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 96th 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 http://www.trb.org/ANB10/ANB10.aspx

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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/ http://www.trb.org/ANB20/ANB20.aspx

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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 http://www.trb.org/ANB25/ANB25.aspx

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Erin Ferguson, Kittelson & Associates Inc.

Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 96th Annual TRB meeting. With this aim, papers sponsored by the Committees ANB10 – Transportation Safety Management, ANB20 – Safety Data, Analysis and Evaluation, and ANB25 – Highway Safety Performance have been split into subthemes and the abstracts reproduced. For each subtheme, a brief comment on the methodological and application perspectives of the presented papers is reported. Further, some papers sponsored by other Interacting Committees which are within the scopes of ANB10[1], ANB20[2], and ANB25[3] have been identified and classified in order to promote better interaction between ANB10, ANB20, ANB25 and these other Committees. Indeed, highway safety is a worldwide major social challenge which requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

This year, fifty-one events sponsored by ANB10, ANB20, and ANB25 are planned:

- Four Committee meetings (see Table 1);
- Nineteen Subcommittee meetings (see Table 2);
- Eight workshops/research discussions (see Table 3);
- Thirteen lectern sessions (see Table 4); and
- Seven poster sessions (see Table 5).

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

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

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

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

Table 1 ANB 10, ANB20, and ANB25 Committee Meetings

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

Table 2 ANB 10, ANB20, and ANB25 Subcommittee Meetings

Time	Title	Location
Monday, 8:00AM – 9:45AM	Surrogate Measures of Safety Subcommittee, ANB20(3)	Marriott Marquis, Ballroom Salon 14 (M2)
Monday, 10:15AM – 12:00PM	Roadway Safety Culture Subcommittee	Marriott Marquis, Supreme Court (M4)
Monday, 1:30PM – 3:15PM	Future Directions in Safety Analysis, Joint Subcommittee of ANB20, ANB25	Marriott Marquis, Ballroom Salon 14 (M2)
Monday, 3:45PM- 5:30PM	Global Road Safety Subcommittee, ANB10(8)	Marriott Marquis, Ballroom Salon 8 (M2)
Monday, 6:00PM- 7:30PM	Traffic Speed and Safety - Cross-cutting Issues, Joint Subcommittee of ANB20, AHB65, ANB10	Marriott Marquis, Ballroom Salon 8 (M2)
Monday, 6:00PM- 9:30PM	Rural Road Safety Policy, Programming, and Implementation Joint Subcommittee of ANB10, AFB30, ANB20	Marriott Marquis, Ballroom Salon 12 (M2)
Tuesday, 1:30PM – 3:15PM	Transportation Safety Planning Subcommittee, ANB10(3)	Marriott Marquis, Ballroom Salon 14 (M2)
Tuesday, 1:30PM – 3:15PM	Emergency Medical Services Safety Subcommittee, ANB10(5)	Marriott Marquis, Ballroom Salon 16 (M2)
Tuesday, 3:45PM – 5:30PM	Toward Zero Deaths Goal Subcommittee, ANB10(9)	Marriott Marquis, Ballroom Salon 7 (M2)
Tuesday, 6:00PM – 7:30PM	School Transportation Subcommittee, ANB10(6)	Marriott Marquis, Ballroom Salon 14 (M2)
Tuesday, 6:00PM – 7:30PM	Animal-Vehicle Collisions Subcommittee, ANB20(2)	Marriott Marquis, Ballroom Salon 12 (M2)
Tuesday, 7:30PM – 10:00PM	Intersections, Joint Subcommittee of AHB65, AFB10, AHB70, and ANB20	Marriott Marquis, Supreme Court (M4)
Wednesday, 8:00AM – 9:45AM	Bicycle and Pedestrian Safety Analysis, Joint Subcommittee of ANB20, ANF10, ANF20, ANB25	Marriott Marquis, Ballroom Salon 8 (M2)
Wednesday, 12:15PM – 2:15PM	Highway Safety Performance User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marriott Marquis, Ballroom Salon 10 (M2)
Wednesday, 12:15PM – 2:15PM	User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marriott Marquis, Ballroom Salon 7 (M2)
Wednesday, 12:15PM – 2:15PM	International Research Subcommittee, ANB25(5)	Marriott Marquis, Ballroom Salon 13 (M2)

Time	Title	Location
Wednesday, 6:15PM – 7:15PM	Policy and Legal Aspects Subcommittee, ANB25(1)	Marriott Marquis, Ballroom Salon 14 (M2)
Wednesday, 6:15PM – 7:15PM	Conferences and Meetings Subcommittee, ANB25(4)	Marriott Marquis, Ballroom Salon 16 (M2)
Wednesday, 7:30PM – 9:30PM	Combined Highway Safety Performance Research Subcommittees Meeting	Marriott Marquis, Ballroom Salon 8 (M2)

Table 3 ANB 10, ANB20, and ANB25 Workshops/Research Discussions

Time	Title	Location
Sunday, 9:00AM - 12:30PM	(119) Multimodal Performance-Based Design: Which Was First, the Car or the Bicyclist?	Convention Center, 204A
Sunday, 9:00AM - 12:30PM	(120) Unpaved Roadway Safety Research: Development of a National Agenda	Convention Center, 209A
Sunday, 9:00AM - 12:00PM	(136) Performance Measures and Targets Across the Pillars of the Decade of Action for Road Safety	Convention Center, 101
Sunday, 9:00AM - 12:00PM	(138) Crash Modification Factors: Can Driving Simulators Identify Crash Mechanisms?	Convention Center, 102A
Sunday, 9:00AM - 12:00PM	(139) How to Reverse the Increase in Pedestrian Fatalities: Identifying Problems and Solutions	Convention Center, 102A
Sunday, 1:30AM - 4:30PM	(183) Framework for Assessing and Transferring Highway Safety Performance Measurement to Both Developing and Developed Countries	Convention Center, 102A
Sunday, 3:00PM - 5:00PM	ANB10, ANB20, ANB25 – Research Discussion	Marriott, Salon 11 (M2)
Thursday, 8:00AM - 12:00PM	(900) Alternative Statistical Methods to Assess Highway Safety Performance	Convention Center, 102B

Table 4 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(245) Transportation Innovations May Improve Safety	Convention Center, 103B
Monday, 10:15AM – 12:00PM	(330) New Sources and Methods to Extract Data to Inform Safety Analysis	Convention Center, Salon B
Monday, 1:30PM – 3:15PM	(397) Transportation Safety Management: From Start to Finish	Convention Center, Salon B
Monday, 3:45PM – 5:30PM	(456) Doctoral Student Research in Transportation	Convention Center, Salon B
Tuesday, 8:00AM – 9:45AM	(536) Analysis of International Road Safety Data	Convention Center, 102B
Tuesday, 8:00AM – 9:45AM	(538) Advances in Highway Safety Performance	Convention Center, 103A
Tuesday, 6:00PM – 7:30PM	(766) Are We Too Comfortable? Changing the Culture of Transportation Research	Convention Center, 152B
Wednesday, 8:00AM – 9:45AM	(801) Accident Investigations by the National Transportation Safety Board	Convention Center, Salon B

Wednesday, 10:15AM – 12:00PM	(833) Hot Topics and Emerging Themes in Ecology and Transportation	Convention Center, 140A
Wednesday, 10:15AM – 12:00PM	(849) Coasting to Make Strides in Pedestrian and Bicycle Safety	Convention Center, Salon B
Wednesday, 2:30PM – 4:00PM	(869) Maintaining Connectivity: Reducing Costs and Improving Efficiencies of Landscape Design and Maintenance of Wildlife Crossing Infrastructure	Convention Center, 145B
Wednesday, 2:30PM – 4:00PM	(877) National Highway Traffic Safety Administration Behavioral Safety Research & Data Systems	Convention Center, Salon B
Wednesday, 4:30PM – 6:00PM	(888) National Highway Traffic Safety Administration Data Systems & Vehicle Safety Research	Convention Center, Salon B

Table 5 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 10:15AM – 12:00PM	(328) Transportation Safety Management: Creating Safer Systems	Convention Center, Hall E
Monday, 10:15AM – 12:00PM	(329) School Transportation Research	Convention Center, Hall E
Monday, 3:45PM – 5:30PM	(448) Tenth Annual Case Studies in Performance-Based Analysis of Geometric Design	Convention Center, Hall E
Tuesday, 8:00AM – 9:45AM	(537) Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations	Convention Center, Hall E
Tuesday, 10:15AM – 12:00PM	(589) It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis	Convention Center, Hall E
Tuesday, 10:15AM – 12:00PM	(590) Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes	Convention Center, Hall E
Wednesday, 8:00AM – 9:45AM	(802) Highway Safety Performance	Convention Center, Hall E

2 Crash Data and Data Analysis

Mohamad Banihashemi, GENEX Systems

As expected, Crash Data and Data Anaysis contains a wide variety of subjects in highway safety. Of papers submitted to the 2017 Annual Meeting, there were fifty-seven papers that fit in this major category, with several sub-categories into which these papers could be split: Crash Data Collection and Source, Calibration of Crash Prediction Models, Vision Zero and Performance-Based Analysis, Use of Spatial Data in Safety Analysis, Speed and Safety and Secondary Creashes, Intersection Safety, Pedestrian and Bicyclists' Safety, Human Factors Affecting Safety, and a wide veriety of Non-Human-Factors Affecting Safety and Safety Models.

Crash Data Collection and Source: Gan, A. et al. (17-01430) introduced a prototype system to collect data from police reports. So, J. et al. (17-00084) used in-vehicle black-box data for the purpose of safety analysis. Montella, A. (17-02595) used a web-based software to improve the crash data collection. And N. Lyu at al. (17-04325) used 3D laser scanning data in nidentifying collision angle in their crash analysis.

Calibration of Crash Prediction Models: Geedipally, S. et al. (17-04529) explored the need for calculating and using jurisdiction specific calibration factors when using crash prediction models. And Parvin, N. et al. (17-06475) compared the calibration of the HSM models to the development of SPFs for specific jurisdictions.

Vision Zero and Performance-Based Analysis: Richer, C. et al. (17-06147) developed a data-driven process within a Vision Zero Initiative for LA to get to zero traffic fatality by 2015. Black, T. et al. (17-06325) developed the data strategy for LA Vision Zero initiative. Islam, M et al. (17-06667) introduced a quantitative performance-based process within the Metropolitan Improvement Study (MTIS) framework. Markt, J. et al. (P17-021450)conducted a pilot performance-based study in Iowa. And Lubliner, H. and C. Bornheimer (17-P17-21452) conducted a performance-based analysis in Kansas.

Use of Spatial Data in Safety Analysis: Cai, Q. et al. (17-01200) used spatial data in Macro-level Crash modeling. Kocatepe, A. et al. (17-06321) investigated the spatial crash proneness by using a combination of socioeconomic and crash hotspots data. Ulak, M. et al (17-05135) conducted spatial analysis of severe crash hotspots accessability to hospitals. And H. Naqvi and G. Tiwari (17-05012) performed a spatial analysis of fatal crashes on national highways of India.

Speed and Safety and Secondary Creashes: Sun, D. et al. (17-05398) studied the effect of speed on safety in school zones in City of Edmonton, Canada. Goodal, N. (17-06790) estimated the probability of secondary crashes occurance by using speed data. Ly, T. et al. (17-03542) used several explanatory variables to estimate the probability of secondary

crashes occurance. And Gargoum, S. et al. (17-04643) classified the road segments into high and low-speed regimes in evaluating safety.

Intersection Safety: Yang, Z. et al. (17-00869) conducted a multiobjective evaluation of two-way stop-controlled intersections considering safety, operational, and environmental factors. Nightingle, E. et al. (17-000077) investigated the effects of several factors on crashes at high-speed rural intersections. Jolovic, D. et al. (17-01695) studied the effect of signal timing on severity and frequency of crashes at intersections. Himes, S. et al. (17-03500) evaluated the safety effect of red-light indicator lights in Florida. And Yassin, J. et al. (17-04529) conducted a research study to evaluate the intersection safety benefits of the box span signal configuration.

Pedestrian and Bicyclists' Safety: Prato, C. et al. (17-01803) conducted a spatial abnalysis of pedestrian crashes in Denmark. Kaygisiz, O. and G. Hauger (17-03495) conducted a network-based point pattern analysis of bicycle crashes in Vienna, Austria. Karaka, I et al. (17-04587) conducted a cross-sectional study of pedestrian and bicyclist crashes considering population characteristics and mode of commuting. Tothman, L. et al. (17-04638) performed a before-after study on the effect of the pedestrian countdown signals on safety. Medury, A. et al. (17-05404) investigated the under-reporting of the pedestrian and bicyclist crashes around university campuses. Brunson, C. et al. (17-05455) studied the crashes of the left-turning vehicles with pedestrians and bicyclists. Berkow, M. et al. (17-05645) proposed templates for collecting sidewalk-related bicycle crashes. Schneider, R. et al (17-05716) prepared a comparison of the fatal pedestgrian and bicycle crashes in metropolitan regions. Wang, J. et al. (17-06180) estimated exposure to risk of bicyclists in Minneapolis. Le, T. et al. (17-05379) evaluated the safety effects of low-cost systemic safety improvements on intersection safety. Sobhani, A. et al. (17-06356) evaluated the effect of some major treatments on pedestrian crashes in Victoria, Australia. And Verbas, O. et al. (17-06486) modeled the safety effects of red-light cameras.

Human Factors Affecting Safety: Islam, T. et al (17-04744) studied the effect of traffic safety culture on traffic fatalities and injuries. Jalayer, M. and M. P. Rouhalamin (17-01182) and B. Zhang et al. (17-05146) studied the phenomenon of wrong-way driving. Morris, C. (17-01665) studied the falatity risk by age, sex, and mode of travel. Hassan, H. et al. (17-03478) studied the effect of drivers tailgating on crashes. Mamdoohi, A. and O. Nordfjærn (17-04061) studied the safety effect of driver behavior in Iran. And Razi Ardakani, H. et al. (17-06836) studied the effect of driver's distraction on crashes using nested logit model.

Non-Human-Factors Affecting Safety and Safety Models: The safety effects of a wide veriety of non-human factors were studied in this year's papers. Kumar, A. et al. (17-01660) studied the effect of response time of the emergency medical services (EMS) on fatal crashes. Also Hu, W. et al. (17-05293) studies the effect of the access to Trauma centers on fatal crashes. Dadashova, B. et al. (17-02571) evaluated the effect of commercial motor vehicle volume on roadway safety. Avelar, R. et al. (17-00042) conducted an evaluation on the effect of tire

debris on crashes. Jared, D. et al. (17-00809) studied the mitigations to deer crashes. Wu, J. et al. (17-00940) analysed the effect of driving cycles on crash risk on freeways. Bush, K. and C. Chavis (17-06829) analysed the effect of on-street parking on the safety of urban artetials. Lyon, C. et al. (17-00432) studied the safety effects of in-lane curve warning pavement markings and oversized chevron signs. Park, J. and M. Abdel-Aty (17-00439) evaluated the use of multiple CMFs n crash prediction models. Rahmani Firouzabadi, R. et al. (17-01356) developed a safety assessment tool for work zones. Musey, K. et al. (17-02448) studied the impact of high friction surface treatment on safety. Green, E. et al. 917-05747) studied the effect of segment length on the results of safety models. Pu, Z. et al. (17-05863) evaluated the safety effects of variable speed limits on safety. And Abuzwidah, M. and M. Abdel-Aty (17-06894) evaluated the effect of high occupancy toll lanes on safety of freeways.

Smmaries of the above papers are shown below:

Authors	Qing Cai, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01200
Paper Title	Comparative Analysis of Zonal Systems for Macro-level Crash Modeling: Census Tracts, Traffic Analysis Zones, and Traffic Analysis Districts
Abstract	Macro-level traffic safety analysis has been undertaken at different spatial configurations. However, clear guidelines for the appropriate zonal system selection for safety analysis are unavailable. In this study, a comparative analysis was conducted to determine the optimal zonal system for macroscopic crash modeling considering census tracts (CTs), state-wide traffic analysis zones (STAZs), and a newly developed traffic-related zone system labeled traffic analysis districts (TADs). Poisson lognormal models for three crash types (i.e., total, severe, and non-motorized mode crashes) are developed based on the three zonal systems without and with consideration of spatial autocorrelation. The study proposes a method to compare the modeling performance of the three types of geographic units at different spatial configuration through a grid based framework. Specifically, the study region is partitioned to grids of various sizes and the model prediction accuracy of the various macro models is considered within these grids of various sizes. These model comparison results for all crash types indicated that the models based on TADs consistently offer a better performance compared to the others. Further, the models considering spatial autocorrelation outperform the ones that do not consider it.

Authors	Albert Gan, Florida International University (FIU) Priyanka Alluri, Florida International University (FIU) Haifeng Wang, Florida International University (FIU)
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01430
Paper Title	A Prototype System for Collection of Safety Data from Police Crash Reports
Abstract	Police crash reports include useful additional information that is not available in crash summary records. This information may include police sketches and narratives and is often needed for detailed site-specific safety analysis. In addition, some agencies also routinely review police reports to correct miscoded and missing crash types. As a result, safety analysts often spend much of their time to review police reports on a regular basis. However, reviewing police crash reports and recording review information in Florida has not been an easy process. This paper introduces a newly developed web-based system designed for the Florida Department of Transportation (FDOT) to facilitate the process of reviewing police crash reports and recording review results. The system allows projects to be set up for specific study locations and target review questions. The review questions can be set up for different data entry formats, including dropdown list, checkbox, radio button, single and comment box. A user-friendly interface is provided to allow the users to review the police reports specified in a project and to save the review results together with their respective crash records in the database. The results can then be downloaded to a local drive for further safety analysis. The system reduces the police report review processing time by multiple folds and helps cut down on the project backlogs at FDOT safety offices. The system can serve as a prototype and be adapted for other transportation agencies to facilitate their review of police crash reports and collection of safety data.

Authors	Anil Kumar, San Jose State University Osama Abudayyeh, Western Michigan University Tycho Fredericks, Western Michigan University Megan Kuk, Western Michigan University Michelle Valente, Western Michigan University Kaylie Butt, Milwaukee School of Engineering
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01660
Paper Title	Trend Analyses of Emergency Medical Services for Motor Vehicle Crashes: Michigan Case Study
Abstract	Timely response of an EMS personnel at a crash site may help prevent loss of a life and thereby impact the quality of life for an individual at risk. With that said, availability and access to quantitative data involved in the EMS activities becomes critical. This study was conducted to review the EMS data collected by The Michigan Department of Community Health (MDCH), Emergency Medical Services (EMS) Section from a 5-year period starting 2010. The specific intent was to identify current EMS response, treatment, and transport trends. Among the results noted in this paper, it was identified that on average, total time involved from the dispatch call to the drop off of a patient from a motor vehicle crash in the state of Michigan were 56.99 minutes and 42.97 minutes for rural and urban areas, respectively. The results from this study could be utilized to guide and direct future EMS initiatives relating to motor vehicle crashes. The analysis might also be beneficial in predicting the types of injuries that occur in specific types of vehicle crashes. Several challenges and recommendations are also provided in this paper.

Authors	Bahar Dadashova, Texas A&M Transportation Institute Blanca Arenas-Ramirez, Universidad Politecnica de Madrid Camino Gonzalez-Fernandez, Universidad Politecnica de Madrid Raul Avelar, Texas A&M Transportation Institute Francisco Aparicio, Universidad Politecnica de Madrid
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-02571
Paper Title	Evaluation of Potential Impact of Decreasing Commercial Motor Vehicle Volume on Roadway Safety in Spain
Abstract	Spain's Ministry of Transportation (MFOM) envisions to increase the railway share of goods transportation from 4.1% to 8-10% by 2020 in order to improve the roadway safety as well as decrease greenhouse emissions. This in turn implies that the volume of commercial motor vehicle (CMV) will potentially decrease. This paper was developed with the purpose of evaluating the impact of this potential decrease in CMV miles on road safety. For this purpose, the research team studied the data collected (2010) from two major freight corridors in Spain: Almería (south-east) -Barcelona (north-east) and Madrid (center) - Irún in the Vasque Country (north). To carry out the empirical study, the factors affecting the prediction of the road safety indicator were identified through negative binomial regression models. In order to estimate the effect of the CMV removal from the traffic flow, simulation scenarios with new traffic volume data were generated, assuming that CMV traffic decreases of 5%, 10% and 15%. We also considered the potential changes in the remaining traffic volume after the CMV volume decrease. It is assumed that the remaining traffic will either remain the same or increase due to induced traffic (i.e. rebalance of transportation supply and demand, or the attraction of more users to the roads because of reduced CMV traffic). New crash data was simulated using the potential scenarios where the CMV and remaining traffic volume change their values. Comparing the results of the simulated and observed crash data the authors observed that decreasing CMV volume may have both positive and negative impact on road safety. The direction of this impact is site-specific and significantly depends on the facility type. The research team also observed that the effect of the induced traffic is another important factor that should be taken into account when decreasing the truck volume.

