an urban residential context by employing a mixed-effect intervention model, which can address the limitations of existing methodologies. To model the mean free-flow speed and probability of speed below or equal to various thresholds, mixed-effect normal regression and binomial logistic regression models were used, respectively. The use of a comprehensive, unique, and disaggregated dataset enabled not only the before-after evaluation of the PSL reduction, but also exploration of the effects of various temporal, traffic, and road geometry factors on speed behaviour. Results demonstrated the appropriateness of

using the mixed-effect model for the speed data. The parameter estimations showed that night-time, weekends, the high proportion of vans/buses/trucks, evening peak periods, collector roads (as opposed to local roads), and lower hourly traffic volume were all associated with an increase in mean free-flow speed and a decrease in the probability of speed below or equal to various speed thresholds. The evaluation results showed that the mean free-flow speed reduced by 3.85 km/h in the after period, while speeds below or equal to 50 km/h, 60 km/h, 70 km/h, and 80 km/h increased by 20.0%, 9.2%, 2.8%, and 0.9%, respectively. All the improvements were statistically significant, implying the effectiveness of the PSL reduction in influencing vehicle speed behaviour.

Authors	Reid Ewing, University of Utah Shima Hamidi, University of Utah James B. Grace, University of Louisiana, Lafayette
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3063
Paper Title	Urban Sprawl as a Risk Factor in Motor Vehicle Crashes
Abstract	A decade ago, compactness/sprawl indices were developed for metropolitan areas and counties which have been widely used in health and other research. In this study, we first update the original county index to 2010, then develop a refined index that accounts for more relevant factors, and finally seek to test the relationship between sprawl and traffic crash rates using structural equation modeling. Controlling for covariates, we find that sprawl is associated with significantly higher fatal crash rates likely due to the higher traffic speeds and greater vehicle miles driven in such areas. Conversely, sprawl may negatively related to total crashes and nonfatal injury crashes. The most likely explanation is the greater prevalence of fender benders and other minor accidents in the low speed, high conflict traffic environments of compact areas, negating the lower vehicle miles traveled per capita in such areas.

Authors	Paul de Leur (corresponding), Vancouver, Canada Michael Weightman, Insurance Corporation of British Columbia, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-3440
Paper Title	The Effectiveness Of The High Risk Corridor Program In British Columbia
Abstract	British Columbia's High-Risk Corridor (HRC) Program was created by recognizing that a safe roadway environment is a shared responsibility, involving several public agencies including the police, the road authority, and others. In BC, another public agency interested and responsible for road safety is the Insurance Corporation of BC (ICBC), which is a provincial agency responsible for vehicle insurance and driver licensing services. It was felt that coordinated and strategic efforts by public agencies responsible for road safety could yield greater safety benefits as compared to individual agency efforts that are undertaken in isolation. This paper provides an overview of British Columbia's HRC Program and presents a case study example to demonstrate the success of the program in reducing the frequency and severity of collisions on a high-risk corridor. The paper also describes the technical elements of the program, including how corridors are defined as high-risk, as well as the collision and infrastructure analysis used to guide the interventions deployed as part of the program. The details of the strategic efforts and coordination by the various agencies will be detailed to illustrate the range and integration of the road safety initiatives. Finally, the results from a robust, time-series evaluation are presented to show the significant and positive safety impact of the HRC Program, which has resulted in a large reduction in the frequency and severity of collisions.

Authors	Robert B. Noland (corresponding), Rutgers University Feiyang Sun, Cornell University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	281
Session Title	Safety Management Data Analytics
Paper Number	15-4377
Paper Title	Why have traffic fatalities dropped in the US?
Abstract	A comprehensive analysis of state-level data from 1984 to 2011 provides evidence on the sources of recent US traffic fatality reductions and the effectiveness of various policies. The largest reductions in fatalities are generally associated with decreases in household median income, a proxy for economic activity. Changes in the road network, mainly increasing the number of lanes on arterial and collector roads has increased fatalities. Graduated licensing policies, mobile communication device laws, safety-belt laws and motorcycle helmet requirements are all associated with reductions in fatalities. In particular, between 2006 and 2012, the further implementation of graduated licensing and mobile communication device laws in additional states accounts for substantial reductions in nationwide fatalities. Other control factors include a proxy for medical technology, population and demographic changes, and various other proxies that are related to economic activity, with mixed effects on fatality reduction.

Authors	Alexander Paz, University of Nevada, Las Vegas Naveen Veeramisti, University of Nevada, Las Vegas Indira Khanal, University of Nevada, Las Vegas Justin Baker, University of Nevada, Las Vegas
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-1990
Paper Title	Development of Comprehensive Database System for SafetyAnalyst
Abstract	This study developed a comprehensive database system to provide data to multiple traffic safety applications with focus on Safety Analyst. A number of data management tools were developed to extract, collect, transform, integrate, and load the data. In addition, the proposed system includes consistency-checking capabilities to ensure the adequate insertion and update of data into the database system. The proposed system caters roadway, ramp, intersection, and traffic characteristics data for Safety Analyst. The database was developed for the entire Clark County, the largest county in Nevada including the cities of Las Vegas, Henderson, Boulder City, and North Las Vegas. The developed database was then used to identify the sites with potential for safety improvements based on various analyses. In this study, specifically two case studies result were reported and analyzed. The first case identified sites, including all roadway elements with default and calibrated Safety Performance Functions (SPFs), with potential for safety improvements considering fatal and all injury crashes. The second case identified sites, intersections with default and calibrated SPFs, with potential for safety improvements considering fatal and all injury crashes. Conclusions were developed about the calibration of safety performance functions and the classification of site subtypes. Guidelines were provided about selection of a particular network screening type or performance measure for network screening. In general, this study addressed barriers associated with the use of Safety Analyst.