Authors	Tazul Islam, City of Edmonton Laura Thue, City of Edmonton Jana Grekul, University of Alberta
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-04744
Paper Title	Understanding Traffic Safety Culture: Implications for Increasing Traffic Safety
Abstract	Despite the success of various engineering, education and enforcement measures, fatalities and injuries from traffic collisions have remained as one of the major global problems. Recently, it has been advocated that addressing this massive problem requires a fundamental transformation in the traffic safety culture of road users. Consequently, measuring and understanding traffic safety culture has gained growing attention in the field of traffic safety. To this end, this study, believed to be the first of its kind in Canada, aimed to (i) measure traffic safety culture related to distracted driving, impaired driving and speeding, (ii) investigate how perceptions of these major issues are associated with self-reported behaviour and support for related enforcement and policy, and (iii) explore the effect of respondents' socio-demographic characteristics on traffic safety culture. A telephone survey based on a stratified random sample of approximately 1000 residents in the Edmonton region of Alberta, Canada, was conducted in 2014. Descriptive analysis, multivariate confirmatory factor analysis and structural equation modeling were performed. The descriptive statistics show the prevalence and often the acceptance of distracted driving, specifically hands-free cell phone use, and speeding on freeways. Detailed results demonstrate statistically significant correlations among perceived threat to personal safety, acceptability of behaviours, self-reported behaviours, support for enforcement and support for law and policy. In addition, perceived threat to personal safety was found to have a statistically significant influence on self-reported behaviour, and support for enforcement, law and policy. Finally, various socio-demographic characteristics have a significant effect on the perceived threat of traffic behaviours to personal safety. The results from this study can be used to better guide educational campaigns to transform traffic safety culture from one that is risk receptive to one that is protective.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-05293
Paper Title	Access to Trauma Centers for Fatal Crashes in the United States
Abstract	Existing research indicates that around 90% of all US residents have access to at least one level I or II trauma center within 60 minutes. However, a limitation of these estimations lies in that they are based on where people live and not where people are injured, which may overestimate the access to trauma center for seriously injured patients in fatal crashes. In this study, the Fatality Analysis Reporting System (FARS) data from 2013 to 2014 were collected and analyzed to quantify the access of injured patients to trauma centers for fatal crashes across states. Two types of distance, linear distance and route distance, were calculated using ArcGIS. The Northeast region had the nearest average linear and route distance between fatal crash and trauma center (25.3 km and 31.7 km, respectively), followed by the Midwest (44.4 km and 54.1 km), the South (47.3 km and 57.0 km), and the West (50.9 km and 67.5 km). The estimated transport time to the nearest level I/II trauma center was also calculated and compared to the recorded transport time. The comparison results revealed that the different states adopted different trauma triage protocols, resulting in different utilization rate of the level I/II trauma center among states. A linear regression analysis demonstrated that the longer the average route distance, the less the seriously injured patients in fatal crashes were taken to level I/II trauma center directly.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06147
Paper Title	Vision Zero Technical Analysis in Los Angeles, California: Data-Driven Effort to Eliminate Traffic Fatalities
Abstract	In August 2015, Los Angeles Mayor Eric Garcetti issued Executive Directive 10, *Vision Zero Initiative,* establishing a goal of zero traffic deaths in Los Angeles by 2025. In response to this directive, the Los Angeles Department of Transportation (LADOT) completed an in-depth, data-driven process to build the foundation of a city-wide Vision Zero initiative. This study documents the innovations developed to analyze collision data, pair countermeasures to specific data-driven trends, and prioritize high-collision locations. A team of planners, engineers, statisticians, and data analysts worked together to create a process grounded in national best practices and tailored to meet the specific needs of LADOT. This study can be used as a guide to help cities develop their own robust data-driven Vision Zero process, to develop an understanding of collision patterns across the city, pair countermeasures in locations where the greatest collision reduction could be obtained, and prioritize the most critical intersections. More immediately, this study positions LADOT to develop an Action Plan, including prioritized locations and project descriptions for the first several years of Vision Zero infrastructure investment and any related projects through LADOT's normal course of work.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06321
Paper Title	Socioeconomic Characteristics and Crash Proneness: Case Study in Florida Using Two-Step Floating Catchment Area Method
Abstract	The objective of this study is to investigate the spatial crash proneness among different population groups using a Gaussian-based two-step floating catchment area (2SFCA) method. This is performed by developing a special form of crash-to-population ratio that incorporates the crash hotspots as well as the socioeconomic data. While identifying the crash hotspots, four different age groups are considered: 17 and younger, 18 to 21, 22 to 64 and 65 and older. For each age group, different crash hotspots are identified based on the number of severely injured occupants of that age group involved in crashes. Using these age-specific crash hotspots, further socioeconomic analysis is conducted weighting the distances between crash hotspot locations and population block groups. This analysis included data on the ethnicity, poverty, education level, and vehicle ownership. Results indicate that several high and low crash prone areas are correlated with the socioeconomic characteristics of those areas. The developed approach has the potential to improve understandings of the relationships between socioeconomics and crash proneness.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06325
Paper Title	Vision Zero and Beyond: A Simple Yet Powerful Data Strategy for Evaluating Potential Engineering Solutions
Abstract	As cities adopt Vision Zero goals to eliminate traffic fatalities, many find they are limited in resources to carry out such an ambitious program. With constraints in time, funding, and staffing, many cities are taking a data-driven approach to reduce fatalities as quickly and cost-effectively as possible. The Los Angeles Department of Transportation (LADOT), in collaboration with the Los Angeles County Department of Public Health (LACDPH), developed a simple—yet powerful—database and analysis tool that now plays a key role in how Los Angeles prioritizes projects, applies for grant funding, and designs for safety on our streets. Moving beyond the macro-level Vision Zero strategy development, this tool provides a more targeted approach to estimating the safety benefit of specific engineering countermeasures. Providing highly customizable queries, the process proposed in this paper can be implemented quickly and applied to improve the work transportation planners and engineers already do on a daily basis, such as apply for grants to fund basic safety improvements.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06667
Paper Title	Performance-based Assessment to Transportation Safety Planning for Metropolitan Travel Improvement Study
Abstract	Nebraska sets the ambitious 'toward zero deaths' goal as part of the Strategic Highway Safety Plan (SHSP). Improving highway safety by reducing fatalities and serious injuries on all public roads is integral to the transportation safety management in Nebraska. With the vision of Metropolitan Improvement Study (MTIS) for Omaha, Nebraska and Council Bluffs, Iowa by Nebraska Department of Roads (NDOR) and Metropolitan Area Planning Agency (MAPA), quantitative safety performance stands as an important milestone and key decision making factor. This study focuses on the process and outcome of performance-based safety evaluation of freeways and major arterials for the MTIS by applying the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) and the Federal Highway Administration (FHWA) Crash Modification Factor Clearinghouse. An HSM predictive network screening method was applied to identify the locations with potential for safety improvements. A detailed analysis of the most recent five years of historical crash data was performed to understand the contributing factors. With this knowledgebase, strategies to mitigate severe crashes were determined. This leads to predictive safety performance of six strategy packages for the design year 2040. This paper focuses on a performance-based approach to compare safety performance to transportation planning alternatives. Thus, this study establishes a framework to implement the quantitative safety evaluation process envisioned in HSM in the direction 'towards zero deaths.' Moreover, this study paves an avenue to make informed decisions by the safety professionals, designers, planners, and policy makers at state and local levels.

Authors	Danyang Sun, University of Alberta Karim El-Basyouny, University of Alberta Shewkar Ibrahim, City of Edmonton
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	329
Session Title	School Transportation Research
Paper Number	17-05398
Paper Title	Speed and Safety Assessment of School Zones: Case Study of City of Edmonton, Canada
Abstract	This paper describes a study undertaken to assess the speed and safety effects of reducing speed limits from 50-to-30 km/h in school zones in Edmonton, Canada. A longitudinal (before-and-after) study was conducted to evaluate the changes in collisions and vehicular speeds. Statistical analyses were employed to test the significance of the impacts. The results indicated that mean speeds and 85th percentile speeds were reduced by 12.2 and 12.0 km/h, respectively. More so, the analysis revealed speed variation was smaller in the after period. Moreover, speed distribution plots were depicted to compare the speeds before and after the speed limit change. The results indicated that the speed distributions shifted to the left, showing significant reductions in all speed ranges, especially when considering locations with high speeds. The findings from the speed analysis indicated a positive safety effect from introducing school zones. To corroborate this finding, a simple before-and-after collision analysis was conducted. The evaluation results revealed that fatal/injury collisions were statistically significantly reduced by 41.2%, and injuries to vulnerable road users were statistically significantly reduced by 71.4%. Consequently, the results of this study provide strong evidence that reducing speed limits to 30 km/h in school zones can bring about significant safety effects by reducing vehicular speeds and fatal/injury crashes. The results also showed that for every 1 km/h reduction in mean speed, fatal/injury crashes were reduced by 4%, which is consistent with findings from previous research.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-00869
Paper Title	Multiobjective Evaluation in Countermeasure Selection at Two-Way Stop-Controlled Intersections Considering Traffic Operation, Safety, and Environment
Abstract	This study aims to develop a procedure to conduct multi-objective evaluation in traffic countermeasure (CM) selection process at two-way stop-controlled (TWSC) intersections. To illustrate the procedure, the economic benefits of three vehicle safety related CMs were calculated considering not only the safety impacts but also the operational and environmental impacts. First, for each countermeasure, VISSIM simulation models were developed to obtain the average delay, vehicle emission and fuel consumption for the intersection both before and after the treatment. The traffic operational impacts were calculated as the change in delay costs. The environmental impacts were calculated as the change in vehicle emission and fuel consumption costs. Next, the safety impacts were calculated as the crash reduction benefits for different CMs using safety performance functions (SPFs) and crash modification factors (CMFs). Finally, the life cycle cost (LCC) method was used to combine the different components in the total benefit. The Monte Carlo (MC) simulation method was used to conduct uncertainty analysis by using random sampling from probability descriptions of uncertain input variables to generate a probabilistic description of results. The findings showed first, that the operational and environmental impacts accounted for a large proportion of the total impacts, which can significantly affect the selection of CMs. Second, the rankings of the CMs differ depending on whether the safety impacts alone are considered, or whether the safety, operational and environmental impacts are considered together. The study illustrates the detailed process of evaluating projects considering multiple objectives. This process offers policy and decision makers a solid and practical reference of how to conduct multi-objective evaluation. The findings also explain how different objectives can countervail with each other in improving motorist safety at TWSC intersections.

Authors	Noah Goodall, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-06790
Paper Title	Probability of Secondary Crash Occurrence on Freeways Using Private-Sector Speed Data
Abstract	A percentage of crashes on freeways are suspected to be caused in part by the congestion or distraction from earlier incidents. Identifying and preventing these secondary crashes are major goals of transportation agencies, yet the characteristics of secondary crashes—in particular the probability of their occurrence—are poorly understood. Many secondary crashes occur when a vehicle encounters non-recurring congestion, yet previous efforts to identify incident queues and their secondary crashes have relied either on deterministic queuing theory, or on data from uniformly-spaced, dense loop detectors. This study is the first analysis of secondary crash occurrence integrating incident timelines and traffic volumes with widely-available (and legally obtained) private sector speed data. Analysis found that 9.2% of all vehicle crashes were secondary to another incident, and that 6.2% of these crashes were tertiary to another primary incident. Secondary crashes occurred on average once every 10 crashes and 54 disabled vehicles. The findings support a fast incident response, as the probability of secondary crash occurrence increases approximately one percentage point for every additional 2-3 minutes spent on-scene in high volume scenarios.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-05135
Paper Title	GIS-Based Spatial and Statistical Analysis of Severe Crash Hotspot Accessibility to Hospitals
Abstract	Previous studies have examined the hospital accessibility problem, and exhaustively investigated several aspects of roadway crashes such as their severity, frequency, influential factors, and clustering behavior. However, even though studies have looked at crashes and hospital accessibility separately, the relationship between them, in terms of accessibility of severe crash hotspots to hospitals with emergency services, still remains unclear. In this study, we investigate this accessibility using a geographic information systems (GIS)- and statistics-based analysis to detect high risk locations. We also examine several environment-, traffic-, and human-related factors to identify the determinants of the crashes that constitute the hotspots via a hierarchical multinomial logistic regression analysis. Results show that several roadway segments portend an elevated threat of injury and fatalities on drivers and passengers not only due to a higher probability of being severely injured, but also because of their low accessibility with respect to hospitals having emergency service. Regression analysis, on the other hand, illustrates and verifies that particular spatial, traffic-, and roadway related factors such as intersection presence or speed limits imperil traffic safety substantially. The knowledge gained from this study can help agencies and officials pinpoint and investigate high risk locations to enhance the safety of roadway users.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00042
Paper Title	Safety Evaluation of the Seasonality of Crashes with Tire Debris on Highways and Freeways
Abstract	This paper investigated the safety implications of tire debris deposited on Texas highways. The researchers performed two analyses in this investigation: a safety analysis and an analysis on the quantity of observable tire debris on Texas highways. The safety analysis was based on a set of 2,247 crashes with foreign objects on the pavement for years 2012-2014. Examining crash narratives, the authors identified a subset of 251 crashes that involved tire debris specifically. This analysis found increased odds of observing crashes with tire debris at facilities with higher speed limits, with more lanes, with higher percentage of trucks in their traffic stream, and at rural facilities compared to urban facilities. The authors performed additional analyses on a different dataset containing data on tire debris observed during field visits that occurred during summer and fall of 2015 for a probability sample of Texas highways. A total of 14,998 pieces of tire debris were identified from these visits at freeways and highways located in both rural and urban environments. The first analysis utilized support vector regression and was exploratory in nature. This analysis suggested that truck average annual daily traffic (AADT) and speed limit along a highway section are the covariates that most directly correlate with the amount of observable tire debris. The second analysis on this dataset was a formal statistical evaluation that found that, indeed truck percent and speed limit do associate statistically with the presence of tire debris on Texas highways, along with other covariates. Overall, the analyses seem to indicate that a significant increase in tire debris quantity as well as a significant increased risk of crashes with tire debris during the summer months.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00084
Paper Title	Perspectives of In-Vehicle Black Box Recording Data for Safety Analysis
Abstract	This study investigated potential uses of in-vehicle black box video recording data for the purpose of safety analysis. An in-vehicle black box device is attached on the front windshield of a vehicle and collects video images of the front and rear side of vehicle, speed, acceleration rate, location, and g-force. Considering this data collection capability of the black box devices, this study developed potential use-cases of the safety studies as the followings, i) understanding of crashes, ii) an analysis of crash severity, and iii) identification of the safety threshold. In this study, the black box data were collected from the crashes occurred in the City of Incheon, South Korea. The preliminary studies of the three use-cases indicates that the black box data are good supplements to understand crash situations, and especially integrating the black box data and the crash reports is promising to have a better understanding of crash situations, by providing various views of the crashes. Some recommendations for future research are also provided.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00809
Paper Title	Understanding White-tailed Deer Sensory Abilities, Behavior, and Movement Ecology to Mitigate Deer-Vehicle Collisions: the Value of Long-term, Collaborative Research
Abstract	Deer-vehicle collisions (DVCs) are a nationwide concern resulting in loss of human lives and financial loss from vehicle damage. Wildlife warning reflectors, vehicle-mounted sound emitters, and roadside fences have been proposed to mitigate DVCs. However, these deterrents have been marketed and implemented with little scientifically based testing of their efficacy, especially in terms of how they are perceived by deer and how they do (or do not) alter deer behaviors. This paper provides a detailed review of a 14-year collaborative research program between Georgia Department of Transportation (GDOT) and university researchers designed to investigate the sensory abilities of white-tailed deer (Odocoileus virginianus) and deer behavior as a basis for testing methods for deterring deer from entering roadways. State highway departments should consider the results of this empirical research before implementing vision- or sound-based deterrents or roadside fencing. These results also will provide a basis for planning additional research projects designed to mitigate DVCs in other states.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00940
Paper Title	Effect of Road Characteristics and Driving Cycles on Accident Risk on Full-Access-Control Highways
Abstract	Crashes on freeways have caused severe life and property losses in the United States. In order to better predict crash risk on full-access-control roads, the correlation between crash rate and roadway characteristics along with traffic factors is studied in this paper. The traffic characteristics considered in this paper were extracted from driving cycles. Driving cycles and roadway features were generated from the Strategic Highway Research Program 2 (SHRP 2) database. A total of 1,089 road segments with driving cycles information and crash rate information were reserved for regression analysis. A negative binomial model of freeway crash rate is performed to evaluate the effect of different factors on the incidence of crashes on full-access-control highways. The diagnositics plots showed that negative binomial is a valid model for the data. The coefficient value and its significance level were estimated for each of the selected variables. For roadway characteristics, the results of the analysis indicate that for an urban area, the number of through lanes in one direction and speed limits have a significant influence on the crash risk, while functional system, curve level, and grade level have less of an effect on crash risk. For traffic factors, high average speed and high fluctuation in vehicle speed will significantly increase crash rate. The results of this research can be used to help engineers predict crash risk in different highway locations and take measures to improve traffic safety on full-access-control highways.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-01182
Paper Title	Multiple Correspondence Approach to Identifying Contributing Factors Regarding Wrong-Way Driving Crashes
Abstract	On a nationwide scale, according to the National Highway Traffic Safety Administration (NHTSA), an average of 355 fatalities occur each year due to wrong-way driving (WWD). These crashes result in 1.34 fatalities per fatal crash, while for other non-WWD fatal crashes this number drops to 1.10. As such, further in-depth investigation of WWD crashes is necessary. The purpose of this study is twofold: to identify the characteristics that best describe WWD crashes and to verify the factors associated with WWD occurrence. To do so, we collected and analyzed fifteen years of crash data from the states of Illinois and Alabama. The final dataset comprises 398 WWD crashes. The rareness of WWD events and the consequently small sample size of the crash database significantly influence the application of conventional log-linear models in analyzing the data, as they use maximum-likelihood estimation. To overcome this issue, in this study, we employ multiple correspondence analysis (MCA) to define the structure of the crash dataset and identify the significant contributing factors to WWD crashes on freeways. The study results provide policymakers with useful insights into WWD crashes for the development of effective safety countermeasures.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	
Session Title	
Paper Number	17-01665
Paper Title	Motor Vehicle Crash Fatality Risk by Age, Sex, and Mode of Travel
Abstract	This study quantified motor vehicle crash fatality risk in the United States for 2009 by age, sex, and mode of travel (passenger vehicle, motorcycle, pedestrian, bicycle, or bus) using person time as the risk exposure denominator. Fatality risk ratios used either same age-sex or 5-14 year old male passenger vehicle risk as comparison baselines (risk ratio denominators). Comparisons within age-sex groups using their passenger vehicle risk as the baseline revealed very low risk for bus travel and greater risks for pedestrian, bicycle, and especially motorcycle travel, albeit results were not statistically significant in several female groups likely due to small trip sizes. Crash fatality risk was greater for motorcycle versus passenger vehicle travel among both males and females, but not statistically significant for the 15-24 and over-65 year old female groups. Crash fatality risk among males ranged from 34.3 to 381.3 times greater for motorcycle travel in the same age group versus passenger vehicle travel in the 5-14 year old male passenger vehicle group. Passenger vehicle travel fatality risk also varied across age-sex groups, e.g., 9.6 times greater for 15-24 year old males, and 4.7 times greater for over-65 year old females, compared to 5-14 year old males.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-01803
Paper Title	Integrating Police Reports with Geographic Information System Resources for Uncovering Multidimensional Patterns of Pedestrian Crashes in Denmark
Abstract	Promoting walking goes a long way in contributing to the sustainability and health of future cities and regions, and improving pedestrian safety is essential for building more sustainable and healthier communities. As the problem is multidimensional in nature, this study looks at patterns of pedestrian crashes with a multidimensional perspective that goes beyond the traditional investigation of pedestrian characteristics and behaviour by analysing the effect of the built environment, the land use and the traffic conditions at the crash location. Moreover, this study goes beyond the analysis of traditional police reports by integrating them with geographic information system resources that are becoming increasingly available worldwide. This study analyses a sample of 7469 crashes between a pedestrian and another road user that occurred in Denmark between 2006 and 2015. The crash locations were geocoded and matched to a detailed traffic network, a transport planning model, and several resources detailing building and land use composition. Latent class analysis was applied to uncover patterns of pedestrian crashes for both the fully identified records and the substantial amount of hit-and-run records. Findings from this study reveal a major red thread in the lack of hazard awareness for both pedestrians and road users and suggest solutions from both the behavioural and the infrastructure perspectives: major needs are (i) educating pedestrians about the risks related to drinking and then walking along major roads in the darkness, (ii) making crossings for pedestrians and approaches for road users easier to understand and to access in order to reduce unnecessary conflicts, and (iii) designing traffic calming solutions around major shopping and leisure locations in dense city centres.

Authors	Alfonso Montella, University of Naples Federico II
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-02595
Paper Title	Improvement of Crash Data Collection, Processing and Analysis by a Web-Based Software
Abstract	Real-world crash data play a vital part in the development of safer transport since information on crash data is essential as a means of understanding where and why crashes occurred in the past and how the occurrence of similar events may be prevented in the future. First step of the development of an effective safety management system is to create reliable crash databases since the quality of decision making in road safety depends on the quality of the data on which decisions are based. Since existing databases show significant drawbacks, which hinder their effective use for safety analysis and improvement, in this paper we present the development and evaluation of a web-based software for crash data collection, processing and analysis. The software development was based both on the detailed critical review of existing Australasian, EU, and U.S. crash databases and software as well as on the continuous consultation with the stakeholders. The evaluation was carried out comparing the completeness, timeliness, and accuracy of crash data before and after the use of the software in the town of Vico Equense, in south of Italy. The evaluation phase showed several significant advantages. The time saving was more than one hour per crash, i.e., a 36% reduction. The amount of collected information increased from 82 variables to 268 variables, i.e., a 227% increase. The most valuable benefit of the new procedure was the reduction of the police officers mistakes during the manual operations of survey and data evaluation.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-03478
Paper Title	Drivers' Time Headway Characteristics and Factors Affecting Tailgating Crashes
Abstract	The tailgating is a common phenomenon where aggressive drivers attempt to drive very closely to vehicles ahead pushing the leading vehicle's driver to get out of the way. Tailgating drivers are usually overestimating their skills with the belief that they can avoid rear-end collisions. The primary objective of this paper is to investigate the tailgating behavior and time headway characteristics in UAE. It also aims to provide a better understanding of the characteristics of at-fault drivers involved in tailgating-related crashes and to further identify the significant factors that affect the occurrence of such crashes. Two datasets were used in the analysis. The first is the time headway data collected from a total of 291 locations covering freeways and urban areas. A slightly more than 185,000,000 records have been analyzed to test the percentages of drivers with 1 and 2 seconds or less time headway. The second dataset include a total of 12,611 severe traffic crashes that occurred in UAE between 2010 and 2015. The findings indicated that an average of 7.1 % and 13.6 % of vehicles had a headway less than or equal to one and two second, respectively. In addition, a binary logistic regression model was developed to determine the significant factors affecting the occurrence of tailgating crashes. The model resulted in a set of significant factors including drivers' factors (i.e., gender and nationality), vehicle factor (i.e., vehicle type), road and environment factors (i.e., road type, number of lanes and road surface condition).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-03495
Paper Title	Network-Based Point Pattern Analysis of Bicycle Accidents to Improve Cyclist Safety: Case in Vienna, Austria
Abstract	Examining of the spatial distribution of bicycle accidents in different conditions and periods is very important issue to increase cyclist safety. This paper describes a point pattern analysis methodology of 1437 bicycle accidents resulted in injury or death in Centre of Vienna, Austria during the period 2012–2014. The Network-based Kernel Density Estimation was used to examine the hotspots of bicycle accidents and the Network-based Nearest Neighbor Distance method was taken into account to check the significance of the hotspots. Moreover, The Global Cross Nearest Neighbor Distance Method was performed to test the effect of urban components on the distribution of bicycle accidents. In order to understand the temporal and conditional differences, the accident data were analyzed in terms of four different grouping orders. In the first grouping approach, all accident data were considered. Then the accident data was classified according to season, light condition and precipitation condition, respectively. As a result, a systematic framework was proposed for spatio-temporal analysis of bicycle accidents for built environment. The framework can serve as a guide for determining effective strategies of cyclist safety in urban areas.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03542
Paper Title	Unified Framework for Analyzing Attributes of Primary and Secondary Accidents
Abstract	In the past, accident analysis and prevention studies tended to focus on a specific component of the crash modelling process; either crash classification, identification of risk factors, or advancement of modelling methodology. The objective of this study is to develop a comprehensive framework that allows both non-secondary and secondary crashes to be identified and modelled. This study further uses survival analysis to explore the relationship between primary and secondary incidents; something which has not been explored before. The proposed modeling framework comprises a negative binomial formulation to model non-secondary crashes, a binary logit formulation to model the probability of a secondary accident occurring and a hazard-based model to capture changes in the likelihood of occurrence of secondary accident as time passes. A variety of explanatory variables are studied in each of the modeling steps, including temporal and spatial conditions, geometric design, weather condition, and traffic conditions. The modeling dataset is collated using two major motorways in Sydney for accidents happening in the period of 2011 to 2013 using speed measurements for three and a half hours after the recorded time of the primary crash to determine the crash boundary. Speed was found to be one of the key variables in crashes. Besides, likelihood of a secondary incident was found to be heavily influenced by a combination of weather conditions and driver expectations. In general, a secondary crash was seen to be highly probable during the first 60 minutes of the primary crash occurring, but this probability decrease as time passes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04061
Paper Title	Predictors of Crash Among Iranian Drivers; An Exploratory Analysis of Developed Driver Behavior Questionnaire
Abstract	More than 16500 people lose their lives each year due to traffic accidents in Iran, which reflects one of the highest road traffic fatality rates in the world. The present study aims to investigate the dimensional structure of an extended Driver Behavior Questionnaire (DBQ) in Iran and examine gender differences in the dimensions. An additional aim is to test whether DBQ dimensions and demographics are associated with accident involvement. Based on Iranian driving behavior, a modified (36 items) Internet-based version of the DBQ was distributed among Iranians through social networks and email services. Results of Principal Component Analysis based on a sample of 634 Iranians from fifty different cities in Iran identified a five-dimension solution named `speeding and pushing violations`, `lapses and errors`, `violations causing inattention`, `aggressive violations` and `rule violations` which account for 41.4 percent of the total variance. Results also showed that females were more prone to lapses and errors, while males reported more violations than females. Logistic regression analysis identified `violations causing inattention` (P-value 0.000) and `speeding and pushing violations` (P-value 0.000) along with high education (P-value 0.000) as predictors of self-report accident involvement in a three-year period among Iranian drivers. Results are discussed in line with road traffic safety countermeasures suitable for an Iranian context.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04325
Paper Title	Modeling Vehicle Collision Angle in Traffic Crashes Based on Three-Dimensional Laser Scanning Data
Abstract	In road traffic accidents, the analysis of a vehicle's collision angle plays a key role in identifying a traffic accident's form and cause. However, because accurate estimation of vehicle collision angle involves many factors, it is difficult to accurately determine it in cases in which less physical evidence is available and there is a lack of monitoring. This paper establishes the mathematical relation model between collision angle, deformation, and normal vector in the collision region according to the equations of particle deformation and force in Hooke's law of classical mechanics. At the same time, the surface reconstruction method suitable for a normal vector solution is studied. Finally, the estimation model of vehicle collision angle is presented. In order to verify the correctness of the model, verification of multi-angle collision experiments and sensitivity analysis of laser scanning precision for the angle have been carried out using three-dimensional (3D) data obtained by a 3D laser scanner in the collision deformation zone. Under the conditions with which the model has been defined, validation results show that the collision angle is a result of the weighted synthesis of the normal vector of the collision point and the weight value is the deformation of the collision point corresponding to normal vectors. These conclusions prove the applicability of the model. The collision angle model proposed in this paper can be used as the theoretical basis for traffic accident identification and cause analysis. It can also be used as a theoretical reference for the study of the impact deformation of elastic materials.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-04587
Paper Title	U.S. County-Level Cross-Sectional Study of Pedestrian and Bicyclist Crashes, Population Characteristics, and Mode of Commuting
Abstract	This paper provides a multivariate cross-sectional analysis of pedestrian and bicyclist fatal crashes occurring in 655 US counties over a six-year period between 2008 and 2013. Interestingly, the results suggest that increased levels of pedestrian and bicyclist activity may not necessarily lead to increased crash risks. In fact, the absolute numbers of commuters walking and bicycling to work are found to have a marginal effect on crashes when controlled for other population and environmental characteristics, such as population, population density, poverty levels, unemployment rates, average commute time, and climate. On the other hand, the relative share of workers walking to work is, surprisingly, inversely related to the number of pedestrian crashes. It is argued that counties with higher shares of walking commuters may offer environments that are safer or more conducive for walking to work. Second, unobserved changes in driver behavior when encountering pedestrians and bicyclists may explain some of this variability in crash statistics. The paper suggests that pedestrian and cyclist crashes could thus be driven by divergent causal mechanisms and uniquely different dynamics between pedestrians, bicyclists, drivers, and their greater physical environment. The study also provides evidence of similarly complex dynamics between pedestrian/bicyclist crashes and several other variables, including population density, public transportation ridership and average commute time.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-04638
Paper Title	Spatial Distribution of Pedestrian-Motor Vehicle Collisions Before and After Pedestrian Countdown Signal Installation in Toronto, Canada
Abstract	Pedestrian countdown timers (PCS) have been installed in many cities over the last 15 years. Few studies have evaluated the effectiveness of PCS on pedestrian motor vehicle collisions. This study compared the spatial patterns of collisions pre and post installation of PCS for intersections with PCS and roadways without PCS in the City of Toronto, and examined differences by age. Countdown times were installed at the majority of Toronto intersections from 2007-2009. The spatial patterns were compared between four years of police-reported collisions prior to the installation of the timers to four years after the installation at 1864 intersections. The spatial distribution of collisions was estimated using kernel density estimates and simple point patterns examined changes in spatial patterns overall and stratified by age. Areas of higher or lower point density pre to post installation were identified. Some PCS locations had more collisions after PCS installation; particularly for adult and older adult pedestrians. Increased adult pedestrian collisions were concentrated downtown, whereas older adult collision increases occurred throughout the city following no spatial pattern. There was a reduction in children's collisions at both non-PCS and PCS locations, with greater reductions at non-PCS locations. There was generally a more consistent reduction in collisions post installation at the non-PCS locations compared to the PCS locations. PCS can be used to improve pedestrian safety; however, their effects vary both by age and by location. The age and location effects need to be understood in order to consistently improve pedestrian mobility and safety using PCS.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-04643
Paper Title	Factors Affecting the Classification of Road Segments into High- and Low-Speed Collision Regimes
Abstract	The safety of locations operating under high-speed conditions could significantly differ from that of locations operating under low-speed conditions. Therefore, different approaches must be adopted when analyzing and managing speed and safety at locations operating under different regimes. However, first it is necessary to understand the factors affecting which speed-collision classification a site falls under. Locations operating under high speeds are typically expected to have more severe collisions compared to locations where speeds are low. Some locations, however, might experience a high severe collision frequency even when speeds are low, or experience a low collision frequency at high speeds. This paper aims to identify the factors that affecting a sites classification into any of those categories, using data collected at roads in Edmonton, Canada. Locations are divided into four speed-collision bins (high collision, high speed; high collision, low speed; low collision, high speed; low collision, low speed) and GIS maps of locations are produced to explore the spatial distribution of those locations. Moreover, logistic regression is used to understand the role different factors play in identifying the speed-collision bin a certain location belongs to. The results reveal that locations with a high severe collision frequency, despite the low speeds, have a relatively high population of heavy vehicles and trucks and high speed variability. As for locations with low severe collision frequency at high speeds, these locations seem to have a high level of protection through the presence medians and forgiving design, such as shoulders. Moreover, these locations have relatively low access density.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05012
Paper Title	Spatial Analysis of Fatal Crashes on National Highways in India
Abstract	This paper presents spatial analysis of fatal crashes on three National Highways in India. Spatial analysis is done through spatial autocorrelation (Moran's I), kernel density estimation and hot spots analysis by using ArcGIS 10 software. In India, NHs are not fully access control highways, and heterogeneous vehicular traffic ply on highways. The fatal crash for past five years (2009-2013), traffic and highway inventory data have been collected for three NHs (two-lane, four-lane and six-lane). The geographical coordinates for each fatal crash are found out, and individual fatal crashes are plotted using ArcMap (ArcGIS 10). Subsequently, spatial autocorrelation, kernel density estimation technique and Getis-Ord G* (hot spots) statistical analysis are carried out. The study results revealed that fatal crash clusters are not distributed uniformly along the length of NHs; more fatal crash clusters are observed at or near intersections; concentration of fatal crash clusters before highways alignment negotiates with major curves; concentration of fatal crash clusters near urban settings along highway; and, six-lane and four-lane NHs have more fatal crash clusters than two-lane NH perhaps owing to more traffic.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05146
Paper Title	Investigation of Confounding Factors Contributing to Wrong-Way Driving Crashes on Partially and Uncontrolled-Access Divided Highways
Abstract	This study focuses on differentiating the confounding factors that contribute to Wrong-Way Driving (WWD) crashes from other type of crashes on Alabama divided highways by performing statistical analysis. Crash data from 2009 to 2013 including 112 verified WWD crashes is compared with 49,599 other kindof crashes on the same class of roads during the same period. A simple descriptive data analysis was conducted to identify different explanatory variables contributing to WWD crashes. The results illustrated WWD crash temporal distribution, driver characteristics, vehicle characteristics, and environmental conditions. In addition, the Firth's penalized-likelihood logistic regression model was used to identify the statistically significant contributing factors. Odds ratios (OR) of different variables were calculated to measure how each factor affect WWD crashes when compared with other types of crashes. The results show that WW drivers are more likely to be older and DUI. Furthermore, WWD crashes were found to be affected by urban areas and dark road condition. Dark roadway with no lighting condition was found to have the largest OR. To complement the analysis, the contributing factors of those fatal WWD crashes were also investigated. Finally, several countermeasures for reducing WWD crashes on the studied facilities are discussed based on the data analysis results.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	849
Session Title	Coasting to Make Strides in Pedestrian and Bicycle Safety
Paper Number	17-05404
Paper Title	Investigating the Underreporting of Pedestrian and Bicycle Crashes in and Around University Campuses: Crowdsourcing Approach
Abstract	In this paper, the non-motorized traffic safety concerns in and around three university campuses are evaluated by comparing police-reported crash data with traffic safety information sourced from the campus communities themselves. The crowdsourced traffic safety data comprise of both self-reported crashes as well as perceived hazardous locations. The results of the crash data analysis reveal that police-reported crashes underrepresent non-motorized safety concerns in and around the campus regions. The spatial distribution of police-reported crashes shows that police-reported crashes are predominantly unavailable inside the main campus areas, and the off-campus crashes over-represent automobile involvement. In comparison, the self-reported crash results report a wide variety of off-campus collisions not involving automobiles, while also highlighting the issue of high crash concentrations along campus boundaries. An assessment of the perceived hazardous locations reveals that high concentrations of such observations at/near a given location have statistically significant association with both survey-reported crashes as well as future police-reported crashes. This new finding suggests that augmenting our existing knowledge of traffic safety through crowdsourcing techniques can potentially help in better estimating both existing as well as emerging traffic safety concerns.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-05455
Paper Title	Left-Turn Pedestrian and Bicycle Crash Study
Abstract	The Left Turn Pedestrian and Bicycle Crash Study was conducted as part of New York City's Vision Zero effort to address Failure to Yield crashes. New York City Department of Transportation (NYC DOT) conducted a citywide analysis of left turn crashes, a detailed analysis of 1,105 crash reports between 2009 – 2013 at high pedestrian and bicyclist left turn crash locations, and an evaluation of specific safety treatments. This study concludes with the development of an Action Plan to address left turn pedestrian and bicyclist crashes. The citywide and detailed analyses provide important insight into how crashes happen, who is involved, when they occur, and where they are most likely to occur. The study concludes that left turn crashes resulting in pedestrians and bicyclists being Killed or Seriously Injured (KSI) occurred at over three times the rate of pedestrian and bicyclist right turn KSI. All of the left turn pedestrian and bicyclist injuries and fatalities from 2010 – 2014 occurred at just 18 percent of all New York City intersections. The evaluation of current treatments revealed a varied rate of left turn pedestrian, bicyclist, and motor vehicle injury reductions following treatment implementation.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-05645
Paper Title	Improvements to Statewide Collision Reporting to Understand Sidewalk-Related Bicycle Collisions
Abstract	Identifying collision patterns is critical to designing effective infrastructure, education, and enforcement countermeasures, but details regarding bicycle involved collisions are often limited in statewide reporting systems. Location prior to a collision is an essential element of collision reporting and typing for all modes. Nevertheless, bicyclist location is not adequately detailed in many states' collision report templates to enable definitive collision typing. This study was motivated by a bicycle-involved collision analysis in Santa Ana, CA, in which sidewalk-related bicycle collisions were especially difficult to identify because of the lack of bicyclist location information. Upon reviewing other states' collision report templates, it became clear that this deficiency was not unique to California. Sidewalk riding is prevalent in Santa Ana and other communities around the country, and in order to implement effective countermeasures analysts must be able to understand the incidence of sidewalk-related bicycle collisions on an aggregate level.This study conducted a critical review of all state collision report forms in the U.S. to understand how each form was capturing locational information about bicyclist-involved collisions in report fields. The results indicated that many state collision report forms do not provide the necessary level of detail for bicycle involved collision typing, particularly for collisions related to sidewalk riding. Even among the more detailed reports reviewed, there were several opportunities for ambiguity in collision description. This paper defines these ambiguities and provides recommendations for improving statewide collision report forms to better understand sidewalk-related bicycle collisions.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	849
Session Title	Coasting to Make Strides in Pedestrian and Bicycle Safety
Paper Number	17-05716
Paper Title	Comparison of U.S. Metropolitan Region Fatal Pedestrian and Bicycle Crash Rates
Abstract	This paper quantifies fatal pedestrian and bicycle crash rates in the largest metropolitan regions of the United States. Fatal Accident Reporting System (FARS) pedestrian and bicycle crash data were gathered for two time periods: 1999-2003 and 2007-2011. Trip, distance, and time exposure metrics from the 2001 and 2009 National Household Travel Survey (NHTS) were used to represent the crash rate denominator for these two time periods. Margin of error ranges were provided to indicate the level of accuracy available for these trip, distance, and time metrics. At the national level, fatal pedestrian and bicycle crash rates decreased significantly between the two time periods. There were also significant differences in fatal crash rates at the metropolitan level: in general, metropolitan areas that have older urban core areas, well-established public transit systems, and are known as leaders for investing in pedestrian and bicycle projects and programs have among the lowest fatality rates; metropolitan areas that have dispersed, automobile-centric development have among the highest fatality rates. Viewed collectively, lower metropolitan region fatal pedestrian and bicycle crash rates were associated with higher pedestrian and bicycle mode shares, providing further evidence of "safety in numbers" for pedestrians and bicyclists. Lower automobile mode shares are also associated with lower fatal pedestrian crash rates, suggesting that there may be "safety in scarcity" of automobiles.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06180
Paper Title	Exposure to Risk and the Built Environment: Empirical Study of Bicycle Crashes in Minneapolis, Minnesota
Abstract	Estimating exposure to risk and assessing crash risk is necessary to understand and prevent crashes and injuries. However, transportation planners and engineers historically have lacked information about bicycle demand or traffic volumes needed to identify vulnerable locations for bicyclists and evaluate the effectiveness of safety improvement programs. We use peak hour counts of bicycle traffic at 473 locations in Minneapolis and facility demand models estimated from those counts to characterize exposure to risk on the street network in Minneapolis. We aggregate bicycle crashes from 2005 to 2010, estimate crash rates, and test the "safety in numbers" hypothesis that the crash risk for each individual bicyclist will decrease with increasing bicycle traffic. We then use Firth logistic regression to estimate the probability of crashes at intersections and on street segments and assess the effects of built environment variables on the probability of bicycle crashes. We confirm the safety in numbers hypothesis with both counts and modeled estimates of demand. Controlling for exposure to risk, we show that the probability of crashes is higher along street segments with higher land use mix and commercial use and at intersections with higher job accessibility. Bicycle crashes are more likely to occur at intersections with trail crossings. However, street connectivity, measured by intersection density has a negative association with the probability of crashes at intersections. We discuss the implications for bicycling safety and facility improvements.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-06829
Paper Title	Safety Analysis of On-Street Parking on an Urban Principal Arterial
Abstract	This study analyzes the effect of on-street parking on speed, crash rates and capacity on an urban principal arterial. The goal of urban principal arterials is to provide high mobility to a large volume of traffic. Accommodating on-street parking on a roadway of this classification presents additional safety concerns. The corridor of interest, Perring Parkway/Hillen Rd., in Baltimore, Maryland is a high-speed 6-lane divided arterial. This active corridor is a major route for not only traveling students, but also many of the residents and commuters of the Baltimore City metropolitan area. The study site consists of a 1.0-mile portion with limited entry and parking restriction, a 1.3-mile segment along a major university with frequent parking maneuvers, and a 0.8-mile residential and recreation segment. By analyzing factors such as accident rates, causes of accidents and other driver characteristics, this study will present a statistical analysis of the effect of on-street parking on an urban arterial road.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-06836
Paper Title	Crash Type Analysis Using Nested Logit Model: Special Focus on Distraction-Related Factors
Abstract	This work aims to study the factors such as driver's characteristics, environmental conditions, and vehicle's characteristics, that affecting different crash types with a special focus on distraction parameters. For this purpose, distraction factors are divided into five groups of cellphone usage, cognitive distractions, passengers distracting the driver, outside events attracting the driver's attention, and in-vehicle activities. The crash types are divided into two main groups, single-vehicle crashes, and two-vehicle crashes. Single-vehicle crashes include run-off-road crashes, collision with a fixed object or parked vehicle, and collision with a pedestrian (animal). Two-vehicle crashes include rear-end crashes, head-on crashes, angular crashes, sideswipe crashes in opposite direction and also in the same direction. This study takes the crashes occurred in the USA into accounts. Due to the essence of alternatives and the probable correlation in the unobserved error term, the Nested Logit model is developed.The results of model illustrate that all of the aforementioned distraction-related factors increase the probability of run-off-road crashes, collision with a fixed object, and rear-end crashes. Cognitive distraction increases the probability of collision with a pedestrian. Distractions caused by passengers or out-of-vehicle events increase the probability of sideswipe crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-06891
Paper Title	Experimental and Analytical Investigation of the Performance of Suv and Balloon Tires Commonly Used in Qatar
Abstract	The fatality rate in Qatar is significantly higher than many of the best performing nations in the world. Severe single-vehicle rollover crashes are predominant in the country. Vehicle tires failure (such as tread separation and blowouts) and incorrect tires use significantly contribute to loss of control and rollover accidents. This paper presents experimental testing and finite element simulation result to identify the causes of tire failures. The results indicate that balloon tires have limited endurance threshold compared to typical SUV tire and the prolong exposure to heat reduces the life of both types of tires.

Authors	Jonathan Markt, HDR Wiliam Sharp, HDR Christopher Williges, HDR Deanna Maifield, Iowa Department of Transportation
Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	448
Session Title	Tenth Annual Case Studies in Performance-Based Analysis of Geometric Design
Paper Number	P17-21450
Paper Title	Iowa DOT Performance Based Design Pilots
Abstract	Iowa DOT and HDR partnered to put an emphasis on guiding DOT projects toward cost-effective design decisions that improve the performance of state highways for Iowa travelers. The innovative concept driving this performance-based design approach is the target budget. The target budget is the sum of the easy to quantify benefits that a transportation project provides, including: safety benefits, traffic operations benefits, emissions reduction benefits, reduced vehicle operating costs, and asset management savings. The target budget provides a project control to help roadway design staff make trade-offs in design features that balance safety and operational benefits against additional project costs. As part of the pilot study for the target budget concept, HDR evaluated two rural highway improvement projects. Traffic operations benefits were assessed using Highway Capacity Manual methods and safety benefits were assessed using methods from AASHTO's Highway Safety Manual (HSM) and benefits were tallied for a 30 year period. Once the benefits were summed to develop the target budget, project cost estimates were compared to the target budget. The findings from evaluating the two projects could not have been more different. Improvements to Iowa highway 196 addressed corridor needs for pavement and bridge work, but the designed project improvements to widen shoulders based on updated design standards yielded a savings of 38 crashes and a target budget of $8.1 million compared to a project cost of $26.4 million. Conversely, improvements to US 52, a highly curvilinear route, did not bring the highway up to current design standards, but yielded a crash savings of 116 crashes and a target budget of $14.2 million compared to a project cost of $15.4 million. The pilot study identified that a simple procedure utilizing available HSM tools and procedures, such as NCHRP 17-38 spreadsheets, would help the agency to realize additional safety benefits and tailor design projects to provide greater value to Iowa travelers. Developing a Performance Based Design methodology using the pilot projects is the first step to developing tools for Iowa DOT that allow for more flexible tradeoffs of the impact of design decisions' impacts to cost and user benefits. Additional work has already been conducted to confirm that the methodology is applicable to freeway projects and projects in urban areas. Future work would standardize, streamline, and automate the Performance Based Design approach for use on Iowa DOT projects statewide. Target budgets would be established in the preliminary design stage to allow opportunity to modify the design (as needed) to align the operational benefits and project costs.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	448
Session Title	Tenth Annual Case Studies in Performance-Based Analysis of Geometric Design
Paper Number	P17-21452
Paper Title	Performance Based County Road Standards for Johnson County, Kansas
Abstract	Not available.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	538
Session Title	Advances in Highway Safety Performance
Paper Number	17-05379
Paper Title	Safety Effects of Low-Cost Systemic Safety Improvements at Signalized and Stop-Controlled Intersections
Abstract	Packages of intersection treatments, including signing, pavement marking and signal enhancements, were installed at many signalized and stop-controlled intersections in South Carolina. This study evaluated the overall safety effectiveness of the concurrent implementation of these systemic low-cost treatments as part of the FHWA Evaluation of Low Cost Safety Improvements Transportation Pooled Fund. The dataset included both urban and rural 3-legged and 4-legged intersections with two or four lanes on the major road. The study employed an empirical Bayes (EB) before-after analysis. The aggregate results indicate reductions for all crash types analyzed in this study. For signalized intersections, the crash modification factors (CMF) are 0.955, 0.893, 0.974, 0.883, and 0.969 for total, fatal and injury, rear-end, right-angle, and nighttime crashes, respectively. The CMFs for fatal and injury and right-angle crashes are statistically significant at 95-percent and the CMF for total crashes is statistically significant at 90-percent confidence levels. For stop controlled intersections, the CMFs are 0.917, 0.899, 0.933, 0.941 and 0.853 for total, fatal and injury, rear-end, right-angle, and nighttime crashes, respectively. All CMFs for stop-controlled intersections are statistically significant at the 95-percent confidence level. An economic analysis shows that systemic, low-cost intersection treatments are cost effective with conservative benefit-cost ratio estimates of 4.1 for total crashes at signalized intersections and 12.4 for total crashes at stop-controlled intersections.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-00077
Paper Title	An Investigation of Skew Angle and Other Factors Influencing Crash Frequency at High-Speed Rural Intersections
Abstract	Intersections experience a disproportionate share of traffic crashes, injuries, and fatalities due to the increased number of conflicting traffic movements at these locations. These issues are particularly pronounced at rural locations where speeds are generally higher and most intersections are either stop- or yield-controlled. Ideally, intersecting roadways should be oriented at as close to a 90-degree angle as possible. However, intersection design can diverge from this preferred configuration, resulting in a skewed intersection. Skewed intersections have been found to cause safety and operational issues for road users. In order to determine the effect of intersection skewness on crash frequency, crash prediction models were estimated for rural stop-controlled intersections on high-speed two-lane highways throughout the state of Iowa. Separate analyses were conducted for three-leg and four-leg intersections. In both cases, crash frequency was estimated as a function of annual average annual daily traffic, skew angle, and other salient geometric characteristics. The results consistently showed crash frequency to increase with skew angle. A 10-degree deviation from 90 degrees would result in 3 percent more crashes at three-leg intersections and 4 percent more crashes at four-leg intersections. In addition, crashes were also affected by approach surface type, as well as the presence of auxiliary turn lanes and intersection lighting.