Authors	Mohammad Jalayer, Auburn University Huaguo Zhou, Auburn University Jie Gong, Rutgers University Shufu Hu, Southern Illinois University, Edwardsville Mark Grinter, Southern Illinois University, Edwardsville
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-2288
Paper Title	Comprehensive Assessment of Highway Inventory Data Collection Methods for Implementing Highway Safety Manual
Abstract	The implementation of the Highway Safety Manual (HSM) at the state level has the potential to allow transportation agencies to proactively address safety concerns. However, the widespread utilization of HSM faces significant barriers as many state Department of Transportations (DOTs) do not have sufficient HSM-required highway inventory data. Many techniques have been utilized by state DOTs and local agencies to collect highway inventory data for other purposes. Nevertheless, it is unknown which of these methods or any combination of them is capable of efficiently collecting the required dataset while minimizing cost and safety concerns. The focus of this study is to characterize the capability of existing methods for collecting highway inventory data vital to the implementation of the recently published HSM. More specifically, this study evaluates existing highway inventory methods through a nationwide survey and a field trial of the identified-promising highway inventory data collection (HIDC) methods for various types of highway segments. A comparative analysis was conducted to present an example on how to incorporate weights provided by state DOT stakeholders to select the most suitable HIDC method for the specific purpose.

Authors	Qi Shi, University of Central Florida Mohamed A. Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-2313
Paper Title	How Traffic Crashes Affect Congestion on Urban Expressways
Abstract	Provision of efficient and safe services to motorists has long been the major tasks for traffic professionals. Researchers have made considerable effort to explore the crash contributing factors and factors determining the incident durations. However, the issue of how crashes lead to congestion hasn't yet been addressed. This study aims at clarifying this question by evaluating three urban expressways in Central Florida area. Both real-time traffic detection data and individual crash reports were employed. According to the real-time traffic data, it was found that a proportion of crashes led to congestion while other didn't. For a comprehensive interpretation of the distinct effects, four classes of crashes based on their impact on congestion were generated and potential contributing factors were extracted. According to the structure of crash classification, one multinomial and two separate binomial logit models were developed under Bayesian framework to identify the effects of the candidate variables. Conclusion and model performance of the multinomial and binomial logit models generally agree with each other while binomial model offer more straight forward interpretation. Peak hour, number of lanes, weather condition and crash severity significantly affect the probability of the occurrence of the four types of crashes. However, the effects and the significance of some variables differ based on pre-crash congestion status. The findings of this paper suggested the necessity to include real-time traffic data in emergency response strategies. Moreover, the response procedure could also be assisted by the temporal, spatial, weather and severity related information about the crashes.

Authors	Afrid Alavee Sarker, University of Memphis Alireza Naimi, University of Memphis Sabyasachee Mishra, University of Memphis Mihalis M. Golias, University of Memphis Phillip Brad Freeze, Tennessee Department of Transportation
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-2363
Paper Title	Identification of Secondary Crashes in Large-Scale Highway Networks
Abstract	Secondary crash (SC) occurrences are non-recurrent in nature and lead to significant increase in traffic delay and reduced safety. National, state, and local agencies are investing substantial amount of resources to identify and mitigate secondary crashes, reduce congestion, related fatalities, injuries, and property damages. Though a relatively small portion of all crashes are secondary, their identification along with the primary contributing factors is imperative. The objective of this study is to develop a procedure to identify SCs using a static and a dynamic approach in a large-scale multimodal transportation network. The static approach is based on pre-specified temporal and spatial thresholds while the dynamic is based on shockwave principles. The procedure is applied in the State of Tennessee and results show that the dynamic approach can identify secondary crashes with better accuracy and consistency.

Authors	Paul de Leur, Vancouver, Canada David Hill, Insurance Corporation of British Columbia, Canada
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-2981
Paper Title	Justifying Road Safety Investments for Locations Without Collisions by Quantifying Road Safety Risk
Abstract	Since creating a Road Improvement Program, the Insurance Corporation of British Columbia (ICBC) has invested over $110 million dollars towards road safety improvements in British Columbia, Canada. The Road Improvement Program partners with provincial road authorities to identify problem locations and implement interventions to improve road safety. The level of ICBC investment in a safety project has been based on the potential for collision reduction associated with the proposed improvements. The goal has been to target collision prone locations to reduce the frequency and severity of collisions, thereby reducing the auto insurance claims costs to ICBC. Although entirely necessary and effective, the reactive nature of projects funded by the Road Improvement Program did not allow for investments at locations that were deemed to be high-risk, but did not have a significant history of collisions. Recognizing that some attention should be given to these 'high-risk / low crash' locations as well, a new program was developed that could provide funding to support road improvement projects that were not based on a history of collisions. The new program, referred to as the Proactive Road Safety Program, complements the reactive program by providing funding support for projects that can prevent collisions rather than reduce collisions. This paper describes the rationale and methodology that was developed for the Proactive Road Safety Program to quantify road safety risk and assign an economic value to justify funding for proactive road safety projects.