Authors	Craig Lyon, Persaud and Lyon Inc. Bhagwant Persaud, Ryerson University Kimberly Eccles, VHB
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-00432
Paper Title	Safety Evaluation of Two Curve Warning Treatments: In-Lane Curve Warning Pavement Markings and Oversized Chevron Signs
Abstract	The objective of this study was to undertake a rigorous before-after evaluation of the safety effectiveness—as measured by crash frequency—of in-lane pavement marking curve warnings and oversized chevrons in horizontal curves. These strategies were selected for the investigation for the Evaluation of Low Cost Safety Improvements Pooled Fund Study, which functions under the US Federal Highway Administration's Development of Crash Modification Factors program. Data from four states, Iowa, Kansas, Missouri and Pennsylvania were used to estimate crash modification factors (CMFs) for specific crash types including total, fatal+injury, run-off-road, night and night run-off-road using the empirical Bayes (EB) methodology. For in-lane curve warning pavement markings, results indicate that only the CMF estimates for total and night crashes are statistically significant at the 95-percent confidence limit. However, no CMF is recommended at this time since these results are based on few crashes in the after period and should be used with due caution. The sample size for oversized chevron signs was larger but still modest. None of combined results were statistically significant at the 95-percent confidence level. However, the estimated CMF of 0.73 for night crashes, the target crash type, has a relatively low p-value of 0.11. The disaggregate results for this crash type suggest, that sites where advisory speeds have been posted because of a combination of sharper curvature and higher design speeds may yield higher benefit from the installation of chevrons, especially larger chevrons, when compared to locations where advisory speeds are not required.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-00439
Paper Title	Alternative Approach for Combining Multiple Crash Modification Factors Using Adjustment Function and Analytic Hierarchy Process
Abstract	The safety effects of multiple treatments have recently emerged as an important issue of validation of the Highway Safety Manual (HSM) procedures to improve performance of the predictive process. In order to estimate more reliable combined safety effects of multiple crash modification factors (CMFs), several combining approaches have been suggested. However, there are still several critical issues for the existing combining methods such as over-estimation, region specific method, non-scientific approach, etc. Therefore, this study suggests a novel adjustment method to combine multiple CMFs to enhance the reliability of combining the safety effects of multiple treatments. Various combinations of CMFs for single and multiple treatments were estimated or obtained from previous studies by the authors and used for an exploratory analysis. Moreover, an alternative combining approach with the development of adjustment function was suggested through the comparison with the existing combining methods using the multi-criteria decision making process. The results show that the proposed alternative combining method provides better estimates than the existing methods and can account for different roadway types and severity levels. Thus, it can be recommended that the safety effects of multiple treatments are estimated using the proposed new combining approach to overcome the over-estimation issue and produce more reliable results.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-01356
Paper Title	Development of a Safety Assessment Tool for Work Zones
Abstract	The construction of highway rehabilitation projects requires careful planning to minimize adverse impacts and maintain a balance between safety and mobility. Although there are many existing tools to evaluate work zone mobility, there is a need for more practitioner-friendly guidance to facilitate the evaluation of the safety impacts of different construction phasing alternatives. This research sought to address this need by developing crash prediction models and incorporating them into a user-friendly spreadsheet. New models were developed in this study using Missouri data to capture geographical, driver behavior, and other factors in the Midwest. These new models were developed for work zones on both expressways and rural highways. A large sample of work zones in Missouri was utilized to produce 15 work zone crash prediction models. The developed spreadsheet tool implements these models by collecting input data from the user, selecting the best model, estimating the work zone crashes by severity, and converting them to monetary values. In concert with the tool development, a survey of departments of transportation (DOTs), Federal Highway Administration (FHWA) representatives, and contractors was conducted to assess the current state of the practice regarding work zone safety. The survey results indicate that many agencies look at work zone safety informally using engineering judgment. To this end, the developed spreadsheet tool is a user-friendly way for practitioners to uniformly assess the safety impact of work zones.

Authors	Dusan Jolovic, New Mexico State University Abhisek Mudgal, Texas A&M Transportation Institute Ivana Tasic, University of Utah Aleksandar Stevanovic, Florida Atlantic University Peter Martin, New Mexico State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-01695
Paper Title	Impact of Traffic Signal Control Parameters on Frequency and Severity of Intersection-Related Crashes
Abstract	While previous research in the area of intersection crash modeling mostly distinguishes between signalized and unsignalized intersections, this paper provides a detailed insight into the association of signal timing parameters with intersection-related crashes. Crash data were collected for 148 urban signalized intersections in Fort Lauderdale, Florida, for 11 years. Crash frequency is modeled using negative binomial regression, while distinguishing between the crashes that occur upstream and downstream of the intersection. Crash severity is modeled using multinomial logit model for three crash categories: no injury, possible injury, and severe injury or fatality. The results obtained from the crash frequency models clearly show how signal timing parameters have higher influence on crashes that occur upstream of the intersection, as expected. It is found that the average annual daily traffic (AADT) volume, cycle length, offset, number of phases and all-red clearance time have significant impact on intersection crash frequency. Severity of the crashes which were intersection related was influenced by the speed limit, AADT, all-red clearance time, left turn phase setup, number of signal phases, number of approach lanes, split time, and cycle length. Crash frequency models obtained and presented in this paper show the potential for future exploration of developing separate models for crashes that occur upstream and downstream of the intersection. Developed severity models show the need for future consideration of signal timing parameters when modeling intersection-related crashes.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-02448
Paper Title	Safety Impact of High Friction Surface Treatment Installations in Pennsylvania
Abstract	According to the National Highway Traffic Safety Administration (NHTSA), a total of 32,675 people died in motor vehicle crashes on the U.S. highway system in the year 2014. In order to address this issue, transportation professionals have continued to investigate countermeasures to improve roadway safety. High friction surface treatments (HFSTs) have the potential to be a sustainable and cost-effective means of doing so. This pavement overlay system maximizes the existing infrastructure, and provides exceptional skid resistance where friction demand is critical, such as intersection approaches or horizontal curves. This research seeks to review the performance of HFSTs from a safety and economic perspective through an analysis of HFST installation projects in the state of Pennsylvania. Using data provided by the Pennsylvania Department of Transportation (PennDOT), it analyzes the extent of their effectiveness in reducing crash rates and crash severity through a before-after and benefit-cost study of over 70 sites. The results of these two investigations indicate that Pennsylvania received the greatest reduction in crash number and severity as well as the greatest return on investment for intersections on horizontal curves that are located in an urban environment. The results, along with further statistical analysis, will be used to develop crash modification factors and a safety performance function to quantify the expected crash reduction and the average number of crashes per year. The goal of this study is to enable DOTs to maximize return on investment and to better anticipate the safety benefits of HFSTs prior to implementing new projects.

Authors	Scott Himes, VHB Frank Gross, VHB Kimberly Eccles, VHB Bhagwant Persaud, Ryerson University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-03500
Paper Title	Safety Evaluation of Red-Light Indicator Lights in Florida
Abstract	Red-Light Indicator Lights (RLILs) are auxiliary lights mounted on signal heads, mast arms, or poles and directly connected to a traffic-control signal. The RLIL activates at the onset of the red phase and allows an enforcement officer to observe red-light running from downstream of the intersection. This strategy is intended to reduce the frequency of crashes resulting from drivers disobeying traffic signals by providing a safer and more efficient means for police to enforce the red interval. Geometric, traffic, and crash data were obtained at treated four-leg signalized intersections in Florida. 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 four-leg signalized intersections with similar characteristics to the treated sites. The analysis also controls for changes in traffic volumes over time and time trends in crash counts unrelated to the treatment. Results indicate statistically significant crash reductions for most crash types. Disobeyed signal crashes have an estimated crash modification factor (CMF) of 0.71. Total crashes, fatal and injury crashes, right-angle, and left-turn crashes have estimated CMFs of 0.94, 0.86, 0.91, and 0.60, respectively. The benefit-cost ratio estimated with conservative cost and service life assumptions is 92:1 for four-leg signalized intersections. The results suggest that the treatment, even with conservative assumptions on cost, service life, and the value of a statistical life, can be cost effective. In addition to the crash-related benefits, RLILs can improve the efficiency and safety of red-light running enforcement efforts. While this study did not evaluate the efficiency and safety impacts with respect to enforcement, it should be noted that RLILs do allow police to observe violators from a downstream position, eliminating the need for a second observer (upstream) and the need to pursue a violator through the red-light.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-04529
Paper Title	Safety Evaluation of Box Span Signal Configuration
Abstract	A research study was conducted to evaluate the safety benefits of the Box Span Signal Configuration for all drivers and for older drivers' age 65 years and above. The Box Span Signal Implementation was evaluated by performing a literature review, perception survey of Michigan drivers, and crash data analysis. Safety Performance Functions (SPF) were developed as part of the study. Crash Modification Factors (CMF) were developed through the before-after analysis of crash data. A benefit cost analysis was also performed to evaluate the safety benefits. The Box Span Signal Implementation, when replacing a diagonal span configuration, was found to significantly reduce Angle crashes by 12.4 percent for all drivers.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-05091
Paper Title	Exploring the Need for Having Region-Specific Calibration Factors
Abstract	States, or even large urban cities, may experience different numbers of crashes in different regions or parts of the city. This can be attributed to differences in terrain, population, weather, and other unobserved characteristics. Hence, it can impact the calibration procedure and consequently the calibration factor when it is used for a very large area. This study first investigated whether or not having region-specific calibration factors are required and justified for large states, such as Texas and Michigan. Next, region-specific recommendations are proposed to determine whether or not a region-specific calibration factor is needed for the type of facility under analysis. If the region-specific recommendations are met, the agency should derive a region-specific calibration factor using region-specific data. Otherwise, the common statewide factor can be used. The proposed region-specific recommendations are based on the general data at the network level: (1) the total number of crashes, (2) the mean value of traffic flow (ADT/AADT), and (3) the total segment length (or the number of intersections).

Authors	Eric Green, Kentucky Transportation Cabinet Reginald Souleyrette, University of Kentucky Nikiforos Stamatiadis, Kentucky Transportation Cabinet
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-05747
Paper Title	Segment Length and Highway Safety Analysis: Does It Matter?
Abstract	This paper addresses the relationship between roadway segment length and the efficacy of Safety Performance Function (SPF) models. As do many states, Kentucky uses the *Highway Safety Manual's* network screening procedure to develop priority lists for its Highway Safety Improvement Program. This paper demonstrates that choice of average roadway segment length can result in markedly different priority lists — in some cases the overlap between different lists is less than 20 percent. Therefore, the objective of this paper is to report on an investigation of the effect of segment length on the development of SPFs and identify average lengths that produce the best-fitting SPF. Several goodness-of-fit metrics are used to compare 16 different segment lengths using the same roadway network and crash data. These metrics as well as Cumulative Residual (CURE) Plots are used to compare model performance. Very short segments produce model bias while longer segments result in the higher absolute deviation, — neither is desirable. For data from Kentucky parkways (i.e., roads designed like freeways) a segment length of approximately 2 miles (3.2 Km) appears to achieve optimal performance among key metrics.

Authors	Ziyuan Pu, University of Washington Zhibin Li, Southeast University Wenbo Zhu, University of Washington Zhiyong Cui, University of Washington Yinhai Wang, University of Washington
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-05863
Paper Title	Evaluating Safety Effects of Variable Speed Limit System using Empirical Bayesian Before-After Analysis
Abstract	Variable speed limits (VSL) have been increasingly used to improve traffic safety on freeway mainlines. The primary objective of this study was to evaluate the safety impacts of the VSL system implemented on Interstate 5 in Washington since 2010. An observational Empirical Bayesian (EB) before-after analysis was conducted based on 9787 crashes that occurred in the 72-month period. The analysis was conducted for all crashes, and crash severity levels. The EB before-after result implied that the total crash count was reduced by 29% with a standard deviation of 5% after the VSL system was applied in Washington. The counts of crashes with no injury and possible injury decreased more than crashes with severe injuries. The evaluation results of this study are particularly valuable for policy making associated with VSL system implementation projects.

Authors	Amir Sobhani, VicRoads Chris Jurewicz Tariro Makwasha, Australian Road Research Board (ARRB) Hafez Alavi, Transport Accident Commission (TAC) Michael Nieuwesteeg, Transport Accident Commission (TAC)
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-06356
Paper Title	Evaluation of Key Engineering Treatments Addressing Major Pedestrian Casualty Crashes in Victoria, Australia
Abstract	Pedestrian injury and mortality are a global issue, with more than 270,000 pedestrians killed worldwide each year. In Victoria, 249 road fatalities were reported in 2014, 18% of which were pedestrians. These statistics convinced the Victorian road safety partners to develop a major program to reduce the number of severe pedestrian casualties. One of the main challenges in development of pedestrian safety programs is selection of engineering crash treatments leading to the most effective reduction in number of pedestrian crashes. This approach relies on accurate quantification of the effectiveness of such treatments. This study conducted a literature review of the effectiveness of different pedestrian treatments in Australia and in other countries. This literature review assessed the availability and accuracy of reported crash modification factors (CMF) for each treatment type. Then, four major treatment types which have not been evaluated accurately, were selected for evaluation. These treatment types included 'median', 'kerb extension', 'full-time fully controlled right turn signals' and 'part-time fully controlled right turn signals'. A quasi-experimental before-after treatment/control evaluation design was utilized to assess the effectiveness of these treatment types. Required data for treated and control sites were collected from Local Government Areas (LGAs) and VicRoads from Melbourne metropolitan area. A log-linear Poisson model was applied to estimate effectiveness of each treatment. The key findings were that median (flush or physical) CMF for all casualty crashes was 0.65, and for 0.45 for pedestrian casualty crashes. For kerb extensions the all casualty crash CMF was 0.46. For the full-time application of fully controlled right turns, the all casualty crash CMF was 0.48, and for part-time application of the same treatment the CMF was 0.89 (low significance). Site availability limitations meant that only one CMFs related to pedestrian crashes could be found. Some significant results were reported for fatal and serious injury crash CMFs. Nevertheless, the paper shows how these treatments address the main pedestrian movement types involved in serious pedestrian casualties. Outputs of this study will improves the cost-effectiveness and accuracy of pedestrian road safety treatment programs through updated and more accurate CMF values for the most effective and relevant pedestrian safety treatments. The findings will be useful to road agencies seeking to reduce incidence and severity of pedestrian casualties.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-06475
Paper Title	Comparison of Calibrated Highway Safety Manual Model and Jurisdiction–Specific Safety Performance Functions for Rural Two-Lane Highways
Abstract	The Highway Safety Manual (HSM) includes safety performance functions (SPF) for predicting crashes in various roadway categories using roadway characteristics and crash data. The HSM provides a general SPF resulted from research using data from several states across the U.S. However, driving behavior and crash recording practices vary among different states and therefore, agencies are recommended to calculate a calibration factor. This paper compared the accuracy of crash prediction for the calibrated HSM versus a newly developed Minnesota-specific SPF. Therefore, three different statistical models including Poisson (constant only), Poisson, and a negative binomial model were used to develop the Minnesota-specific SPF using the rural two-lane roadway data for the entire state of Minnesota (32,000 miles). The comparison showed that the calibrated SPF predicts as well as the newly developed SPF and there is no significant difference between those two models. Thus, use of calibrated HSM SPF is recommended for predicting rural two-lane crashes in the state of Minnesota. A minimum effort of updating the calibration factor periodically is recommended.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-06486
Paper Title	Modeling the Safety Effects of Red-Light Camera Enforcement with Spillover Effects
Abstract	This study proposes an Empirical Bayesian (EB) before-after analysis method to model the safety effects of Red Light Cameras (RLC) capturing the spillover effect. Zero-Inflated Negative Binomial (ZINB) models are used to estimate Safety Performance Functions for crashes of different types at the intersection, approach level separately for the before and after periods. Two methods are proposed to capture the spillover effect of the behavior at the RLC intersections to the reference intersections. The three models (no spillover, uncontrolled spillover, and controlled spillover) are applied to data from the City of Chicago's RLC program. The analysis is applied at the intersection approach level, and includes a larger number of intersections than previous studies. The results are largely in agreement with previous RLC studies in the literature.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-06894
Paper Title	Effects of Using High Occupancy Toll Lanes on Safety Performance of Freeways
Abstract	The use of High Occupancy Toll Lanes (HOT-Lanes) system has risen dramatically in the recent years. Applying this system helps relieve congestions and generate revenues to meet some of the transportation needs. In 2008, Florida converted its underused High-Occupancy-Vehicle (HOV-lanes) on I-95 to HOT-lanes called 95-Express. Although the HOT-Lanes offer users reliable travel times by managing traffic volume through dynamic tolls especially during peak hours, there is a lack of research that quantifies the traffic safety impact of this system. The main goal of this study is to investigate and provide an up-to-date traffic safety impact of the HOT-Lane system of the whole roadway segment. It is also to investigate for the first time the safety impact of applying this system on each of the HOT-lanes and on the General-Purpose Lanes (GP-Lanes) separately. The results proved that the HOV-to-HOT conversion does not significantly affect the safety performance of the roadway segments as a whole. However, there is an indication that the safety at the HOT-Lanes was significantly improved by reducing all crash categories. On the other hand, all crash categories have increased on the GP-Lanes; this is logical since the crashes remain the same for the whole segment (HOT-Lanes and GP-Lanes) and decreased on the HOT-Lanes, they are expected to increase on the GP-Lanes. Therefore, it can be concluded that the HOT-lanes are safer than the GP-Lanes. Overall, future research is strongly recommended to reach clear conclusions about the safety effectiveness of this system.

3 Network Screening

Raghavan Srinivasan, University of North Carolina, Chapel Hill

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

From a methodological perspective, the following methods were used:

- Bayesian joint model of frequency and proportion (Cai et al., 17-03158);
- Bayesian spatial analysis to evaluate the effect of neighboring structures on spatial crash frequency modeling (Cheng et al., 17-04119) ;
- Bayesian approach to address temporal correlation (Cheng et al., 17-05548) ;
- Negative binomial regression with empirical Bayes (Thomas et al., 17-06635, 17-06840).

From an applications perspective, the papers addressed the following issues:

- Pedestrian and bicycle crashes at the macro level (traffic analysis zone level) (Cai et al., 17-03158);
- Injury and fatal crashes at the county level (Cheng et al., 17-04119);
- Injury and fatal crashes at the traffic analysis zone level (Cheng et al., 17-05548);
- Analysis of pedestrian crashes for systemic applications (Thomas et al., 17-06635);
- Analysis of bicycle crashes for systemic applications (Thomas et al., 17-06840).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-03158
Paper Title	Bayesian Joint Approach of Frequency and Proportion Modeling at Macro Level: Case Study of Crashes Involving Pedestrians or Bicyclists
Abstract	Macro-level traffic crash analysis has been conducted to incorporate traffic safety into long-term transportation planning. At macro-level, various models have been estimated to analyze crash frequency and the effects of interaction between different crash types. This study proposes a Bayesian joint model of frequency and proportion to explore the dependency of crashes by transportation modes or severity levels on total crashes. The joint model with two components is developed for crashes involving pedestrians or bicyclists. Using the data collected in Florida, the proposed joint model is compared with the traditional negative binomial model. The dependency of crashes involving pedestrians or bicyclists on total crashes can be clearly presented by the proposed joint model. Meanwhile, the comparison results indicate that the joint model can provide better data fit and more significant variables. To illustrate the application of the proposed model, a joint performance measures to identify hot zones for crashes involving pedestrians or bicyclists is proposed. The screening results reveal that the joint approach can identify hot zones with more detailed information.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-04119
Paper Title	Evaluating the Influence of Neighboring Structures on Spatial Crash Frequency Modeling and Site Ranking Performance
Abstract	A large number of neighborhood weight matrices have been adopted for modeling crash spatial heterogeneity. However, there has been little evaluation of the influence of these different weight matrix structures on the crash prediction modeling performance. This study is focused on investigation of 17 different spatial-proximity matrices for development of spatial crash prediction models and site ranking using county-level data in California. Among the group of matrices being evaluated, traffic exposure-weighted and population-weighted distance-based matrices are first proposed in the traffic safety field. To address serial correlation of crashes in successive years, Bayesian spatial analysis was conducted with the combination of a first order autoregressive (AR-1) error process and time trend for crashes. Two diagnostic measures were used for assessment of goodness-of-fit and complexity of models. In addition, seven evaluation criteria were employed to assess the benefits associated with better fitting models in site ranking. The results showed that modeling performance gets improved with the increase of number of neighbors being considered in the weight matrix. However, the larger number of neighbors also leads to larger variability of modeling performance. Specifically, Queen-2 and Decay-50 models proved to be superior among the adjacency and distance-based models, respectively. The significance of incorporating spatial correlations was highlighted by the consistently poor performance of the Base model which included only heterogeneity random effect. Finally, the model-fitting performance seems to be strongly correlated with the site ranking performance. The models with closer goodness-of-fit tend to yield more consistent ranking results.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05548
Paper Title	Alternative Ways of Addressing Temporal Correlation in Crash Frequency Modeling
Abstract	Compared with the large amount of research using various ways of addressing serial correlations among crash data, there is little research dedicated to the evaluation of the different temporal treatments on modeling performance. To add to the current literature the much-needed research, this study first proposed a new method which combines the strengths of time-varying coefficients and autoregressive process, and then compared its performance with seven other temporal models used in the past. Ten years of crash data and other covariates associated with traffic analysis zones in the City of Irvine, California were employed. Bayesian hierarchical approach was employed to account for the structural heterogeneities. The comparisons were conducted for assessment of goodness-of-fit, accuracy of crash estimation, and relative performance of site ranking. The modeling results indicated that the proposed model appeared to have the best fit with actual crash data and a relatively lower complexity than other competing models. Longitudinal and cross sectional validations using RSS (Residual Sum of Squares) demonstrated that the proposed model had very significant superiority at crash prediction with an RSS score three times smaller than the worst performing model. The site ranking evaluation established that there is a statistically significant correlation between site ranking performance and modeling performance.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	849
Session Title	Coasting to Make Strides in Pedestrian and Bicycle Safety
Paper Number	17-06635
Paper Title	Predicting the Future: Systemic Pedestrian Safety Analyses in Seattle, Washington
Abstract	The aim of this study was to use robust methods to identify and prioritize locations at risk for future pedestrian crashes and injuries to broaden treatment priorities beyond only high crash locations. To accomplish this objective, we developed safety performance function (SPF) models for two high-frequency and/or high-severity pedestrian crash types at Seattle intersections: total pedestrian crashes at intersections, and crashes involving through motorists and pedestrians crossing the intersection. We tested a large number of variables, and found a number of measures of pedestrian activity, roadway, and other built environment measures to aid prediction of pedestrian crashes. Many significant variables were similar in both models and included measures of intersection size and complexity. Larger numbers of legs, larger number of lanes, volume of bus activity, commercial property density, and presence of parking were among the variables associated with more crashes. Pedestrian volume exhibited a curved relationship to crashes, demonstrating the tendency for expected crashes to begin to decline above a threshold volume. The SPFs were used in several ranking methods, including SPF-predicted crashes, empirical-Bayes (EB)-estimated crashes, and Potential for Safety Improvement (PSI, excess crashes) to aid in prioritization of locations that might be candidates for safety improvement. These analyses and associated ranking methods provide a means of prioritizing locations based on model predictions, and are important tools to consider for jurisdictions that wish to take a more proactive approach, in addition to traditional hotspot or frequency-based approaches, to reduce the potential for future crashes and injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06840
Paper Title	In Pursuit of Safety: Systemic Bicycle Crash Analysis in Seattle, Washington
Abstract	This study aimed to use robust methods to identify and prioritize locations at risk for future bicycle crashes and injuries, to broaden treatment priorities beyond only high crash locations. Using data from Seattle, WA, we developed safety performance function (SPF) models for three high-frequency and/or high-severity bicycle intersection crash types: total bicycle crashes at intersections, crashes in which the bicyclist and driver were traveling in opposite directions, and crashes in which the bicyclist and driver were traveling perpendicularly to one another. We tested a large number of variables, and found a number of measures of pedestrian and bicycle activity, roadway, and other built environment measures aided bicycle crash prediction. Several variables that represented intersection complexity and may have been proxies for AADT were significant in all three models, including arterial classification, larger numbers of lanes, and two-way center turn lanes. Interestingly, pedestrian volume exhibited a curved relationship to crashes, demonstrating a potential safety benefit to cyclists from increased pedestrian activity. The SPFs were used in several ranking methods, including SPF-predicted crashes, empirical-Bayes (EB)-estimated crashes, and Potential for Safety Improvement (PSI, excess crashes) to aid in prioritization of locations that might be candidates for safety improvement. These analyses and associated ranking methods provide a means of prioritizing locations based on model predictions, and are important tools to consider for jurisdictions that wish to take a more proactive approach, in addition to traditional hotspot or frequency-based approaches, to reduce the potential for future crashes and injuries.