Authors	Xiao Qin, South Dakota State University Zhaoxiang He, South Dakota State University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-3027
Paper Title	Rural Emergency Medical Service Needs Assessment
Abstract	Unintentional mortality rate attributed to diseases, fertility, and motor vehicle crashes is higher in rural areas than urban areas because of limited accessibility and mobility of emergency medical services (EMS), hospitals as well as the highway network connecting them. For rural states with a long travel distance due to the sparsely distributed population, it is important to gain a reliable assessment of EMS demand and an unbiased evaluation of service performance within the current highway system. The goal of this research was to conduct a needs assessment for rural EMS and to identify issues with respect to delivering quality services. The dataset was from the National EMS Information System (NEMSIS) consisting of 50,396 EMS responses in 2012 in South Dakota. Spatial analysis was focused on visual presentation and cluster analysis of service demand and performance on a county level. Temporal analysis was performed to magnify the service demand by month of year, day of week, and time of day. Descriptive statistics and two-tailed t test were applied for describing and comparing variables of interest. The findings not only offer a comprehensive view of EMS from the geographic and temporal perspectives but also stresses on key time- and distance-dependent factors such as response time, en-route time, on-scene time, and transporting time. For on-going endeavor to enhance EMS, we call for continued effort to improve EMS data quality and recommend linking EMS data with crash outcome for establishing specific, data-driven, and performance-based measures.

Authors	Scott Johnson, City College of New York Camille Kamga, City College of New York
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-3035
Paper Title	Review of Swedish Road Safety Policy in United States and Its Application in New York City Vision Zero Action Plan
Abstract	In 2014 New York City (NYC) began implementing a Vision Zero traffic safety plan. The Vision Zero policy was originally developed by Sweden. The core principle of Vision Zero is “Life and health can never be exchanged for other benefits within the society”. The Vision Zero goal is to reduce traffic related deaths to zero through road design, enforcement, regulations, and education. Sweden by following Vision Zero principles now has one of the lowest traffic fatality rates in the world. Sweden’s neighbor Norway, which has adopted the Swedish policy, has achieved similarly impressive safety improvements on its roadways. In the United States the states of Washington, Minnesota and Utah have adopted Vision Zero policies and road fatalities have fallen 40% in Washington, 43% in Minnesota and 48% in Utah. These states have the most developed programs in the United States. Other states that have adopted variations of the Vision Zero policy are Oregon, Idaho and West Virginia. NYC also has other peer cities to look to as it develops its Vision Zero policy as Chicago began a Vision Zero program in 2012. This paper reviews selected Vision Zero programs successfully implemented in the world by comparing policy, implementation and resource allocation. Key attributes of these programs are analyzed and evaluated to determine components that could be incorporated into NYC’s Vision Zero Action Plan. The success of these programs indicates that enacting a Vision Zero plan in NYC will be a valuable tool in reducing traffic fatalities in New York City especially in fatality factors linked to driver behavior such as speeding, impaired driving and distracted driving that are major contributors to fatalities in NYC. The paper suggests that NYC should also work with New York State to advocate for a statewide Vision Zero program, as it would make it easier to pass Vision Zero legislation and obtain federal resources for the program.

Authors	George Yannis, National Technical University of Athens, Greece Eleonora Papadimitriou, National Technical University of Athens, Greece Marianthi Mermygka, National Technical University of Athens, Greece
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-3104
Paper Title	Multilevel Comparative Analysis of Road Safety in European Capital Cities
Abstract	The objective of this research is the comparative road safety analysis in selected European capital cities, aiming to a better understanding of road accident characteristics and causes in European megacities. Despite the continuous urbanization and the shift of population to large urban areas, this research question has received little attention in the existing literature. A database was developed for this analysis containing data regarding the number and the characteristics of road fatalities, the population and other demographic, socioeconomic and transport indicators of nine selected European capital cities for the period 2007 - 2011. Multilevel Poisson statistical models were developed, allowing for a more accurate representation of the hierarchical structure of road safety data, and they led to the identification of several factors affecting the road safety level in the selected European capital cities, revealing some additional aspects of road safety performance in these cities. Factors found with a statistically significant effect concerned city characteristics (road network length, population density, public transport use) and accident characteristics (road user and vehicle type). The comparison between the European capital cities showed that the larger the city's road network is, the higher the level of road safety is in this city.

Authors	Nicholas J. Ward, Western Transportation Institute Linda Ng Boyle, University of Washington Maria Velasquez, Montana State University, Bozeman Jay Otto, Montana State University, Bozeman Lenore Page, Montana State University, Bozeman
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-3272
Paper Title	Preliminary Efforts to Quantify the Safety Culture of Transportation Agencies
Abstract	"Safety culture" as a term has a long history in organizations where safe operations are critical, such as nuclear power plants, commercial aviation, and healthcare. In transportation, the culture fostered within agencies responsible for traffic safety can have an impact on the types of policies and strategies that are prioritized, funded, and implemented. However, there are currently now instruments that are designed to measure safety culture within transportation agencies. This paper reports on a preliminary attempt to assess the qualities of a new survey of agency safety culture.

Authors	Raymond Richard Geddes, Cornell University Xiaodi Li, Cornell University Omid M. Rouhani, Cornell University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-3463
Paper Title	Effects of Private Road Management on Traffic Safety: Evidence from Mexico
Abstract	There has been increasing scholarly interest in public-private partnerships (PPPs) and innovative financing approaches to deliver transportation infrastructure. Researchers have examined such issues as the effect of PPPs on delivery times, on cost efficiency, and on the cost of capital. There has, however, been relatively little empirical study of the effects of private participation in road management on road safety. We contribute to the literature on PPPs by conducting an empirical study of the effects of alternative types of toll road management, including private, on road safety in Mexico. We utilize an extensive data set examining accidents at the municipal level from 1997 to 2009, resulting in 10,772 observations. We consider several safety measures, including the overall number of accidents, the number of fatal accidents, the number of car collisions, and the number of fixed-object collisions. We control for a number of independent variables in addition to the type of road manager. We find little evidence that private management of Mexican toll roads has a statistically discernible effect on road safety, either positive or negative. Our findings may help to allay fears that private participants will sacrifice road safety in the interest of greater profits.

Authors	Jaehyun So, Technische Universität München, Germany In-Kyu Lim, Virginia Department of Transportation Young-Jun Kweon, Virginia Department of Transportation
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4002
Paper Title	Exploring Traffic Conflict-Based Surrogate Approach for Safety Assessment of Highway Facilities
Abstract	This study explored potential use of the traffic conflict-based surrogate safety assessment method as an alternative way of evaluating safety performance of roads and identifying potential sites for safety improvement. While the statistical modeling method based on historical crash data (i.e., crash-based method) has been widely used in safety studies, it is limited when crash data are not available or sufficiently enough to perform reliable statistical analysis. On the other hand, the traffic conflict-based method using traffic conflicts estimated by microscopic traffic simulation models has been recently gaining attentions for safety studies as an alternative to the crash-based method. This study compared these two major safety assessment streams in assessing a crash risk to investigate the performance of the traffic conflict-based method as an alternative of the crash-based method in identifying hot-spots. The empirical Bayes (EB) method coupled with the safety performance function (SPF), called the EB-SPF method, was used as a benchmark and the conventional crash frequency (CF) method was used as a comparison supplement: these two methods are viewed as the crash-based methods in that they rely on crash data. The traffic conflicts were estimated using the microscopic traffic simulation model, VISSIM. The safety evaluation was performed separately for 24 signalized intersections and 86 segments in Tysons Corner area, Virginia. The estimated safety measures from the three methods (i.e., EB-SPF, CF, traffic conflicts) were compared using Pearson correlation analysis, and hot-spot identification results were compared using the rank-based mean absolute error values. As for the intersections, the conflict-based method was found to have a fairly high correlation with a coefficient of 0.71 with the EB-SPF method in resulting outcomes and performed better than the crash frequency method in identifying hot-spots. As for the segments, the conflict-based method outperformed the crash frequency method in terms of correlation coefficients as well as the MAE values. Thus, the conflict-based method can serve as a viable option for safety performance evaluation and hot-spot identification, especially when sufficient crash data are not obtainable.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4156
Paper Title	Comparison of Experimental, Quasi-experimental, and Nonexperimental Designs When Predicting Effectiveness of Road Safety Campaigns
Abstract	The ultimate aim of a road safety campaign is to contribute to the reduction of the number of road crashes and the number of people killed or injured on the roads, by influencing road users' behavior. Since human parameters are a major factor to road crashes, road safety campaigns should include interventions that address aspects which motivate users to adopt a safe driving behavior, and consequently quit from unsafe actions. A large number of road safety communication campaigns has been designed and realized in the recent years; however, their explicit impact on driving behavior and road accidents' rates has been estimated in a rather low proportion. Based on the findings of the evaluation of three road safety communication campaigns addressing the issues of drinking and driving, seat belt usage and driving fatigue, the aim of this paper is to assess the applicability of different types of research designs, i.e. experimental, quasi-experimental and non-experimental designs, when estimating the effectiveness of road safety campaigns. In order to reach this aim, an integrated evaluation plan was developed, taking into account the structure of evaluation questions and the definition of measurable variables, the selection of alternative research designs, and the appropriate data collection methods and techniques. When testing different research designs, results showed that the separate pre-post samples design demonstrated better predictability than other designs, especially in the data obtained from the intervention group after the realization of the campaign. In addition, referring to the construction of the prediction models, it was observed that the more constructs were added to the independent variables, the higher the model predictability was. Specifically, the construct that mostly affects intention was behavioral beliefs, followed by risk comprehension. On the other hand, the parameter that mostly affects behavior is intention, whereas the rest constructs had a lower impact.