4 Safety Performance Functions

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

The safety performance function studies aim at identifying factors that contribute to crashes and it is interested in quantifying the effect of the significant crash contributing factors. The subcommittee identified seventeen papers related to safety performance functions. These papers could be categorized by their study units, methodologies, applications, and interesting crash contributing factors, among which the methodologies are the main interests of these studies.

As for the study units, the majority of the papers focused on segments, including rural two-lane segments (17-00239, 17-05593), urban arterial segments (17-02472), and expressway and freeway segments (17-01165, 17-03977, 17-04420). Meanwhile, two studies analyzed the safety performance of signalized intersections (17-00677, 17-03604). Additionally, researchers also explored the safety performance of zones, for example, traffic analysis zones (17-02834, 17-03834, 17-04634, 17-05548).

New methodologies are one of the most promising parts in these studies. In order to count for the spatial heterogeneity, several models were proposed, such as Bayesian Spatially varying coefficients model (17-02834, 17-04119), geographically weighted regression model (17-04634). And for addressing temporal correlation between observations, a study used independent-over-time random effects model (17-05548). Meanwhile, researchers adopted Multivariate copula-based count model to deal-time the heterogeneous dependency issue among crash types (17-03977). Additionally, the unobserved heterogeneity was considered in several studies by implementing random parameters models (17-03604, 17-03834, 17-01165). Furthermore, some researchers simultaneously analyzed crash frequency and crash types to better understand crash mechanisms (17-03158).

While some papers identified the typical crash causal factors such as geometric parameters (17-03604) and speed and speed variation (17-02472), several papers found some interesting crash contributing factors such as geometric and regionality attributes (17-00677), jobs-housing ratio (17-04634), night-to-day traffic volume (17-05593), and Gas Dynamic Analogous Exposure (GDAE) quantifies the meeting frequency of two vehicle types (17-03834).

Two papers used new types of data to develop SPFs. Taxi-based high frequency GPS data was obtained and assessed (17-02472). Also, permanent automatic traffic recorders data was used to estimate traffic volume during day and night time based on the spatial interpolation methods (17-05593).

Different types of crashes (i.e., rear-end, turning, motorcycle, sideswipe, fixed objects, multi-vehicle crashes involving taxi, etc.) were investigated in developing the SPFs (17-00677, 17-

03977, 17-03834). Moreover, several papers studied non-motorized crashes (17-03158, 17-06635).

Lastly, the papers suggested several application approaches such as identification of hot zones (17-03158), screening of locations at risk for future pedestrian (17-06635), incident likelihood prediction (17-04420, 17-01165), probabilistic principal component analysis for missing data imputation and support vector machines (17-04420), accounting for the nonlinearity (17-00239), and applying different types of crash safety analysis to explore crash mechanisms (17-01165).

Authors	Asad J. Khattak, The University of Tennessee Behram Wali, The University of Tennessee Xiaobing Li, The University of Tennessee
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00239
Paper Title	Exploring Non-Linear Dependencies in Correlates of Roadway Crashes
Abstract	For practical considerations and in many cases the difficulty to collect detailed crash-related data, Annual Average Daily Traffic (AADT) and segment length are often used as the main correlates for predicting crash frequencies on segments. Typically, crash frequencies are assumed to linearly depend on traffic exposure related factors which may not realistically represent the underlying complexity embedded in crash data generated by physical and social elements of transportation systems. Thus, the objective of the current study is to investigate and quantify nonlinear dependencies of crash frequency on traffic exposure related factors. Using crash data collected on rural two-lane two-way roads in Tennessee, total crashes and total injury crashes were modeled using Negative Binomial Generalized Additive Models (NBGAMs) that are well-suited for conceptualizing non-linear relationships. In addition, including too few explanatory factors (such as AADT and segment length only) in crash frequency modeling may lead to omitted variable bias, and in such cases the nonlinearity may be an outgrowth of missing information on important variables. To address this issue, additional data on important correlates are collected and incorporated in NBGAM framework. The modeling results show that the relationship between crash frequencies (total crashes and total injury crashes) and AADT is clearly non-linear. Importantly, the non-linear dependency of crash frequencies on segment length is more complex than its dependence on AADT. The goodness of fit measures indicates the promising potential of NBGAMs in approximating non-linear dependencies of crash frequencies on associated factors. Important practical implications of results are presented with respect to rural two-lane two-way road safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00677
Paper Title	Assessing Safety of Signalized Intersections Influence of Geometric Attributes and Regionality on Traffic Accident Risks
Abstract	Traffic accidents constitute extremely serious social problems. Thus, it is essential to identify and remove the risk factors affecting traffic accidents to enhance traffic safety at intersections. This study identified and quantified the main factors influencing traffic accident risks at signalized intersections to propose effective countermeasures. In particular, Google Earth was used to collect numerical data related to the geometric attributes of intersections in three different regions in Japan, namely Kagawa, Shiga, and Aichi. A lognormal hurdle model that considered regionality and geometric attributes was then used to quantify factors influencing the risk of traffic accidents involving various types of collisions. The important findings of the study included the following: (i) The results indicated the existence of significant regional differences in the geometric attributes of intersections in regions. (ii) The findings revealed that intersection size (indicated by the distance between stop lines), length of crosswalks, and setback distance of crosswalks generally and significantly influenced all collision risk types. In addition, a compact intersection lowered the risk of all collision types. (iii) In most cases, regional dummy variables were statistically significant, thereby suggesting that in addition to intersection geometric attributes, regional differences in factors influenced collision risks. Thus, it could be reasonably assumed that regionality stemmed from differences in driving characteristics.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-01165
Paper Title	Analysis and Comparison of Safety Models Using AADT, Hourly Traffic, and Microscopic Traffic
Abstract	There have been plenty of traffic safety studies based on average daily traffic (ADT), average hourly traffic (AHT), and traffic in 5-minute intervals. Nevertheless, there is not enough research which compared the performance of these three types of safety studies. This study collected data from three expressways, including traffic data at 1-minute intervals, detailed crash information, and geometric characteristics. A Bayesian Poisson-lognormal model was used to estimate total crash frequency using ADT, a Bayesian multilevel Poisson-lognormal model estimating hourly crash frequency prediction using AHT, and a Bayesian multilevel logistic regression model for real-time safety analysis using microscopic traffic indicators in 5-minute intervals. The model results showed that the crash contributing factors found by different models were comparable but not exactly the same. Four variables, i.e., the logarithm of volume, segment length, number of lanes, and existence of weaving segment, were found to be positively significant in the three models, and four other variables were only significant in one or two models. The ADT-based, AHT-based, and 5-minute-based models were used to predict safety conditions at different levels: total, hourly, and 5-minute intervals. The results indicated that the AHT-based crash estimation model performed the best in predicting total and hourly crash frequency, and the real-time crash prediction model was the best in identifying crash events for dangerous segments in 5-minute intervals. The AHT was recommended for future long term traffic safety analysis, and traffic in 5-minute intervals was suggested for the implementation of Active Traffic Management.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-02472
Paper Title	Speed, Speed Variation, and Crash Relationships for Urban Arterials
Abstract	Speed and speed variation are closely associated with traffic safety. There is, however, a dearth of research on this subject for the case of urban arterials in general and in the context of developing nations. In downtown Shanghai, the traffic conditions in each direction are very different by time of day, and speed characteristics during peak hours are also greatly different from those during off-peak hours. Considering that traffic demand changes with time and in different directions, arterials were divided into one-way segments by the direction of flow in this study and time of day was differentiated and controlled for. In terms of data collection, traditional fixed-based methods are widely used in previous studies, which fails to capture the spatio-temporal distributions of speed along a road. A new approach is introduced to estimate speed variation by integrating spatio-temporal speed fluctuation of a single vehicle with speed differences between vehicles using taxi-based high frequency GPS data. With this approach, this paper aims to comprehensively establish a relationship between speed, speed variation and traffic crashes for the purpose of formulating effective speed management measures, specifically using an urban dataset. From a total of 234 one-way road segments from eight arterials in Shanghai, mean speed, speed variation, geometric design features, traffic volume, and crash data were collected. Because the safety effects of mean speed and speed variation may vary at different segment lengths, arterials with similar signal spacing density were grouped together. To account for potential correlations among these segments, a Hierarchical Poisson Log Normal model with random effects was developed. Results show that a 1% increase in mean speed on urban arterials is associated with a 0.7% increase in total crashes, and larger speed variation was also associated with increased crash frequency.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-02834
Paper Title	Modeling crash spatial heterogeneity a Bayesian spatially varying coefficients approach
Abstract	This study was performed to investigate the spatially varying relationships between crash frequency and related risk factors. A Bayesian spatially varying coefficients model was elaborately introduced as a methodological alternative to simultaneously account for the unstructured and spatially structured heterogeneity of the regression coefficients in predicting crash frequencies. The proposed method was appealing in that the parameters were modeled by a conditional autoregressive prior distribution, which involved a single set of random effects and a spatial correlation parameter with extreme values corresponding to pure unstructured or pure spatially correlated random effects. A case study using a three-year crash dataset from the Hillsborough County, Florida, was conducted to illustrate the proposed model. Empirical analysis confirmed the presence of both unstructured and spatially correlated variations in the effects of contributory factors on severe crash occurrences. The findings also suggest that ignoring spatially structured heterogeneity may result in biased parameter estimates and incorrect inferences, while assuming the regression coefficients to be spatially clustered only is probably subject to the issue of over-smoothness.

Authors	Qing Cai, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-03158
Paper Title	Bayesian Joint Approach of Frequency and Proportion Modeling at Macro Level Case Study of Crashes Involving Pedestrians or Bicyclists
Abstract	Macro-level traffic crash analysis has been conducted to incorporate traffic safety into long-term transportation planning. At macro-level, various models have been estimated to analyze crash frequency and the effects of interaction between different crash types. This study proposes a Bayesian joint model of frequency and proportion to explore the dependency of crashes by transportation modes or severity levels on total crashes. The joint model with two components is developed for crashes involving pedestrians or bicyclists. Using the data collected in Florida, the proposed joint model is compared with the traditional negative binomial model. The dependency of crashes involving pedestrians or bicyclists on total crashes can be clearly presented by the proposed joint model. Meanwhile, the comparison results indicate that the joint model can provide better data fit and more significant variables. To illustrate the application of the proposed model, a joint performance measures to identify hot zones for crashes involving pedestrians or bicyclists is proposed. The screening results reveal that the joint approach can identify hot zones with more detailed information.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03604
Paper Title	Random Parameter Negative Binomial Model for Signalized Intersection Accidents in Seoul, South Korea
Abstract	This study focuses on a traffic accident frequency model using a random parameter negative binomial approach. This method allows for the consideration of unobserved heterogeneity in accident data that current popular methods such as Poisson or Negative Binomial models cannot account for. A four-year (2007-2010) continuous panel of accident histories at 95 signalized intersections in Seoul, Korea, was used to estimate the random parameter negative binomial model with traffic volumes and various geometric characteristics at intersections. Our results show that the presence of a left-turn exclusive lane on a major road, the existence and length of a median barrier, and the existence of a pedestrian island on a major road are random parameters, and an additional ten variables significantly affected the safety at the intersections as fixed parameters. The fixed parameters were associated with major and minor roadway heavy vehicle volume, exclusive turn lane presence on major and minor roadway, taxiway lane presence, median barrier presence, as well as the number of lanes on major and minor roadway. The insights from this study indicate the need for broader analysis of lane channelization, lane exclusion and lane geometry effects as potential random parameters in intersection accident propensities.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03834
Paper Title	Gas Dynamic Analogous Exposure Approach to Multiple-Vehicle Crash Frequency Modeling Case Study of Crashes Involving Taxis
Abstract	Exposure is a frequency measure of being in situations in which crashes could possibly happen. In multiple vehicle crash frequency modeling, traditional exposure measures may not be representative enough because they may include situations where vehicles rarely meet each other and multiple vehicle crashes can never happen. This study aims to propose a novel Gas Dynamic Analogous Exposure (GDAE) for modeling multiple vehicle crash frequency. We analogize the meeting frequency of vehicles with the collision frequency of gas molecules because both systems consider the number of encounters of discrete entities. A meeting frequency function of vehicles is derived based on the collision theory of gas molecules with consideration of constrained vehicular movement by the road alignments. The GDAE is subsequently formulated based on the major factors contributing to the vehicular meeting frequency. The proposed GDAE investigates and provides insight into the mechanism of vehicle meetings. To demonstrate the applicability of the GDAE, zonal crash frequency models are built based on the multiple vehicle crashes involving taxis in 399 zones of 26 broad districts of Hong Kong in 2011. The GDAE outperforms the conventional time exposure in multiple vehicle crash modeling. To account for the heterogeneity among the 26 broad districts, both fixed-effects and random-effects NB models are established. The fixed-effects NB model is found to better fit the crash data. Explanatory factors contributing to the zonal multiple vehicle crashes involving taxis are identified. The proposed GDAE is proved to be a promising exposure measure for modeling multiple vehicle 19 crash frequency.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03977
Paper Title	Multivariate Copula-Based Count Model to Examine Interdependency Among Freeway Crash Types
Abstract	A multivariate count model is developed by introducing a simple and practical formula. The formulation begins with a modification of the standard ordered response model to adopt the count outcomes nature. This modification is accomplished by introducing a non-linear asymmetric interdependence structure among the error terms using a copula-based approach. To avoid simulated maximum-likelihood for evaluating the multi-outcome density, we utilize the composite marginal likelihood (CML) approach. The proposed model allows positive and negative dependency among the count outcomes as well as a variety of dependent structures including radially asymmetric or tail dependency without a need for a simulation mechanism. We apply these techniques to study the interdependence structure among four types of traffic crashes using three years (2005-2007) of a cross-sectional crash data record for 274 multilane freeway segments in the State of Washington, USA. These four categories of crash types are the rear end; sideswipe; fixed objects and other crash types. The empirical results show a significant presence of unobserved heterogeneous dependency across these types of crashes. The results indicate the important role of unobserved heterogeneity for variance and covariance structure estimation. An important outcome of this result is that it can affect inference on the relative impact of roadway geometrics on crash occurrence. For example, we find that horizontal curve related parameters on freeway segments substantially increase the joint likelihood of rear-end, sideswipe, fixed objects and other crash types, when compared to the characteristics of vertical curves.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-04119
Paper Title	Evaluating the Influence of Neighboring Structures on Spatial Crash Frequency Modeling and Site Ranking Performance
Abstract	A large number of neighborhood weight matrices have been adopted for modeling crash spatial heterogeneity. However, there has been little evaluation of the influence of these different weight matrix structures on the crash prediction modeling performance. This study is focused on investigation of 17 different spatial-proximity matrices for development of spatial crash prediction models and site ranking using county-level data in California. Among the group of matrices being evaluated, traffic exposure weighted and population-weighted distance-based matrices are first proposed in the traffic safety field. To address serial correlation of crashes in successive years, Bayesian spatial analysis was conducted with the combination of a first order autoregressive (AR-1) error process and time trend for crashes. Two diagnostic measures were used for assessment of goodness-of-fit and complexity of models. In addition, seven evaluation criteria were employed to assess the benefits associated with better fitting models in site ranking. The results showed that modeling performance gets improved with the increase of number of neighbors being considered in the weight matrix. However, the larger number of neighbors also leads to larger variability of modeling performance. Specifically, Queen-2 and Decay-50 models proved to be superior among the adjacency and distance-based models, respectively. The significance of incorporating spatial correlations was highlighted by the consistently poor performance of the Base model which included only heterogeneity random effect. Finally, the model-fitting performance seems to be strongly correlated with the site ranking performance. The models with closer goodness-of-fit tend to yield more consistent ranking results.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04420
Paper Title	Missing Information Imputation for Traffic Incident Likelihood Prediction for Urban Expressways
Abstract	The traffic incident likelihood estimation has been an important issue in transportation safety studies. The problem of missing data or imperfect information may have a negative impact on the accuracy of traffic incident likelihood prediction models. In this paper, a novel approach is proposed that combines the probabilistic principal component analysis (PPCA) for missing data imputation and support vector machines (SVMs) as the incident likelihood prediction model. This paper is one of the first attempts to cope the missing traffic information imputation with incident likelihood prediction. The backward sequential feature selection is conducted to choose the optimal combination of explanatory variables in order to avoid the overfitting issue. To verify how the PPCA method affects the prediction accuracy of SVMs with 3 kinds of kernels, i.e., linear, Gaussian, and polynomial, the proposed approach is applied to a field study on an urban expressway. The models are trained and tested with 123 crash records and 5-month traffic flow data. The 5-fold cross validation is employed to train the classifier and verify its prediction accuracy under different percentages of missing information. Numerical results show that SVM models with full explanatory variables without feature selection result in the similar values as the feature selection model when the missing ratio increases from 0 to 40%, in terms the area under the curve (AUC) of receiving operation characteristic (ROC). It verifies the stable performance of PPCA in missing data imputation for the traffic incident likelihood prediction. SVM models established on the basis of selected features show comparable AUC values with full features when the missing rate is close to zero. However, feature selection leads to lower AUC values with the increase of missing rates. It indicates that the selection of explanatory variables and PPCA-based missing data imputation may not be implemented simultaneously when the missing rate of observations is high.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04634
Paper Title	Evaluation of the Impacts of the Jobs-Housing Balance on Traffic Safety
Abstract	This study aimed to investigate the effects of jobs-housing balance on traffic safety. The crash data, demographiccharacteristics, employmentdata, road networkcharacteristics, household characteristics and traffic data were collected from the Los Angeles in 2010. The one-way ANOVA testresults suggested that the jobs-housing ratio significantlyaffects traffic safety in terms of crash frequency at traffic analysis zone (TAZ)level. To quantify the safety impacts of jobs-housing balance, the geographicallyweighted regression(GWR)was further conducted to linkcrash frequency at TAZwith jobs-housing ratio and other contributing factors. The comparison results showed that the GWRprovide better fitness to the data than do the generalized linear regression as the GWR accountsfor the spatial heterogeneity. The GWR results indicated that the jobs-housing relationshiphas a statistically significant association with crash frequencyat TAZs when the factors of traffic conditions, road network characteristics, demographic characteristics, and household characteristics are controlled.Crash frequencyat TAZincreases with an increase in jobs-housing ratio, but begins to going down slightly when jobs-housing ratio grows above the inflection point of 7. To further investigate the interactive effects between jobs-housing balance and other factors, a comparative analysis was conducted to investigate the elasticities of contributing factors under different jobs-housing ratios. The results indicate considerable interactive effects that the traffic conditions, road network characteristics, demographic characteristics, and household characteristics have different effects on crash frequency under various jobs-housing ratios.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05548
Paper Title	Alternative Ways of Addressing Temporal Correlation in Crash Frequency Modeling
Abstract	Compared with the large amount of research using various ways of addressing serial correlations among crash data, there is little research dedicated to the evaluation of the different temporal treatments on modeling performance. To add to the current literature the much-needed research, this study first proposed a new method which combines the strengths of time-varying coefficients and autoregressive process, and then compared its performance with seven other temporal models used in the past. Ten years of crash data and other covariates associated with traffic analysis zones in the City of Irvine, California were employed. Bayesian hierarchical approach was employed to account for the structural heterogeneities. The comparisons were conducted for assessment of goodness-of-fit, accuracy of crash estimation, and relative performance of site ranking. The modeling results indicated that the proposed model appeared to have the best fit with actual crash data and a relatively lower complexity than other competing models. Longitudinal and cross sectional validations using RSS (Residual Sum of Squares) demonstrated that the proposed model had very significant superiority at crash prediction with an RSS score three times smaller than the worst performing model. The site ranking evaluation established that there is a statistically significant correlation between site ranking performance and modeling performance.