Authors	Liisa Ecola, RAND Corporation Jeanne Ringel, RAND Corporation Erin K. Sauber-Schatz, Centers for Disease Control and Prevention Johanna P. Zmud, Texas A&M Transportation Institute
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4279
Paper Title	Developing Online Tool to Calculate Costs and Effectiveness of Policies to Reduce Fatalities and Injuries from Motor Vehicle Crashes
Abstract	This paper provides a high-level overview of the approach, data, and assumptions used to produce an online tool that allows state health departments, departments of transportation, and decision makers to assess the costs and effectiveness of implementing up to 12 interventions and to select those most effective in reducing deaths and injuries from motor vehicle crashes for a given implementation budget. It also provides examples of how costs and effectiveness estimates were developed for certain interventions, as well as information about how the tool works in various modes of analysis. The RAND Corporation developed the tool for the Centers for Disease Control and Prevention's National Center for Injury Prevention and Control.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4373
Paper Title	Quality of Injury Severity Classification by Police: Important Step for Reliable Assessment
Abstract	This study aims to assess the under-reporting and misclassification of the traffic injury severity reported by the police for the first time in Portugal. The non-fatality traffic injuries classified by the police are compared with the information recorded by the hospitals using linked data. The underreporting in the police data was found to be of 29%. Therefore, a significant number of road traffic casualties admitted in the hospitals were not known by the police. Taking advantage of the linked information on accident injuries, the misclassification in the police reports is assessed considering two criteria: the length of hospital stay (LS) and the maximum abbreviated injury scale (MAIS). The latter criterion corresponds to the common definition recently established by the European Commission, which has the advantage of representing the medical conditions of the casualty. The comparison between police classification and LS indicates that a discrepancy between the police reports and the established police definition exists maybe because no systematic communication between the police and the hospitals is established. Notably, the police classification shows inferior levels of misclassification regarding the MAIS when compared to the LS, with a tendency to overclassified the injury severity. A remarkable proportion of severe injuries reported by the police are, in fact, slight injuries. Additionally, using univariate and multivariate analyses, factors contributing to the misclassification of casualties by the police are identified. Finally, similarly to the fatality adjustment coefficient used in Portugal and in other European countries in the past, non-fatality adjustment coefficients were computed to estimate the total casualties taking into account the under-reporting and misclassification phenomena.

Authors	Chia-Yuan Yu, Texas A&M University, College Station
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4414
Paper Title	Disparity in Traffic Safety Across Neighborhoods with Different Economic Statuses and Ethnic Compositions
Abstract	Crashes are not equally distributed across different communities or different socioeconomic groups. For example, more socioeconomically deprived areas experienced more traffic crashes. Several possible reasons were identified in previous studies, including the possibility of lower household vehicle ownership in low income areas (which in turn generate more pedestrian activities and lead to more conflicts between pedestrians and vehicles), insufficient non-motorized infrastructure in low income areas (which increase the danger for pedestrians), and higher traffic volumes in areas with more non-white populations. Moreover, most studies on disparity issues primarily focused on pedestrian injuries. Current evidence regarding disparities in crashes with different levels of injury severity is still limited. Further, possible moderator effects of socio-demographic characteristics on built environment–traffic safety relationships are unclear. This study explored differences in crash frequency across neighborhoods with different economic statuses and ethnic compositions, and further tested the potential moderator effect of socio-demographic characteristics on the built environment–traffic safety association. The results revealed that some built environmental variables (e.g., arterial roads, office uses, and schools) showed significant impacts on traffic safety only in areas with high percentages of non-white population and population below the poverty line and not in low-percentage areas. This suggested that policies and programs related to these built environmental attributes in promoting traffic safety may bring more benefits to areas with more non-white or lower-income populations. Tailored traffic safety strategies are need for areas with more non-white and low-income people.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4422
Paper Title	Ranking Cities for Safety Investigation by Potential for Safety Improvement
Abstract	Numerous methods have been proposed in the past to conduct the identification of hotspots (HSID). However, most of them are dedicated to the micro-level analysis such as roadway segments and intersections. Very limited studies are focused on the HSID of more aggregate levels, which in general have larger sample means and wider dispersion in the collision counts. The authors performed a city-level HSID by using the four-year data of 265 cities in California. It is intended to equip road safety professionals with more useful tools to compare the safety performance of city as a whole. Potential for Safety Improvement (PSI) was adopted as a measure of crash risk to compare alternate HSID methods, including the Empirical Bayes (EB) and three full Bayesian (FB) alternatives, Negative-Binomial (FBNB), Poisson Log-Normal (FBPLN), and the Poisson Temporal Random Effect (FBPTRE), for ranking the safety performance of cities. Five evaluation tests which contain the Site Consistency Test, the Method Consistency Test, the Total Rank Difference Test, the Total Performance Difference Test and the Total Score Test were applied to evaluate the performance of the four HSID methods. Moreover, two cutoff levels, top 5% and 10% cities, were employed for more reliable results. Overall, the study results are consistent with the results of previous quantitative evaluations focused on micro-level HSID. The three FB approaches significantly outperform the EB counterpart. The method accounting for temporal random effect produces more reliable HSID results than those without considering the serial correlations in collision counts.

Authors	Young-Jun Kweon, Virginia Department of Transportation Cheol Oh, Hanyang University, South Korea Kyeong-Pyo Kang, Korea Transport Institute
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4528
Paper Title	Guiding Road Safety Programs Based on Analysis of Disaggregate Crash Data
Abstract	Safety programs are formulated at various geographic levels, and a data-driven approach for such programs has been increasingly encouraged. A national traffic safety plan was created in 2013 in Korea by the collective efforts of many government entities. Under the guidelines of the plan, safety programs are formulated using a data-driven approach. However, a data-driven approach can be employed in various ways, ranging from use of highly aggregate statistics to analysis of individual crash records. Use of aggregate statistics is beneficial to reveal a tendency hidden in a vast quantity of individual crash records so that general guidance can be derived. However, aggregate statistics might blur or disguise important aspects that would be revealed if disaggregate data were carefully analyzed. The purpose of this study was to derive guidance for programs addressing the traffic safety issues of a fairly large area with about 12 million residents, using about 120,000 crash records collected in 3 years in Korea. Factors found to be associated with a more severe consequence were different across road classes and crash types. For example, a nighttime occurrence of vehicle-vehicle crashes was associated with more severe injury on expressways but not on national and provincial highways. On national highways, summer and fall were associated with more severe injury in vehicle-vehicle crashes and less severe injury in vehicle-person crashes. Guidance for safety programs can be derived from the study findings to address the different needs and conditions of road classes. For example, safety programs for national highways should focus on interventions for summer and fall and foggy conditions for reducing severity in vehicle-vehicle crashes and interventions in winter and spring, nighttime, and rainy/cloudy/foggy conditions in addressing vehicle-person crashes.

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	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4597
Paper Title	Seasonal Effects of Crash-Contributing Factors on Highway Safety
Abstract	A longitudinal negative binomial model is developed in this paper that takes into account the seasonal effects of crash causality factors based on ten years (2002-2011) of Missouri Interstate highway crash data. The technique of generalized estimating equation (GEE) with autoregressive correlation structure is used. The results explain the overall effect of seasonality and whether the magnitude and/or type of various effects are different according to climatic changes. Traffic volume was found to have an appreciable effect in increasing the crash occurrence in spring and lower effect in winter, compared to the fall season. Fewer crashes were associated with higher pavement serviceability (measure of pavement surface quality, higher value is better) and this effect was found to be highest in the spring season followed by summer and winter, again when compared to the fall season. Heavy vehicles were found to reduce the likelihood of crash occurrences and this effect is higher in urban areas; although compared to other times of the year, the effect of heavy vehicles is lower during the summer season. The results indicated that the fall season is associated with the lowest crash frequency compared to the other seasons; winter season having the highest impact followed by summer and spring. This paper also evaluated the effects of the Missouri's Strategic Highway Safety Plan (MSHSP) implemented from 2005-2011. The plan was found to be effective as it reduced the crash frequency. Similar strategic plans therefore should be initiated in the future as well.

Authors	Ryan Philip Stone, Texas A&M Transportation Institute Beverly T. Kuhn, Texas A&M Transportation Institute Justin Yates, Texas A&M University
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4670
Paper Title	Public Reception of Variable Speed Limits
Abstract	Improving driver safety is a process that requires new methods and inventions, which often creates mixed reactions amongst drivers. Such is the case with the variable speed limit (VSL) pilot project administered by the Texas A&M Transportation Institute for the Texas Department of Transportation. The VSLs are designed to produce slower, safer vehicle speeds in order to reduce congestion and speed differentiation, but how the public would react to these new speed limits was questionable. This research focused on analyzing public perception of VSLs in the earliest stages of the project and determining the reasons for these perceptions. Positive feedback was desired primarily for the sake of greater driver compliance to the VSLs. Using various social media sites and live streams, individual responses were compiled by researchers to determine overall project feedback. An overwhelming majority of responses were negative mainly due to misconceptions about the purposes of VSLs. However, it appeared past experience with or a pre-developed understanding of VSLs most often resulted in positive feedback. These results suggested that residents of the study should have been better informed about VSLs before deployment for the sake of a reception that would aid the project.