Authors	Anusha Musunuru, University of Utah Ran Wei, University of Utah Richard Porter, University of Utah
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	330
Session Title	New Sources and Methods to Extract Data to Inform Safety Analysis
Paper Number	17-05593
Paper Title	Predicting Day and Night Traffic Volumes on Rural Roads for Statistical Road Safety Modeling
Abstract	Statistical road safety modelers have commonly used some combination of segment length and traffic volume as measures of exposure. Traffic volume is usually represented in statistical road safety models with average annual daily traffic (AADT), which turns out to be a highly influential right-hand-side variable for regression models of expected crash frequency. Models that use AADT alone do not explicitly capture differences in traffic volume patterns throughout the 24-hour day, which can also have significant effects on safety performance. This study adds to the existing literature by developing more disaggregated estimates of traffic volumes for day and night conditions in rural areas and modeling road safety using those estimates. The proposed approach is demonstrated using data from all ATR stations in Utah, with subsequent safety analysis focused on rural, two-lane horizontal curve segments. Universal kriging, along with multiple covariates, proved to be an effective spatial technique for predicting day and night traffic volumes at unmeasured locations using data from permanent traffic recording stations. Predicted day and night traffic volume estimates were incorporated into statistical road safety models of the expected number of crashes on rural, two-lane horizontal curves to determine how this "new" information impacts safety model estimation results. The parameter estimate for the predicted ratio of night-to-day traffic volume was positive and statistically significant, verifying the hypothesis that horizontal curves with higher proportions of traffic at night are expected to experience more crashes than similar curves with higher proportions of traffic during the day.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	849
Session Title	Coasting to Make Strides in Pedestrian and Bicycle Safety
Paper Number	17-06635
Paper Title	Predicting the Future Systemic Pedestrian Safety Analyses in Seattle, Washington
Abstract	We aimed to use robust pedestrian safety analysis methods to identify and screen locations at risk for future pedestrian crashes and injuries to help Seattle, WA broaden treatment priorities beyond only high crash locations. To accomplish this objective, we developed safety performance functions (SPF) for two high-frequency and/or high-severity pedestrian crash types at Seattle intersections: total pedestrian crashes, and crashes involving straight through motorists striking crossing pedestrians. Using data from the entire network, we tested a large number of variables measuring pedestrian activity, roadway, and the built environment. Many significant variables were similar in both models and included a number of measures of activity and intersection size and complexity. Pedestrian volume exhibited a curved relationship to crashes, demonstrating the tendency for expected crashes to begin to decline above a threshold value; however, the causes of this relationship are unknown. The SPFs were used in several ranking methods, including SPF-predicted crashes and empirical-Bayes (EB)-estimated crashes, to aid in prioritization of locations that might be candidates for safety improvement. The analyses and associated ranking methods provide a means of prioritizing locations beyond crash hot spots, based on model predictions of locations that may be hazardous for pedestrians. Based on this example, this is an important, and feasible approach for jurisdictions to consider that wish be more proactive in addressing the potential for future pedestrian crashes and injuries. Jurisdictions must, however, begin routinely collecting or estimating the data, including pedestrian activity and motor vehicle traffic, needed to implement the method efficiently.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06840
Paper Title	In Pursuit of Safety Systemic Bicycle Crash Analysis in Seattle, Washington
Abstract	This study aimed to use robust methods to identify and prioritize locations at risk for future bicycle crashes and injuries, to broaden treatment priorities beyond only high crash locations. Using data from Seattle, WA, we developed safety performance function (SPF) models for three high-frequency and/or high-severity bicycle intersection crash types: total bicycle crashes at intersections, crashes in which the bicyclist and driver were traveling in opposite directions, and crashes in which the bicyclist and driver were traveling perpendicularly to one another. We tested a large number of variables, and found a number of measures of pedestrian and bicycle activity, roadway, and other built environment measures aided bicycle crash prediction. Several variables that represented intersection complexity and may have been proxies for AADT were significant in all three models, including arterial classification, larger numbers of lanes, and two-way center turn lanes. Interestingly, pedestrian volume exhibited a curved relationship to crashes, demonstrating a potential safety benefit to cyclists from increased pedestrian activity. The SPFs were used in several ranking methods, including SPF-predicted crashes, empirical-Bayes (EB)-estimated crashes, and Potential for Safety Improvement (PSI, excess crashes) to aid in prioritization of locations that might be candidates for safety improvement. These analyses and associated ranking methods provide a means of prioritizing locations based on model predictions, and are important tools to consider for jurisdictions that wish to take a more proactive approach, in addition to traditional hotspot or frequency-based approaches, to reduce the potential for future crashes and injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06880
Paper Title	Analysis of Bicycle Crashes with Spatial Autocorrelation Comparison of Conditional Autoregressive Models
Abstract	Bicycle crash frequency models are usually developed using macro-level crash data to evaluate the effects of various socioeconomic and demographic, land use, bicycle infrastructure, roadway, and traffic factors. One inherent property of macro-level or aggregate data is the presence of spatial correlation in the data, which is largely ignored in traditional negative binomial models. Conditional autoregressive (CAR) models within the hierarchical Bayesian framework are popular alternatives to account for spatial correlation in macro-level data. However, the scope of the CAR models is not broadly explored in transportation safety. This study estimates a number of different CAR models that take different structure for analyzing spatial dependence in the data. The analysis is performed using four years of bicycle crash data from 2011 to 2014 aggregated over census block groups in Florida. To gain more understanding of the relationship between bicycle crashes and bicycle trips, bicycle activity data collected from Strava smartphone application were used in the models. The results show that the presence of spatial correlation is significant in the bicycle crash frequency data, indicating bicycle crashes at neighboring census block groups is likely to be similar compared to those at distant census block groups. The variables that are credible within the Bayesian 95% credible interval and tend to increase bicycle crashes at census block groups include traffic volume, road density, urban principal arterials, urban collectors, occupied housing units, male population, younger population, households with no automobile, work trips by bicycle, and bicycle activity.

5 Crash Severity Prediction

Alfonso Montella and Filomena Mauriello, 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 forty-one papers dealing with crash severity prediction. The number of papers dealing with crash severity prediction is much higher than in the previous TRB Annual Meetings (24 in 2016, 29 in 2015, 16 in 2014, 25 in 2013, and 19 in 2012), highling how this issue is becoming important for the scientific community.

These papers are scattered across various sessions, with most papers presented at the poster session 537 Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations (Tuesday, 8:00 AM – 9:45 AM).

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 (un-ordered) models used in the papers presented at the Annual Meeting were:

- Binomial logit model (Chathuranga and Dissanayake, 17-01298; Eustace and Elmagri, 17-00645; Kitaly et al., 17-06386; Welch and Zhang, 17-06520);
- Multinomial logit model (Grag and Boyle, 17-04687; Jolovic et al., 17-01695; Kelarestaghi et al., 17-06006; Kesavareddy et al., 17-05555; Sze et al., 17-00668);
- Random parameters logit model (Gong and Fan, 17-03864; Guo et al., 17-05698; Wang et al., 17-05464);
- Linearised spatial logit model (Prato et al., 17-01831);
- Skewed logit model (Balakrishnan et al., 17-01243);
- Probit model (Kitaly et al., 17-06386); and
- Complementary log-log model (Kitaly et al., 17-06386).

The following ordered regression modeling approaches were used:

- Ordered logit model (Chen et al., 17-05275; Kang and Khattak, 17-06202; Welch and Zhang, 17-06520);
- Random parameters ordered logit model (Russo, 17-00941);
- Multi-level random parameters ordered logit model (Liu and Khattak, 17-06412);
- Generalized ordered logit model (Bahrololoom et al., 17-06640; Burks et al., 17-01449);
- Hierarchical ordered logit model (Chen et al., 17-05275; Yoon at al., 17-01275);

- Ordered probit model (Bahrololoom et al., 17-06640; Ghasemzadeh et al., 17-06764; Goswamy et al., 17-05675; Li et al., 17-00962; Robartes and Chen, 17-05491);
- Random parameters ordered probit model (Osman et al., 17-04765; Xu et al., 17-00241);
- Generalized ordered probit model (Bahrololoom et al., 17-06640); and
- Partial Proportional Odds (PPO) models (Baireddy et al., 17-03502; Penmetsa et al., 17-05023; Rouholamin et al., 17-01086).

Some papers used data mining techniques, such as association rules (Das et al., 17-01166), Bayesian Networks (Cai and Lu, 17-03904; Yan et al., 17-02777), Classification And Regression Trees (CART) (Chen et al., 17-05258; Eustace and Elmagri, 17-00645), decision trees (Ghasemzadeh et al., 17-06764) random forest models (Kesavareddy et al., 17-05555), Structural Equation Modeling (SEM, also known as latent variable modeling and casual modeling) (Hassan et al., 17-04852; Shaaban and Kim, 17-00700) and Multiple Indicators-Multiple Causes (MIMIC) which is a special case of SEM (Song et al., 17-02318), Support Vector Machine models (SVM) (Chen et al., 17-05258).

Some authors used a combination of techniques. Chen et al. (17-05258) used CART to identify significant variables that were selected as input in a SVM. Kesavareddy et al. (17-05555) used a random forest model was to identify significant variables that were selected as input in a binomial logit model. Ghasemzadeh et al. (17-06764) used a decision tree to identify significant variables that were selected as input in an ordered probit model. Kang and Khattak (17-06202) used a combination of data mining (K-means, Latent Class Cluster, and Variational Bayesian Latent Class Cluster) and statistical regression (ordered logit) methods to cluster the crash data into subsets and then identify factors associated with severity levels. Yan et al. (17-02777) used an Improved Markov Blanket (IAMB) algorithm to extact significant variables and Bayesian Networks and CART to evaluate its performance.

Theofilatos et al. (17-02516) used cusp catastrophe models.

From an application point of view, the papers addressed:

- Environmental factors (Bahrololoom et al., 17-06640; Baireddy et al., 17-03502; Balakrishnan et al., 17-01243; Burks et al., 17-01449; Cai and Lu, 17-03904; Chathuranga and Dissanayake, 17-01298; Chen et al., 17-05275, 17-05258; Das et al., 17-01166; Eustace and Elmagri, 17-00645; Ghasemzadeh et al., 17-06764; Gong and Fan, 17-03864; Goswamy et al., 17-05675; Grag and Boyle, 17-04687; Guo et al., 17-05698; Hassan et al., 17-04852; Jolovic et al., 17-01695; Kelarestaghi et al., 17-06006; Kesavareddy et al., 17-05555; Kitaly et al., 17-06386; Li et al., 17-00962; Liu and Khattak, 17-06412; Osman et al., 17-04765; Prato et al. 17-01831; Rouholamin et al., 17-01086; Russo, 17-00941 ; Shaaban and Kim, 17-00700; Song et al., 17-02318; Sze et al., 17-00668; Theofilatos et al., 17-02516; Wang et al., 17-05464; Welch and Zhang, 17-06520; Xu et al., 17-00241; Yan et al. 17-02777);

- Highway characteristics (Bahrololoom et al., 17-06640; Baireddy et al., 17-03502; Balakrishnan et al., 17-01243; Burks et al., 17-01449; Cai and Lu, 17-03904; Chathuranga and Dissanayake, 17-01298; Chen et al., 17-05275, 17-05258; Das et al., 17-01166; Eustace and Elmagri, 17-00645; Ghasemzadeh et al., 17-06764; Gong and Fan, 17-03864; Goswamy et al., 17-05675; Grag and Boyle, 17-04687; Guo et al., 17-05698; Hassan et al., 17-04852; Kelarestaghi et al., 17-06006; Kesavareddy et al., 17-05555; Kitaly et al., 17-06386; Li et al., 17-00962; Liu and Khattak, 17-06412; Osman et al., 17-04765; Prato et al. 17-01831; Robartes and Chen, 17-05491; Rouholamin et al., 17-01086; Russo, 17-00941 ; Shaaban and Kim, 17-00700; Sze et al., 17-00668; Wang et al., 17-05464; Xu et al., 17-00241; Yan et al. 17-02777; Yoon at al., 17-01275);
- Road users' characteristics and behaviour (Baireddy et al., 17-03502; Bahrololoom et al., 17-06640; Balakrishnan et al., 17-01243; Cai and Lu, 17-03904; Chathuranga and Dissanayake, 17-01298; Chen et al., 17-05275, 17-05258; Das et al., 17-01166; Eustace and Elmagri, 17-00645; Gong and Fan, 17-03864; Goswamy et al., 17-05675; Grag and Boyle, 17-04687; Guo et al., 17-05698; Kelarestaghi et al., 17-06006; Kesavareddy et al., 17-05555; Kitaly et al., 17-06386; Li et al., 17-00962; Liu and Khattak, 17-06412; Osman et al., 17-04765; Penmetsa et al., 17-05023; Prato et al. 17-01831; Robartes and Chen, 17-05491; Rouholamin et al., 17-01086; Russo, 17-00941; Song et al., 17-02318; Wang et al., 17-05464; Xu et al., 17-00241; Yan et al. 17-02777; Yoon at al., 17-01275);
- Roadside features (Cai and Lu, 17-03904);
- Traffic control devices (Balakrishnan et al., 17-01243; Burks et al., 17-01449; Eustace and Elmagri, 17-00645; Ghasemzadeh et al., 17-06764; Gong and Fan, 17-03864; Grag and Boyle, 17-04687; Guo et al., 17-05698; Hassan et al., 17-04852; Kesavareddy et al., 17-05555; Jolovic et al., 17-01695; Liu and Khattak, 17-06412; Welch and Zhang, 17-06520; Yan et al. 17-02777; Yoon at al., 17-01275);
- Traffic characteristics (Burks et al., 17-01449; Gong and Fan, 17-03864; Guo et al., 17-05698; Hassan et al., 17-04852; Jolovic et al., 17-01695; Kesavareddy et al., 17-05555; Osman et al., 17-04765; Theofilatos et al., 17-02516); and
- Vehicle characteristics (Cai and Lu, 17-03904; Chathuranga and Dissanayake, 17-01298; Chen et al., 17-05275, 17-05258; Eustace and Elmagri, 17-00645; Gong and Fan, 17-03864; Kelarestaghi et al., 17-06006; Kesavareddy et al., 17-05555; Kitaly et al., 17-06386; Li et al., 17-00962; Liu and Khattak, 17-06412; Osman et al., 17-04765; Penmetsa et al., 17-05023; Prato et al. 17-01831; Robartes and Chen, 17-05491; Shaaban and Kim, 17-00700; Sze et al., 17-00668; Yan et al. 17-02777; Yoon at al., 17-01275); and
- Workzone characteristics (Burks et al., 17-01449; Ghasemzadeh et al., 17-06764 ; Osman et al., 17-04765 ; Sze et al., 17-00668; Yan et al. 17-02777).

The papers investigated also specific road users (with most papers focused on vulnerable road users) and vehicle types, such as:

- Bus (Yoon at al., 17-01275);
- Cyclists (Bahrololoom et al., 17-06640; Grag and Boyle, 17-04687; Kesavareddy et al. 16-06094; Robartes and Chen, 17-05491);
- Emergency vehicles (Eustace and Elmagri, 17-00645);
- Motorcyclits (Rouholamin et al., 17-01086; Wang et al., 17-05464);
- Older drivers (Chathuranga and Dissanayake, 17-01298);
- Pedestrians (Baireddy et al., 17-03502; Das et al., 17-01166; Guo et al., 17-05698; Hassan et al., 17-04852; Kesavareddy et al. 16-06094; Kitaly et al., 17-06386; Prato et al. 17-01831; Song et al., 17-02318; Welch and Zhang, 17-06520); and
- Trucks (Balakrishnan et al., 17-01243 ; Xu et al., 17-00241).

Authors	Jingjing Xu, Wuhan University of Technology Asad Khattak, University of Tennessee, Knoxville (Corresponding Author) Behram Wali, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00241
Paper Title	Injury Severity Analysis of Passenger Vehicle-Truck Collisions and Contributory Unsafe Precrash Behaviors
Abstract	Collisions between heavy trucks and passenger vehicles are a major societal concern primarily due to the severity of injuries involved. This research focuses on investigating the associations between injury severity and unsafe pre-crash driving behaviors (both intentional and unintentional) of passenger vehicle and truck drivers. Due to complex interactions of factors associated with injury outcomes in passenger vehicle-truck collisions, fixed- and random-parameter ordered probit models are estimated using a comprehensive 2013 crash database in Virginia. The models account for unobserved heterogeneity that may arise due to unobserved factors and the models control for several factors that include collision type, roadway type, and temporal factors, while investigating driver behaviors. Compared to truck occupants, passenger vehicle occupants are six times more likely to sustain minor/possible and ten times more likely to receive serious/fatal injuries in collisions. Importantly, improper actions of passenger vehicle drivers (whether intentional or unintentional) are statistically significantly associated with higher likelihood of more severe injuries. Also, passenger vehicle-truck collisions during nighttime and early morning (1 AM to 8 AM) are associated with more severe occupant injuries. The estimation findings suggest that the associations between key factors and level of injury severity are not consistent, and vary significantly across different passenger vehicle-truck collisions. Practical implications of the findings are discussed in this paper.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00645
Paper Title	Exploring Factors Contributing to Injury Severity of Drivers of Emergency Vehicles in Ohio
Abstract	The purpose of this study was to examine the contributing factors and characteristics associated with fatal and injuries sustained by drivers of emergency vehicles (EVs) involved in traffic crashes in the state of Ohio. In a few studies we recently conducted using Ohio's crash data have shown that emergency vehicles have been significant factors in increasing crash and injury severity levels. This study investigated the crash risk factors of crashes involving EVs by using Ohio crash data for 2011-2015. A binary logistic regression model was developed to identify statistically significant factors related to EV fatal and injury crashes. A classification tree model was also used in exploring significant factors that relate to crash severity of EVs. Although the two models agreed on eight significant factors, however, the logistic regression model identified an additional six factors. Significant factors identified type of crash, collision type, speed related, traffic control type, alcohol related, type of emergency vehicle, emergency related trip, female driver, not using seatbelt, curved and graded segment. Educational and enforcement strategies can be used to reduce EV related crashes and injuries.

Authors	Tony Sze, Hong Kong Polytechnic University (Corresponding Author) Ziqi Song, Utah State University William Lam, Hong Kong Polytechnic University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00688
Paper Title	Contributory Factors to Injury Severity of Work-Zone-Related Crashes in New Zealand
Abstract	Upgrading, rehabilitation, and maintenance often take place on existing roads in New Zealand. The adverse effects of poor road condition and reduced road width, due to the presence of work zone, on the safety of road users and workers at the sites have been a concern. Studies have been conducted to examine the risk factors contributing to the occurrence of road crashes in work zones in different countries. Slow and stopped vehicles near the work zones were found the primary cause of crashes and casualties in work zones. However, excessive speed of passing traffic has been recognized as a crucial factor contributing to work zone related crashes in New Zealand. In this study, we attempted to examine the effect of possible risk factors contributing to severe injury and fatality of work zone-related crashes in New Zealand. A multinomial logit regression model was established to measure the association between crash severity and factors including road environment, vehicle attributes, driver behavior and crash circumstance, based on the information on 453 road crashes during the period from 2008 to 2013. Results indicated that time period and vehicle involvement were deterministic to crash severity of crashes at the work zone. This should imply the improvements required in traditional temporary traffic management and work zone treatments and introduction of innovative technologies such as in-vehicle warning system for the enhancement of road safety in the long run.

Authors	Khaled Shaaban, Qatar University (Corresponding Author) Inhi Kim, Monash University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00700
Paper Title	Using Structural Equation Modeling to Understand Red Light Running Related Crashes
Abstract	One of the main factors that contribute to the high number of crashes at signalized intersections is the noncompliance with the traffic signals or in other words red light running. The purpose of this study is to understand the factors affecting the severity of red-light running related crashes using a sample of red-light running related crashes from the State of Florida in the United States. The analysis was conducted using structural equation modeling and revealed that the road and driver-related factors influence the accident severity with road-related factors being the most influencing factors. As far as countermeasures for this type of crashes, enhancement of the road infrastructure can be feasible to make the roads safer for the short term compared to the driver and environment factors that need a long-term plan to be changed. Adding street lighting, clearing obstacles, maintaining the road surface, and increasing the road shoulder width are examples of the some of the solutions that can be implemented. On the driver side, educating drivers not to drink and drive, fastening seat belts, maintaining vehicles should also not be considered. The results also showed that the environment factors did not influence the accident severity. It should be noted that a state like Florida has a mild climate where annual temperature, sunshine hours, and rainfall are similar throughout a year. Obtaining similar data from other states would be beneficial to validate the results obtained.

Authors	Brendan Russo, Northern Arizona University (Corresponding Author)
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00941
Paper Title	Analysis of Factors Affecting Injury Severity in Arizona Animal-Vehicle Crashes Considering Animal Type
Abstract	"Animal-vehicle crashes (AVCs), though somewhat rare as compared to other crash types, can result in severe injuries to crash-involved persons. This may be especially true when these crashes involve large animals such as cattle, horses, elk, or deer; a particular concern in western US states. A majority of the previous research on AVCs has focused on factors affecting the frequency of such crashes, and much has focused exclusively on deer-vehicle crashes. In order to gain new insights into factors affecting the severity of AVCs involving different animal types, this study presents an analysis using six years of AVC crash data from the state of Arizona. Factors affecting the injury severity of over 12,000 drivers and front-seat occupants (as well as motorcyclists) involved in single-vehicle AVCs were analyzed through the development of an ordered logit statistical model. In order to account for unobserved heterogeneity, random parameters (RP) were introduced and the RP ordered logit model provided a significantly superior fit compared to a standard ordered logit model with fixed parameters. Several person- vehicle- roadway- and environmental-related variables, as well as animal type, were found to significantly affect the injury severity of persons involved in AVCs. Interestingly, AVCs involving animals classified as livestock or pets were more likely to result in severe injury outcomes than those involving wild game or non-game animals. Ultimately, the results of this study provide valuable insights which can be used by transportation agencies for planning engineering-, enforcement-, or educational-related countermeasures aimed at reducing the severity of AVCs.

Authors	Yanyan Li, Nagoya University (Corresponding Author) Toshiyuki Yamamoto, Nagoya University Guangnan Zhang, Sun Yat-Sen University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-00962
Paper Title	Relationship Between Fatigue Driving and Injury Severity: Endogenous Binary-Ordered Probit Model Framework Analysis
Abstract	Fatigue driving is one of the most risky driving-related behaviors and represented a significant social and economic cost to the community. Several studies have already examined the relationship between fatigue driving and traffic injury severity from different aspects. However, fatigue driving and injury severity in traffic crash may share some common influential factors. Ignoring the impact of these common factors will lead to endogeneity problem and result in biased parameter estimation. Based on 38564 crash records during 2006-2011 in Guangdong province, China, we apply an endogenous binary-ordered probit model to examine the relationship between fatigue driving and injury severity considering endogeneity of fatigue driving. The results reveal a substantial and significant negative error correlation between fatigue driving propensity and fatal injury propensity. The influence of fatigue driving on injury severity is significantly underestimated if ignoring the unobserved correlation between them. We also separate the sample into commercial vehicle drivers and non-commercial vehicle drivers, and explore the difference of influential factors between these two groups.