Authors	Gokhan Egilmez, North Dakota State University Yong Shin Park, North Dakota State University Deborah McAvoy, Ohio University, Athens
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-4757
Paper Title	Integrating Self-Organizing Maps into Road Safety Benchmarking to Provide Improvement Paths: DEA-Based Kohonen Network Approach
Abstract	Traffic crashes are still one of the leading causes of death worldwide, although tremendous efforts have been placed on reducing the frequency and severity through policy initiatives by governmental agencies and private organization services. A Data Envelopment Analysis (DEA) based road safety benchmarking studies have been utilized as a robust tool to obtain a holistic picture of safety performance of regions, countries, etc. However, utilizing a road safety score with DEA often lacks guidance to provide an improvement path toward increasing road safety performance. Since there is significant variability among different regions in terms of variables such as population or vehicle miles traveled, not all regions can be grouped together to serve as benchmarks. In this study, a road safety assessment of the United States was first performed with a step-wise DEA approach where states were categorized into separate tiers based on their road safety performance. Then the states with similar input and output characteristics were clustered with a Kohonen Network (Self-Organizing Maps), which was used to provide improvement paths for inefficient states. According to the results, most states were found to be inefficient in terms of safety. In addition, safety belt usage, road condition and highway safety expenditures were observed as the most sensitive safety performance indicators (SPIs) to road safety performance.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5041
Paper Title	Optimization-Based Prioritization Model for Highway Safety Countermeasure Implementation Strategy
Abstract	Highway safety improvement countermeasures are evaluated to reduce occurrence of crashes and to enhance economic viability. The Highway Safety Manual 2010 suggests benefit-cost and cost effectiveness analysis methods to justify implementation of potential countermeasures. These methods are efficient for analyzing alternative countermeasures of a single location. Every fiscal year highway agencies are required to evaluate many safety improvement countermeasures for different locations and select candidate locations for possible funding. Often this process is mostly manual and does not guarantee optimum benefit. Moreover, it fails in estimating the future funding requirements. In this paper, an optimization model encompassing multiple time periods based on the benefit-cost and cost effectiveness analysis methods is developed to optimally allocate countermeasures to candidate location to maximize safety benefits subjected budget, and other policy constraints. The proposed model can suggest implementation plans of safety improvement countermeasures to be implemented at candidate locations in a multi-year analysis period. The paper also reviews the budget sensitivity analysis over a multi-year horizon to assess the optimum future funding needs. A real word case study is used to showcase applicability and efficiency of the proposed optimization model. The proposed optimization model extends the cost-benefit and cost effectiveness analysis methods are in line with the economic appraisal and project prioritization process suggested in the Highway Safety Manual 2010.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5108
Paper Title	Exploring Road Safety Analysis and Stakeholder Engagement for Small and Medium-Sized Communities
Abstract	Identifying thematic issues and Accident Prone Locations (APLs) on rural local road network is challenging because of the length and scope of the network and the spatial and temporal variability of crashes. The objective of this paper is to explore the complementarity between road safety stakeholders' point of view and the identification of APLs through an Empirical Bayes (EB) method in a rural, less-dense area of Quebec, Canada. The first step of the method consists in EB analyses with a spatial database containing the accident data, the road network and several environmental attributes of the road sites. The second step is to recruit, interview and summarize the road safety perceptions of various stakeholders, both spatially and thematically. An application of this comparative method in a local and predominantly rural county of 23 municipalities in Quebec shed light on the usefulness of combining qualitative and quantitative data in the identification of possible APLs. The knowledge of the stakeholders gives an insight on the most important road safety issues, while the quantitative analyses tend to both confirm and nuance the APLs to be further investigated.

Authors	Hamed Ahangari, University of Connecticut Carol Atkinson-Palombo, University of Connecticut Norman Garrick, University of Connecticut
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5133
Paper Title	Two Indexes for Assessing Changes in Traffic Fatality in Developed Countries
Abstract	Road safety is a considerable public health concern around the world. National and local governments regularly introduce legislation or strengthen enforcement of existing laws to make roads safer. While road fatalities in almost all developed countries have decreased over the last four decades, the rate of change has varied tremendously from country to country. Our goal in this study is to provide a better understanding of the relative rate of improvement in road fatalities in different countries in the developed world over the last four decades. By using observations for 17 industrialized countries in series of panel data models, we created two indices to compare how well countries are doing with regards to traffic fatality at different points in time. One index is the Overall Traffic Fatality Index (OTFI) based on the raw data but adjusted to control for structural factors that affect all countries over time. The second index, the Adjusted Traffic Fatality Index (ATFI), has additional controls for socio-economic factors, mobility levels, motorization and health care. Based on our conceptual model of factors affecting traffic fatality levels we believe that the ATF index largely reflects the role of country specific factors such as differences in infrastructure, policy, enforcement and driving habits. The ATFI index therefore measures the safety regime for specific countries.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5532
Paper Title	Preparing Input Data for SafetyAnalyst Implementation: Florida Experience
Abstract	SafetyAnalyst is a set of state-of-the-art software tools that integrates all the steps in the roadway safety management process. The software automates the advanced empirical Bayes (EB) analysis procedures, requiring agencies to only need minimum statistical knowledge. Agencies that have implemented SafetyAnalyst have consistently identified converting local data into SafetyAnalyst import files as the most challenging step in deploying the software. This paper summarizes the Florida's efforts in implementing SafetyAnalyst for its state road network. The SafetyAnalyst application process was first introduced. The process integrates the SafetyAnalyst tools, a data conversion tool developed to automatically generate SafetyAnalyst import files, and a Geographic Information System (GIS) tool used to spatially display high crash locations. The procedure employed to generate SafetyAnalyst import files for the state road network in Florida was then presented. A major effort was to collect the data variables that are required by SafetyAnalyst and are currently unavailable in Florida databases. A second major effort involved the conversion of local attribute codes to the standard codes required by SafetyAnalyst. Moreover, a sizeable amount of roadway network data was assigned to the user-defined Florida-specific site subtypes as the data do not match the SafetyAnalyst's default subtypes. Another undertaking was to manipulate the roadway network data since Florida data has several unique characteristics that could not be directly accommodated within SafetyAnalyst. The experience documented in this paper should help provide useful information for agencies that have just gotten started with SafetyAnalyst or are contemplating its implementation.