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Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	593
Session Title	Motorcycle Crash Studies
Paper Number	17-01086
Paper Title	Modeling Single-Vehicle, Single-Rider Motorcycle Crash Injury Severity: An Ordinal Logistic Regression Approach
Abstract	Five years' (2009-2013) worth of crash data was obtained from the Federal Highway Administration's (FHWA) Highway Safety Information System (HSIS) database. This database includes data pertaining to motorcyclist characteristics (e.g., age, condition), temporal variables (e.g., season, day of week), and crash variables (e.g., lighting conditions, accident type), all of which potentially contribute to crashes. A partial proportional odds (PPO) logistic regression model was developed to examine the influence of the explanatory variable on the ordered dependent variable, i.e., injury severity. Moreover, two other popular ordered-response models, i.e., proportional odds (PO) and non-proportional odds (NPO) models, were also developed to evaluate their performances compared to the PPO model. Older riders, DUI riding, not wearing helmets, crashes during summer and weekends, crashes in rural areas, darkness, crashes with fixed objects and overturn/rollover, reckless riding, speeding, and roadway curvatures were found to increase the severity of injuries. In contrast, younger riders, winter season, adverse weather condition, and wet surface were associated with lower injury severities. According to two information criteria calculated for all three developed models fitted to the same data, the PPO model was found to outperform the other models and provide more reliable results. Based on the obtained average direct pseudo-elasticities, this study determines the effect of the various identified variables and develops several safety countermeasures as a resource for policymakers in order to prevent or mitigate the severity of motorcycle crashes in North Carolina.

Authors	Subasish Das, Texas A&M Transportation Institute (Corresponding Author) Raul Avelar, Texas A&M Transportation Institute Karen Dixon, Texas A&M Transportation Institute Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-01166
Paper Title	Pedestrian Crash Analysis Using Association Rules Mining
Abstract	In 2011, 4,432 pedestrians were killed (14% of total traffic crash fatalities) and 69,000 pedestrians were injured in vehicle-pedestrian crashes in the United States. Particularly in Louisiana, Vehicle-pedestrian crashes have become a key concern because of the high percentage of fatalities in recent years. In 2012, pedestrians were accounted for 17% of all fatalities due to traffic crashes in Louisiana. Alcohol was involved in nearly 44% of these fatalities. Therefore, an extensive research on the pedestrian safety in Louisiana is called for. This research utilized the a priori algorithm of association mining technique to discover knowledge from the vehicle-pedestrian crash database. This paper establishes how to apply association rules mining to discover vehicle pedestrian crash patterns using eight years of Louisiana crash data (2004-2011). The results indicated that roadway lighting at night helped in alleviating pedestrian crash severity. In addition, a few groups of interest were identified from this study: male pedestrians' greater propensity towards severe and fatal crashes, younger female drivers (15-24) being more crash-prone than other age groups, vulnerable impaired pedestrians even on roadways with lighting at night, middle-aged male pedestrians (35-54) being inclined towards crash occurrence, and dominance of single vehicle crashes. It is clear that data mining approaches help revealing pedestrian crash patterns that may not always follow the intuitive explanations. The findings of this study can be used by traffic safety professionals to develop better pedestrian crash countermeasures, as well as to design campaings to raise awareness and potentially address the groups of interests identified in the analysis.

Authors	Sivanandan Balakrishnan, RMIT University Sara Moridpour Richard Tay, RMIT University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	398
Session Title	Older Driver and Pedestrian Safety Issues
Paper Number	17-01243
Paper Title	Analysis of Injury Severity in Heavy Vehicles Angle Crashes
Abstract	Crashes involving heavy vehicles are a major road safety concern because of the higher likelihood of fatal and serious injury outcomes. The primary objective of this research is to identify the factors contributing to injury severity in angle crashes involving heavy vehicles. The skewed logistic (Scobit) model is applied to data on two-vehicle angle collisions in Victoria, Australia because of the imbalance or skewness in the injury outcomes. We find that the skewed logit model performs better than the standard binary logit model due to the violation of the symmetry assumption. The factors influencing injury severity in angle crashes involving heavy vehicles include occupants' gender, age and restraint use, vehicles' age, type, movement, fire status, point-of-impact and damage, time-of-day, road classification, posted speed limit, intersection type, and number of occupants involved.

Authors	Sangwon Yoon, Seoul National University Seung-Young Kho Dong-Kyu Kim, Seoul National University
Sponsoring Committee	Task Force on Transit Safety and Security (AP018T)
Session Number	663
Session Title	Timely Topics in Transit Safety and Security
Paper Number	17-01275
Paper Title	Effect of Regional Characteristics on Crash Injury Severity of Local Buses Using a Hierarchical Ordered Model
Abstract	As the importance of public transportation increases, the management of bus-involved crashes has become a crucial issue for traffic safety. Currently, however, there are relatively few studies on crash severity for buses in Korea. The present study investigated factors influencing injury severity of local bus-involved crashes identified based on using commercial vehicle crash data for a five-year period from 2010 to 2014 in Korea. In order to determine unobserved regional effects on crash severity, a hierarchical ordered model was applied to the analysis. Individual crash characteristics were set to lower level variables and regional characteristics were adopted as upper level variables. At the lower level, the factors affecting severity of local bus injury included vehicle speed, vehicle age, road alignment, surface status, road class and traffic light installation as found in previous studies. At the upper level, ratio the factors included road pavement, emergent medical environment, traffic rate of compliance and ratio of elderly in the community. There was 5.1% unobserved variation between regions from the intraclass correlation analysis. The validity of a hierarchical model for local bus crashes was verified by applying the same model on other types of long-distance buses and it appeared that there were no regional effects. This study found a regional effect for local bus crash severity and thus this factor is important when developing prevention plans to reduce local bus crashes. These results contribute to the study of traffic safety.

Authors	Sameera Chathuranga Koththigoda Kankanamge, Kansas State University Sunanda Dissanayake, Kansas State University
Sponsoring Committee	Standing Committee on Safe Mobility of Older Persons (ANB60)
Session Number	744
Session Title	Older Driver and Pedestrian Safety Issues
Paper Number	17-01298
Paper Title	Factors Associated with Severity of Single-Vehicle Crashes Involving Older Drivers with and without Passengers
Abstract	This study identified factors affecting the severity of crashes involving drivers aged 65 years or older. Two binary logistic regression models were developed to identify the influence of environmental, roadway, driver, and vehicle-related factors on crash severity by treating crash severity as a dichotomous variable. Crash severity, the dependent variable for each model, was categorized as injury and fatal (event = 1) in one category and Property Damage Only (PDO) or no injury (non-event = 0) in the other category. The first model (Model A) was developed for single-vehicle crashes involving an older driver only, and the second model (Model B) was developed for modeling single vehicle crashes involving an older driver with at least one passenger, to identify attributes of passengers, if any. Variables such as safety equipment use, day of the week, speed, crash location, light condition, accident class, maneuver, driver ejected or trapped, and weather condition distinguished crash severity for older drivers involved in single vehicle crashes. For model B, accident class, safety equipment use, light condition, driver ejected or trapped, accident location, surface type, vehicle type, and weather condition distinguished the crash severity. Age and gender of the passenger seated in the front seat or whether one or more passengers were present did not significantly affect crash severity. Gender of the older driver is not significant in any model. Findings of this study provided insight on older driver crashes and associated factors.

Authors	Rhyan Burks, Tennessee State University (Corresponding Author) Kevin Soloka, Tennessee State University Deo Chimba, Tennessee State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-01449
Paper Title	Digesting Factors Influencing Construction, Maintenance, and Utility Work-Zone Traffic Injury Severities
Abstract	This study digested factors affecting injury severities resulting from traffic crashes along work zones in Tennessee. Utilizing five years of crash data related to construction, maintenance and utility work zones, statistical analysis was conducted to evaluate the risk factors involved with resulting injury severities. The injury severities were grouped into four categories including PDO under $400, PDO over $400, non-incapacitating and incapacitating/fatal. Most of the crashes (57%) were maintenance work zone related, 27% construction related and 16% utility work zone related. About 60% of the work zone related crashes occurred during the day, 68% along the roadway and 23% at intersections. Traffic, environment, roadway, and crash factors were evaluated through statistical modeling using Generalized Ordered Logit Model (GOLM). The GOLM model was used due to its less restrictive ability in estimation compared to parallel line models such as ordinary ordered logit. Increase in traffic volumes, and the number of lanes along work zones were found to decrease the probability of severe injury crashes. Increase in the percentage of trucks and higher posted limits along work zones increases the probability of severe injury crashes.

Authors	Dusan Jolovic, New Mexico State University Abhisek Mudgal, Texas A&M Transportation Institute Ivana Tasic, University of Utah Aleksandar Stevanovic, Florida Atlantic University Peter Martin, New Mexico State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-01695
Paper Title	Impact of Traffic Signal Control Parameters on Frequency and Severity of Intersection-Related Crashes
Abstract	While previous research in the area of intersection crash modeling mostly distinguishes between signalized and unsignalized intersections, this paper provides a detailed insight into the association of signal timing parameters with intersection-related crashes. Crash data were collected for 148 urban signalized intersections in Fort Lauderdale, Florida, for 11 years. Crash frequency is modeled using negative binomial regression, while distinguishing between the crashes that occur upstream and downstream of the intersection. Crash severity is modeled using multinomial logit model for three crash categories: no injury, possible injury, and severe injury or fatality. The results obtained from the crash frequency models clearly show how signal timing parameters have higher influence on crashes that occur upstream of the intersection, as expected. It is found that the average annual daily traffic (AADT) volume, cycle length, offset, number of phases and all-red clearance time have significant impact on intersection crash frequency. Severity of the crashes which were intersection related was influenced by the speed limit, AADT, all-red clearance time, left turn phase setup, number of signal phases, number of approach lanes, split time, and cycle length. Crash frequency models obtained and presented in this paper show the potential for future exploration of developing separate models for crashes that occur upstream and downstream of the intersection. Developed severity models show the need for future consideration of signal timing parameters when modeling intersection-related crashes.

Authors	Carlo Prato, University of Queensland (Corresponding Author) Sigal Kaplan, Technical University of Denmark Alexandre Patrier, Technical University of Denmark Thomas Rasmussen, Technical University of Denmark
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-01831
Paper Title	Considering Built Environment and Spatial Correlation in Modeling Injury Severity for Pedestrian Crashes
Abstract	Active travel contributes to the sustainability of regions and the health of its inhabitants, but only safe roads for pedestrians and cyclists guarantee the achievement of these benefits. This study focuses on the safety of pedestrians and looks at mitigating and aggravating factors that are associated with the injury severity of pedestrians when they experience crashes with another road user. In particular, this study overcomes existing limitations in the literature by posing the attention on the built environment and considering the spatial correlation across crashes. Crash data for 6539 pedestrian crashes occurred in Denmark between 2006 and 2015 were merged with geographic information system resources containing detailed information about built environment and exposure at the crash locations. A linearized spatial logit model allowed estimating the probability of the pedestrian sustaining a severe or fatal injury conditional on the occurrence of a collision with another road user. This study confirms previous findings about older and intoxicated pedestrians being the most vulnerable, collisions with heavy vehicles leading to the most severe consequences, and roads with higher speed limits being related to the most severe outcomes. This study provides novel perspectives by showing positive spatial correlation that implies clustering of crashes with the same severity outcome. Also, this study highlights the need for thinking about traffic calming measures for making easier for pedestrians to cross and road users to approach, illumination for mitigating the difficulties related to the darkest hours, road surface maintenance in particular in the event of precitipations, and reduction of speed limits in particular in rural areas. Moreover, this study stresses the role of the built environment in the proximity of the crash and suggests that awareness is the key, as shopping areas, residential areas, low speed roads, and walking traffic density are positively related to a reduction in pedestrian injury severity. All these areas have in common a large mass of pedestrians that make other road users more aware and attentive, but the same does not seem to apply in less dense areas.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	330
Session Title	New Sources and Methods to Extract Data to Inform Safety Analysis
Paper Number	17-02318
Paper Title	Exploring Vehicle–Pedestrian Crash Severity Factors Based on In-Car Black Box Recording Data
Abstract	This study investigated the main factors affecting the pedestrian's injury severity of taxi-pedestrian crashes on urban arterial roads using the video recording data collected by an in-car black box device. While many previous studies have used interview data collected by police officers/witnesses, such data can lead to subjective and erroneous understandings regarding the crash situations. In contrast, the in-car black box recording data is a more reliable data source by virtue of direct crash observation. The black box video-recording data are advantageous for the safety studies because they provide not only video image information but also speed information that is measured in real-time including the time before-and-after a crash occurs. By analyzing the black box data, this study defined new reasonable independent explanatory variables affecting pedestrians' injury severity of taxi-pedestrian crash, which could not have been identified by the conventional crash report-based method. A Multiple Indicators Multiple Causes (MIMIC) model was used to investigate the relationship between the explanatory variables and injury severity. A total of 484 taxi-pedestrian crash scenes for 2 years were used for the multivariate analysis in a Metropolitan city of Incheon, South Korea. It was discovered that the crash characteristics most strongly associated with increased crash severity were pedestrian's failure in watching for approaching vehicles, pedestrian's jaywalking, pedestrian being classified as elderly (more than 65 years old), vehicle's excessive speed (more than 60 km/h), driver's failure to immediately stop, limited driver vision, and nighttime period. Finally, this study emphasized the potential of individualized black box video recording data for the purpose of analyzing the crash severity by extracting additional explanatory variables and also for the purpose of exploring the factors affecting crash severity. The utility of this new crash analysis data source (black box video recordings) is expected to be beneficial when a new transportation policy is established for the purpose of reducing pedestrian crash severity.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-02448
Paper Title	Safety Impact of High Friction Surface Treatment Installations in Pennsylvania
Abstract	According to the National Highway Traffic Safety Administration (NHTSA), a total of 32,675 people died in motor vehicle crashes on the U.S. highway system in the year 2014. In order to address this issue, transportation professionals have continued to investigate countermeasures to improve roadway safety. High friction surface treatments (HFSTs) have the potential to be a sustainable and cost-effective means of doing so. This pavement overlay system maximizes the existing infrastructure, and provides exceptional skid resistance where friction demand is critical, such as intersection approaches or horizontal curves. This research seeks to review the performance of HFSTs from a safety and economic perspective through an analysis of HFST installation projects in the state of Pennsylvania. Using data provided by the Pennsylvania Department of Transportation (PennDOT), it analyzes the extent of their effectiveness in reducing crash rates and crash severity through a before-after and benefit-cost study of over 70 sites. The results of these two investigations indicate that Pennsylvania received the greatest reduction in crash number and severity as well as the greatest return on investment for intersections on horizontal curves that are located in an urban environment. The results, along with further statistical analysis, will be used to develop crash modification factors and a safety performance function to quantify the expected crash reduction and the average number of crashes per year. The goal of this study is to enable DOTs to maximize return on investment and to better anticipate the safety benefits of HFSTs prior to implementing new projects.

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Sponsoring Committee	Standing Committee on Statistical Methods (ABJ80)
Session Number	288
Session Title	Statistical Methods In Transportation
Paper Number	17-02516
Paper Title	Stochastic Cusp Catastrophe Models with Traffic and Weather Data for Crash Severity Analysis on Urban Arterials
Abstract	The investigation of crash severity with freeway traffic and weather data has recently received significant attention by researchers. This paper extends previous research by proposing nonlinear models for modeling crash injury severity enhanced with traffic and weather data collected from urban arterials in Athens, Greece. Cusp catastrophe models are applied and compared with traditional statistical models. The results of crash severity models support the potential applicability of the cusp catastrophe theory to road safety, at least when crash severity is expressed as the number of severely and fatally injured by total number of persons involved in a crash. Variations in speed, average flow upstream of the location of interest, crash type and wind speed, were found to have a potential effect on the system dynamics. However, findings do not always confirm the strong presence of nonlinearity. When crash severity is expressed as the number of injured persons by the total number of vehicles involved in a crash, linear models could also be used to describe the underlying phenomenon.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-02777
Paper Title	Novel Feature Extraction Model for Traffic Injury Severity and Its Application to FARS Data Analysis
Abstract	The prevention of severe injuries during crashes has become one of the leading issues in traffic management and transportation safety. Identifying the impact factors which significantly affect traffic injury severity is critical for reducing the occurrence of severe injuries. In this study, the Fatality Analysis Reporting System (FARS) data from 2010 to 2014 was selected as the datasets for analysis. An algorithm named Improved Markov Blanket (IAMB) was proposed to extract the significant and common factors which affect crash injury severity from 29 variables related to driver characteristics, vehicle characteristics, accidents types, road condition, and environment characteristics. The Pearson correlation coefficient test is applied to verify the significant correlation between the selected factors and traffic injury severity. Two widely used classification algorithms (Bayesian networks and C4.5 decision tree) were employed to evaluate the performance of the proposed feature selection algorithm. The calculation result of the correlation coefficient, accuracy of classification, and classification error rate indicated that the IAMB not only could extract the significant impact factors, but also could improve the accuracy of classification. Meanwhile, the relationship between five selected factors (atmospheric condition, time of crash, alcohol test result, crash type, and driver distracted) and traffic injury severity was also analyzed in this study. The results indicated that crashes occurred in bad weather condition (e.g. foggy or worse), during night time, in drunk driving, in crash type of single driver, and in distracted driving are associated with more severe injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-03502
Paper Title	Factors Contributing to Injury Severity of Pedestrian Crashes at Uncontrolled Locations in Illinois
Abstract	Contributing factors associated with injury severity of pedestrian crashes were often studied in the past. Very few of those studies have emphasized on a specific location type for these crashes. Pedestrian crashes that occurred at uncontrolled locations (where neither a traffic signal nor a stop sign is present) are at the focal point of this study. To this end, crash data from the state of Illinois and that belongs to a five-year period between 2010 and 2014 were analyzed. Preliminary data analysis showed that the percentage of fatal and A-injury crashes occurred at uncontrolled locations is higher than at controlled locations. Risk factors associated with different injury severity levels of pedestrian crashes at uncontrolled locations were identified using the partial proportional odds model, which accounts for ordinal nature of injury severity. The results of the analysis indicated that the probability of a severe injury pedestrian crash at uncontrolled location is increased by summer season, fall season, younger drivers, older pedestrians, pedestrians wearing no contrasting clothing, rural setting, dark unlit roads, presence of ice on roads, divided roadways, cities with population between 25,001 and 50,000 people and cities with population of more than 50,000 people. Whereas, crosswalks, child pedestrians and adult pedestrians tend to decrease the probability of severe injury pedestrian crashes at uncontrolled locations. The results of this study can help policymakers and planners to incorporate specific considerations (i.e., goals, objectives, performance measures, and targets) in the state level strategic highways safety plans.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03864
Paper Title	Modeling Single-Vehicle Run-Off-Road Crash Severity in Rural Areas: A Mixed Logit Model Approach
Abstract	This study investigates factors that significantly contribute to driver injury severities resulting from single-vehicle run-off-road (ROR) crashes. A mixed logit model approach is employed to explore the possible heterogeneous effects associated with each age group: young (ages 16 to 24), middle-aged (ages 25 to 65), and older drivers (ages over 65). Likelihood ratio tests indicated that the development of separate injury severity models for each age group is statistically superior to estimating a single model using all data. Based on the crash data collected from 2009 to 2013 in North Carolina, a series of driver, vehicle, roadway, and environmental characteristics are examined. Both parameter estimates and their elasticities are developed and used to interpret the models. The estimation results show that contributing factors which significantly affect the injury severity of a single vehicle ROR crash differ across three age groups. Inexperience, drug or alcohol involvement, use of restraint device, and horizontal curves are found to affect crash injuries and fatalities in all age groups. Reckless driving, speeding, distraction, accompanied by passengers, and driving an SUV or a van are found to have a more pronounced influence in young and middle-aged drivers than older drivers. Compared to the passenger cars, older drivers are less likely to experience possible injuries in a large-size vehicle (e.g., truck or bus). Driving on a roadway segment with a lower average annual daily traffic volume also decreases the likelihood of being fatally injured for young drivers.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03904
Paper Title	Analysis of Factors Affecting Serious Multifatality Crashes in China Based on Bayesian Network Structure
Abstract	A serious multi-fatality crash is defined as a motor-vehicle crash resulting in more than ten deaths, which causes catastrophic losses of human life and property and even threats social stability. Thus, this study aims to identify and analyze risk factors affecting serious multi-fatality crashes using Bayesian networks. First, a Bayesian network structure was constructed based on expert experience and the Dempster-Shafer evidence theory. Second, the structure was amended to satisfy the conditional independence test. Finally, 484 serious multi-fatality crashes for the period 2000-2012 in China were inputted into the Bayesian network to calculate the posterior probability of each factor. Results showed that the most influential factor was driver behavior, followed by vehicle condition, road condition and external environment. And compared to the other behaviors, speeding and mistaken adjustment had greater influence on serious crashes. The findings in this study provide useful and valuable information for engineers to take corrective and preventative measures to reduce the probability for serious multi-fatality crashes.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	245
Session Title	Transportation Innovations May Improve Safety
Paper Number	17-04306
Paper Title	Understanding the Relationship Between Crash Severity, Change in Velocity, and Driver's Reaction
Abstract	A driver's reaction may influence the risk and severity of road crashes. Even though many studies have analyzed the factors influencing drivers' injury severity, little is understood about the relationship between driver's reaction, delta–v and driver's injury severity. This study develops a modelling framework to better understand this relationship. Three models, replicating driver's reaction, change in velocity (delta-v) and the driver's injury severity, are developed to analyze the hierarchy of factors influencing these three components of a crash. The data used for this estimation consists of two-vehicle crashes extracted from the United States National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) for the period between 2009 and 2014.The results show that as drivers' age increases the possibility of a reaction before the crash. This possibility is also increased when there are adverse surface conditions, non-straight horizontal curves, non-level vertical curves and on local roads. Reacting before a crash reduces the delta-v of the crashes and consequently the injury severity of the driver. The modelling results confirm that a higher delta-v is associated with higher occupant injury severity. Future research should focus on a more in depth understanding of factors influencing driver inattention to reduce occupant injury severity. In addition, the results of this research suggests that improving vehicle technologies such as 'Auto Emergency Braking System', can reduce severity of road crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-04687
Paper Title	Factors That Affect Bicycle-Vehicle Crashes: Implications from U.S. Crash Data
Abstract	In the United States, reducing bicycle crashes is an area of concern as many cyclists are injuredannually. Many of the most severe crashes for cyclists are those that involve interactions or collisions with motor vehicles. Identifying nationwide and regional trends in crash severity may provide some insights for future policies, roadway designs, and research. In this study, crash data from the US DOT for the years 2011 to 2014 was used to examine this issue. The data is from the General Estimates System (GES), which contains information about bicycle-motor vehicle crashes such as personal, vehicle, and environmental characteristics. Five multinomial logit models were developed to examine factors that impact the crash injury severity on a national level and regional level. The regional level (based on the GES categories) were Northeast, Midwest, South, and West. There were common factors identified for all five models that include including cyclist gender, time of day, and the vehicle trajectory. However, there were also differences in the regional models and these are discussed in this paper in terms of more targeted roadway improvements.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-04765
Paper Title	Analysis of Driver Injury Severity for Different Work Zone Areas
Abstract	Work zones are an integral part of the transportation system consisting of roadway construction, maintenance, and utility installation. In this paper we attempt to investigate the causal factors contributing to driver's injury severity in the different areas composing a work zone. Considering the discrete ordinal nature of injury severity categories, the Mixed Generalized Ordered Response Probit (MGORP) modeling framework was adopted. The empirical analysis was conducted using 10 years of the Highway Safety Information System (HSIS) work zone crashes database. Elasticity analysis suggests that airbag deployment, alcohol involvement, ejection, seatbelt use, and partial control-of-access are key factors that increase likelihood of severe injuries. Also, the effects of several covariates were found to vary across different areas within the work zone.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-04852
Paper Title	Structural Equation Modeling: Application to Pedestrian Safety in Washington, D.C., and Exploration of the Impact of Variable Scaling Procedures
Abstract	In a commercially vibrant city like Washington D.C., pedestrian–vehicle collisions remain a constant concern. Among the factors impacting pedestrian safety are environmental, traffic, and roadway geometrical factors. The objective of this paper is not only to identify these factors and their impact on safety using data from the MS2-Howard crash data base. A structural equation modeling approach is applied to establish the relationship between the descriptive exogenous variables and the severity related endogenous variables. This paper also explores the changes in model estimation results based on different variable scaling procedures. Results indicate that uncontrolled roadway segments and pedestrians crossing at non-intersections create the most hazardous situations for pedestrians. Furthermore, differences in coefficient valued based on various scaling procedures create changes in coefficients throughout the entire model. Thus indicating that in order for the structural approach to be applied in a thorough and proper manner, various structures and scales should be tested and results should be interpreted contextually using a variety of different measures.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05023
Paper Title	Examining Injury Severity of Not At-Fault Drivers in Two-Vehicle Crashes
Abstract	The focus of this paper is to examine the injury severity of not at-fault drivers in two-vehicle crashes. North Carolina crash data collected from 2009 to 2013 was used for analysis. Ordered probit model was chosen because of the ordinal nature of the dependent variable (injury severity of driver not at-fault). However, the data failed to obey the proportional odds assumption accompanied with the ordered probit model. Therefore, a partial proportional model was fitted for two-vehicle crashes. Compared to at-fault drivers' physical condition, not at-fault drivers' physical condition has a greater effect on injury severity of not at-fault driver. Exceeding speed limit, aggressive or reckless driving, and going wrong way are the three traffic rule violations of at-fault drives that are more likely to result in severe injuries to not at-fault drivers compared to disregarding traffic signals/signs/markings. Similarly, at-fault drivers with two and three violations are 68% and 186% are more likely to result in severe injuries compared to at-fault drivers with only one violation. Overall, motorcyclists are observed to be at highest risk with the odds of severe injury to motorcyclist not at-fault. Female at-fault drivers are less likely to result in severe injury to not at-fault drivers. They are also more likely to get severely injured when they are not at-fault.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05258
Paper Title	Analyzing Driver Injury Severity Outcomes in Rollover Crashes Based on a Support Vector Machine Model
Abstract	Rollover crash is one of the major types of traffic crashes that induce fatal injuries. It is important to investigate the factors that affect rollover crashes and their influence on driver injury severity outcomes. This study employs support vector machine (SVM) models to investigate driver injury severity patterns in rollover crashes based on two-year crash data gathered in New Mexico. The impacts of various explanatory variables are examined in terms of crash and environmental information, vehicle features, and driver demographics and behavior characteristics. A classification and regression tree (CART) model is utilized to identify significant variables and SVM models with polynomial and Gaussian radius basis function (RBF) kernels are used for model performance evaluation. It is shown that the SVM models produce reasonable prediction performance and the polynomial kernel outperforms the Gaussian RBF kernel. Variable impact analysis reveals that factors including comfortable driving environment conditions, driver alcohol or drug involvement, seatbelt use, number of travel lanes, driver demographic features, maximum vehicle damage in crashes, crash time, and crash location are significantly associated with driver incapacitating injuries and fatalities. These findings provide insights for better understanding rollover crash causes and the impacts of various explanatory factors on driver injury severity patterns.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05275
Paper Title	Identifying Significant Factors for Driver Injury Severities in Rural Non-Interstate Crashes: Hierarchical Ordered-Logit Analysis
Abstract	Rural non-interstate crashes induce a significant amount of severe injuries and fatalities. Examination of such injury patterns and the associated contributing factors is of practical importance. Taking into account the ordinal nature of injury severity levels and the hierarchical feature of crash data, this study employs a hierarchical ordered logit model to examine the significant factors in predicting driver injury severities in rural non-interstate crashes based on two-year New Mexico crash records. Bayesian inference is utilized in model estimation procedure and 95% Bayesian Credible Interval (BCI) is applied to testing variable significance. An ordinary ordered logit model omitting the between-crash variance effect is evaluated as well for model performance comparison. Results indicate that the model employed in this study outperforms ordinary ordered logit model in model fit and parameter estimation. Variables regarding crash features, environment conditions, and driver and vehicle characteristics are found to have significant influence on the predictions of driver injury severities in rural non-interstate crashes. Factors such as road segments far from intersection, wet road surface condition, collision with animals, heavy vehicle drivers, male drivers and driver seatbelt used tend to induce less severe driver injury outcomes than the factors such as multiple-vehicle crashes, severe vehicle damage in a crash, motorcyclists, females, senior drivers, driver with alcohol or drug impairment, and other major collision types. Research limitations regarding crash data and model assumptions are also discussed. Overall, this research provides reasonable results and insight in developing effective road safety measures for crash injury severity reduction and prevention.