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Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5690
Paper Title	Screening Urban Road Networks for Corridors with Promise
Abstract	Both federal and state policy makers increasingly emphasize the need to reduce traffic fatalities and serious injuries. Finding improved methods to enhance roadway safety has become a top priority. In an attempt to reduce the number of crashes and the resulting injuries and fatalities, high crash locations should be identified for increased law enforcement activities, education programs, and engineering improvements. Prioritizing high crash locations for potential improvements would benefit local agencies with limited budgets. The role of corridor level screening is to examine periodically the entire urban roadway network in order to generate a list of corridors ranked in order of priority by which detailed engineering studies should be conducted. Ongoing debates in regards to corridor level network screening include what should constitute a corridor for the purpose of network screening, and how a local agency should perform a corridor screening. This study investigated several options to determine urban corridor limits and discussed the merits and weaknesses of different options. A Corridor Safety Index (CSI) is proposed as a performance measure for corridor screening. The index can be used to screen sites that have promise as locations where improvements will result in substantial crash reduction. The findings will assist engineers to proactively identify and analyze high crash locations from a corridor perspective and detect potential problematic locations not identified through the traditional hotspot analysis.

Authors	Isabel Cristina Victoria, CDM Smith Oscar Daniel Galvis, CDM Smith
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	386
Session Title	Data-Driven Safety Management: Multidisciplinary Approach
Paper Number	15-5770
Paper Title	Advancing Road Safety in Latin American City Through Implementation of Regulatory Measures
Abstract	The Municipal Administration of Bucaramanga has gained national recognition for implementing significant enforcement activities and law changes to ensure the well-being of all who share the road infrastructure. This paper presents the institutional initiatives implemented by the city in the last years, and whether these measures are helping the city to reach the traffic fatalities and injuries goals established in its road safety plan 2011-2016. Motorcyclists are the most vulnerable road users. From 2009 to 2013, motorcyclists have been involved in 42 percent of traffic fatalities and 49 percent of injured people. The analysis of the city's road safety trends points out that the vulnerability of motorcyclists is aggravated by their bad driving behavior. Over 30 percent of traffic violations annually imposed on motorcyclists is due to infringements of traffic laws. This finding calls for the development of a comprehensive program to improve motorcyclists' behaviors in conjunction with permanent observance. This analysis shows the social benefits brought to the City of Bucaramanga by the increased police enforcement and road safety interventions in the last year. From 2012 to 2013, a 46 percent increase in traffic fines contributed to a reduction in the number of injured people (223 less in 2013 compared to 2012) but had no impact on fatality crashes (81 fatality crashes in 2012 and 2013). Although few data were available for the comparative analysis, the preliminary results point out the need for implementing other types of initiatives related to drivers' behavior, road infrastructure, motor vehicles, and the recovery of victims of traffic accidents.

Authors	Kevin N. Chang, University of Idaho Charles Vits, IMMI Brett Seely, University of Idaho
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	387
Session Title	School Transportation Research
Paper Number	15-4802
Paper Title	School Bus Safety: Evaluating the Evolution of Compartmentalization and Seat Belt Restraints
Abstract	Nearly twenty-five million school children in the United States rely on the school bus for transport from home to their local school each day. In 1977, the Federal Motor Vehicle Safety Standard (FMVSS), Number 222, was enacted into law and established the requirements for seating and restraining barriers on school buses, and these requirements have essentially remained unchanged since that time. The compartmentalization component, in which passengers are surrounded by heavy-padded seats, remains as the defining characteristic of FMVSS, Number 222. The safety record of school buses is attributable in large part to the passive passenger protection provided by this standard and other school bus-specific safety standards, along with specialized licensure and training of qualified school bus drivers. This research paper documents the evolution of the modern day school bus and explores the need to consider an update to this standard by examining whether or not additional safety measures such as lap and shoulder restraints should be considered. Two bus crash demonstrations were conducted in August 2013 and November 2013 and the conditions on the school bus during those simulated collisions using full-scale anthropomorphic test devices are described in this paper. The results from the crash demonstrations indicate that there are opportunities to further enhance the safety environment for school bus riders.

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.

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.

AHD55, Signing and Marking Materials

This committee is concerned with all factors affecting the choice, use and performance of paints, durable markings, plastics, and optical elements used in retroreflective signing and marking materials.

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.

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

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