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Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	593
Session Title	Motorcycle Crash Studies
Paper Number	17-05464
Paper Title	Modeling Random Effects of Horizontal Curve Design on Injury Severity of Single-Motorcycle Crashes Using Mixed-Effects Logistic Model
Abstract	Horizontal curves have been of great interest to transportation researchers because of their expected safety hazards to motorcyclists. The impacts of horizontal curve design on motorcycle crash injuries are not well-documented in previous studies. This study aimed to investigate and quantify the effects of horizontal curve design and associated factors on the injury severity of single-motorcycle crashes considering the issue of unobserved heterogeneity. A mixed-effects logistic model was developed based on 2,168 single-motorcycle crashes, which were collected on 8,597 horizontal curves in Florida for a period of 11 years (2005–2015). Four normally-distributed random parameters (moderate curves, reverse-curves, older riders, male riders) were identified. The modeling results showed that sharp curves (radius < 1,500 ft), compared to flat curves (radius ≥ 4,000 ft), tend to increase significantly the probability of severe injury (fatal or incapacitating injury) by 7.7%. In total, 63.8% of single-motorcycle crashes occurring on reverse curves are more likely to result in severe injury, and the remaining 26.2% are less likely to result in severe injury. Motorcyclist safety-compensation behaviors (psychologically feeling safe, then riding aggressively, or vice versa) may result in counterintuitive effects (e.g., vegetation and paved medians, full-access-controlled roads, pavement conditions) or random effects (e.g., moderate curve, reverse-curve). Other significant factors include lighting conditions (darkness, darkness with lights), weekends, speed/speeding, collision type, alcohol/drug impairment, rider age, and helmet use.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-05491
Paper Title	Virginia Automobile and Bicycle Crash Safety Analysis
Abstract	This paper analyzes single bicycle-single automobile crashes by examining bicyclist, automobile driver, vehicle, environmental, and roadway characteristics that influence crash safety. An ordered probit model is used to examine bicyclist injury severity in Virginia police crash report data from 2010 to 2014. Five injury severity levels are considered: fatalities, severe injuries, minor or possible injuries, no apparent injuries, and no injury. The results of this study most notably found automobile driver intoxication to increase the probability of a cyclist fatality six fold and double the risk of a severe injury, while bicyclist intoxication increases the probability of a fatality by 36.7% and doubles the probability of severe injury. Additionally, bicycle and automobile speeds, obscured automobile driver vision, specific vehicle body types (SUV, truck, and van), vertical roadway grades and horizontal curves elevate the probability of more severe bicyclist injuries. Model results encourage consideration of methods to reduce the impact of biking and driving while intoxicated such as analysis of bicycling under the influence laws, awareness of drunk driving impacts on bicyclists, and separation of vehicles and bicycles on the road. Additionally, the results encourage consideration of methods to improve visibility of bicyclists and expectation of their presence on the road.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	802
Session Title	Highway Safety Performance
Paper Number	17-05555
Paper Title	Comparing Crash Severity Risk Factors at Signalized and Stop-Controlled Intersections in Urban and Rural Areas
Abstract	Previous studies have shown that intersections are critical locations on the roadway network, having the majority of crashes. Understanding those factors that affect crash severity at intersections is essential to develop strategies to alleviate any safety deficiency. This paper identifies and compares the significant factors affecting crash severity at signalized and stop-controlled intersections in urban and rural areas in Alabama using five-year crashes from 2010 to 2014. A random forest model was used to rank variable significance and a binary logit model was applied to identify the risk factors at both intersection types in urban and rural areas. Four separate models (urban signalized, urban stop-controlled, rural signalized, and rural stop-controlled) were developed in this study. Roadway characteristics, traffic characteristics, vehicle characteristics, driver characteristics, and environmental conditions were used as independent variables in the models. New variables that were not previously explored were used in this study, such as the roadway type (one-way vs. two-way) and traffic control functioning (yes or no). It was found that one-way roadways and non-functioning traffic signals were associated with a reduction in crash severity at urban signalized intersections. In all the four models, rear-end crashes showed lesser severity compared to side impact crashes. Head-on crashes, higher speed limits, and curved sections showed higher severity in both urban signalized and stop-controlled intersections. In rural stop-controlled intersections, cloudy weather and right-turning maneuver were associated with a severity reduction. Female drivers showed 15% and 45% higher severity likelihood (compared to their male counterparts) at urban and rural signalized intersections, respectively. Strategies to alleviate crash severity at different intersections are suggested.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05675
Paper Title	Identification of Risk Factors Affecting Crash Frequency and Severity on Horizontal Curves Along High-Speed Divided Highways
Abstract	Horizontal curves continue to be a priority area for improving traffic safety as more than 25 percent of all fatal crashes in the United States occur on curves. The purpose of this study was to identify risk factors affecting both the frequency and severity of crashes occurring on horizontal curves along high-speed divided roadways. Data regarding roadway cross-sectional characteristics, traffic volumes, and roadway geometry were obtained for horizontal curves throughout the state of Iowa. These data were integrated with ten years of crash frequency, type, and severity data. Separate negative binomial models were estimated for freeway and non-freeway facilities, both of which showed crashes to consistently increase as curve radius was decreased. Crashes were also significantly more frequent on reverse curves within the non-freeway dataset. Beyond curvature, crashes were also found to increase with traffic volumes while crashes were less frequent on segments where rumble strips or paved shoulders were present. An ordered probit model was also estimated to assess those factors affecting the degree of injury severity sustained by crash-involved drivers. Curvature was shown to have a moderate impact on severity, with severity generally increasing as curves become sharper. Driver age and gender were also found to influence severity, as were collision type, and a variety of other environmental factors and crash characteristics.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-05698
Paper Title	Effects of Demographics and Neighborhood Environment on Pedestrian Injury Severity with Unobserved Heterogeneity
Abstract	This paper examined the effects of demographics and neighborhood environment on pedestrian injury severity to inform proactive countermeasures for improving pedestrian safety. A mixed-effects logistic model addressing unobserved heterogeneity was developed based on 3,948 pedestrian-involved crashes, which occurred in District 7 of Florida from 2011 to 2014. Six normally-distributed random parameters were identified to reflect random effects on the pedestrian injury severity. The heterogeneity of two demographic factors (older and male pedestrians) suggested the need for more customized education programs to improve pedestrian safety awareness and knowledge, especially for older pedestrians. Relative to low-income areas, 67.7% of crashes in higher-income areas are less likely to sustain severe injury. Analysis of sample data also indicated that low-income areas tend to have more unsafe behaviors by pedestrians for severe injury (e.g., pedestrian crossing at dark-unlighted). Higher-income areas tend to have more unsafe behaviors from drivers (e.g., distracted drivers) that are related to higher injury severity. Other significant factors include lighting conditions (daylight, darkness without lighting), speed limit, alcohol/drug impairment, dart/dash, crossing indicator, and traffic control device indicator. Regarding neighborhood land use types, two indicators about the presence of bus stops and department stores/supermarkets nearby are significant, and their effects are also random. Further investigations are needed to systematically identify the need for effective countermeasures in severe injury crash clusters in the future.

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Sponsoring Committee	Standing Committee on Highway/Rail Grade Crossings (AHB60)
Session Number	447
Session Title	Highway/Rail Grade Crossing Accident Analysis
Paper Number	17-06094
Paper Title	A Comparative Study of Rail-Pedestrian and Cyclist Trespassing Crash Injury Severity at Highway-Rail Grade Crossings and Non-Crossings
Abstract	Rail-trespassing crashes that involve various levels of injuries to pedestrians and cyclists are under-researched. Rail trespassing could occur at crossings where pedestrians/cyclists are present at the wrong time and non-crossings where pedestrians/cyclists are definitely not allowed to be present. This paper presents a comparative study examining rail-trespassing crashes in two contexts: highway-rail grade crossings vs. non-crossings. How pre-crash trespassing behaviors and other factors (e.g. crash time, locations, and socio-demographics) differ between grade crossings and non-crossings are explored. The analysis relies on a ten-year (2005-2014) database of rail-pedestrian and cyclist trespassing crash records extracted from a Federal Railroad Administration safety database. Of the 10,146 crashes, 8,258 (81%) occurred at non-crossings, while 1,888 (19%) occurred at grade crossings. About 43% of the crashes were fatal at crossing compared with 53% at non-crossings. The most prevalent pre-crash trespassing behavior is riding (e.g. a bicycle) or operating equipment (51%) at grade crossings, whereas lying, sleeping, running, and walking account for over 60% of non-crossing crashes. A unique aspect of the study is that a diverse set of variables based on geographic variations across counties along with crash/injury data are modeled by estimating mixed-effect ordered logistic regressions. The results show that the correlates of injury severity differ across highway-rail grade crossings and non-crossings. For example, lying or sleeping on or near tracks contributed to higher chances of fatal injury in both settings, however, they were relatively more injurious at grade crossings. The analytical results can provide guidance on railway safety improvement plan

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Sponsoring Committee	Standing Committee on Highway/Rail Grade Crossings (AHB60)
Session Number	447
Session Title	Highway/Rail Grade Crossing Accident Analysis
Paper Number	17-06202
Paper Title	A Cluster Based Approach to Analyze Crash Injury Severity at Highway-Rail Grade Crossings
Abstract	The presence of heterogeneity in the raw crash data can result in estimation of biased model parameters and incorrect inferences. This research investigates severity of crashes reported at highway-rail grade crossings by accounting for heterogeneity. A combination of data mining and statistical regression methods were used to cluster the crash data into subsets and then identify factors associated with crash injury severity levels. This research relied on 2011-2015 Highway-Rail Accident/Incident and Highway-Rail Crossing inventory datasets obtained from the Federal Railroad Administration (FRA). Ordered logit models were estimated for the whole dataset, and each subset obtained by performing cluster analysis. Data subsets were formed using K-means, traditional Latent Class Cluster, and Variational Bayesian Latent Class Cluster methods. Models were estimated using data subsets formed by the Variational Bayesian Latent Class Cluster method and compared to the model results obtained from the full (unclustered) dataset. A comparison revealed that the cluster approach provided more detailed information. Train speed was the only factor that was common across all models in the clustered and unclustered datasets; crash injury severity increased with higher train speed.

Authors	Angela Kitali, University of North Florida (Corresponding Author) Emmanuel Kidando, Florida State University Thobias Sando, University of North Florida Ren Moses, Florida A&M University - Florida State University Eren Ozguven, Florida A&M University - Florida State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06386
Paper Title	Evaluating Pedestrian Crash Severity Using Bayesian Complementary Log-Log Model for Improved Prediction Accuracy
Abstract	Reliable prediction accuracy is an essential attribute for crash prediction models. Generally, more severe injury outcomes, such as fatalities, are rare than less severe crashes, such as property damage only/minor injuries. The Complementary log-log model (Cloglog), commonly used in epidemiology research, is known for its accuracy in predicting rare events. This study implements the Cloglog model in analyzing pedestrian injury severity and compares its performance against the two conventional models used in injury severity research – probit and logit models. A total of 1,397 aging pedestrian crashes that occurred within five years (2009 through 2013) in Florida were used to develop the three models. The response variable, injury severity level, was binary, categorized as either fatal/severe injury or minor/no injuries. The study used three accuracy metrics, i.e., Deviance Information Criteria, prediction accuracy, and Receiver Operating Characteristics curves to compare the performance of each model. The Cloglog model outperformed the probit and logit models in terms of overall goodness-of-fit, and prediction accuracy. More importantly, the Cloglog model outperformed the other two models by far (72% accuracy versus 43% and 41% for probit and logit, respectively), for predicting fatal and severe crashes, based on the recall parameter. However, the other two models outperformed the Cloglog model in predicting crashes with no/minor injuries. Among predictor variables included in the model, six were found to significantly influence aging pedestrian fatal/severe injury at 95% Bayesian Credible Interval. These included; pedestrian age, alcohol involvement, first harmful event, vehicle movement, shoulder type, and maximum posted speed.

Authors	Huiyuan Liu, University of Nebraska, Lincoln Aemal Khattak, University of Nebraska, Lincoln (Corresponding Author)
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-06412
Paper Title	Alternate Indicators for Crash Severity: Analysis of Multivehicle Crashes Based on Multilevel Mixed-Effects Ordered Logit Model
Abstract	The objective of this paper was to explore four common crash severity measures and to compare findings for crashes involving three or more vehicles. The four measures of crash severity were: 1) the most severe injury reported in a crash, 2) property damage amount ($), 3) driver's injury, and 4) occupant's injury. Considering the nested structure of data, a multi-level mixed-effects ordered logit model was used for model estimation. This paper provides the performance of each model and a test between the multi-level ordered model and traditional ordered model. Results showed that some factors (e.g., crash type) had statistically significant effects at most levels in all four models and the effects were also similar while some factors (e.g., driver age) were found to have opposing effects in different models. Not surprisingly, the research showed that results of crash injury severity depended on whichever measure of severity was adopted.

Authors	Elizabeth Welch, University of Texas, Austin (Corresponding Author) Ming Zhang, University of Texas, Austin Junfeng Jiao
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06520
Paper Title	Identifying Factors Explaining Pedestrian Crash Severity: Study of Austin, Texas
Abstract	From the Federal Highway Administration to local departments of transportation, traffic safety is a persistent concern for transportation planners and engineers. Pedestrians are among the most vulnerable road users and require consideration beyond typical analysis of vehicle safety. This study has two objectives: identify environmental, demographic, and behavioral factors explaining crash severity, and compare methods for determining the significance of these factors. Binary and ordered logistic regression models were developed and compared to assess factor significance. Environmental and local factors, such as lighting and speed limit, had the strongest correlation with crash severity in all cases. However, inclusion of driver and pedestrian behavior and demographic characteristics improved the fit of the model and, in some cases, predictive ability. The two model types identified the same significant variables in traffic safety, but the magnitudes of the effects differed by model. This finding demonstrates that while the simpler method may yield the same overall results, combining methods can differentiate factors which contribute to the most severe crashes. These methods require little data enhancement beyond existing police records and can be a model for analysis by practitioners.

Authors	Ali Ghasemzadeh, University of Wyoming Mohamed Ahmed, University of Wyoming
Sponsoring Committee	Standing Committee on Surface Transportation Weather (AH010)
Session Number	318
Session Title	Weather Impacts on Safety and Surface Transportation
Paper Number	17-06573
Paper Title	Probit-Decision Tree Approach to Analyze Effects of Adverse Weather Conditions on Work Zone Crash Severity Using Second Strategic Highway Research Program Roadway Information Data Set
Abstract	Identifying risk factors for road traffic injuries is one of the main priorities of transportation agencies. More than 12,000 fatal work zone crashes were reported between 2000 and 2013. In spite of recent efforts on improving work zone safety, the frequency and severity of work zone crashes are still a big concern for transportation agencies. The effect of work zone on traffic safety is shown to be intensified by adverse weather conditions. Although many studies have been conducted on different work zone safety-related issues, there is a lack of studies that investigate the effect of adverse weather conditions on work zone crash severity. This paper utilized probit-decision tree; a relatively recent and promising combination of machine learning technique and conventional parametric model, to identify factors affecting work zone weather-related crashes severity using a unique dataset collected by the second Strategic Highway Research Program Roadway Information Database. The key strength of this technique lies in its capability of alleviating the shortcomings of both parametric and non-parametric models. The results were compared to a conventional probit model and the proposed probit-decision tree is considered a better technique that outperformed the conventional probit regression because of its high estimation accuracy, robustness and reliability, and its ability of estimating marginal effects of risk factors.

Authors	Sareh Bahrololoom, RMIT University Sara Moridpour Richard Tay, RMIT University Amir Sobhani, VicRoads
Sponsoring Committee	Standing Committee on Bicycle Transportation (ANF20)
Session Number	808
Session Title	Bicycle Safety, Design, and Operations
Paper Number	17-06640
Paper Title	Exploring the Factors Affecting Bicycle Crash Severity in Victoria, Australia
Abstract	Bicycles are among vulnerable road users, so the bicyclists' safety on the road network has been one of the main concerns of researchers and authorities in the last decade. Each year, an average of 35 cyclists are killed and over 2500 cyclists are seriously injured in Australia. In 2008, in Australia, 27 fatalities were cyclists, down from 41 deaths the year prior. Therefore, it is necessary to understand the bicyclists' serious casualty problem in order to reduce the risk of fatality and serious injury crashes on the road network. Although a number of studies investigated the effect of road, environmental, vehicle and human demographic characteristics on bicycle crashes in Victoria, limited research has been conducted to investigate the effect of these parameters on number of fatal and serious injury bicycle crashes. This study compared generalised ordered logit and generalised ordered probit modelling techniques to understand the factors affecting fatal and serious injury bicycle crashes in Victoria, Australia. It examined the effects of human demographics, road, environmental and crash characteristics on severity of bicycle crashes. Road crash information system (RCIS) database is used to develop the models. The results confirmed that the generalized ordered probit model performed better than the generalized ordered logit model. The results further showed that crash time, bicyclist's age, helmet use, speed zone, lighting condition, bicyclist's intent, other road user's intent, traffic control for other road user's approach, spatial location of the crash, road surface of the bicyclist and road layout were the significant variables affecting crash severity of two-vehicles in which at least one bicyclist was involved. This study provided a better understanding of the factors contributing to bicycle serious casualty problem to design and implement safer infrastructure on the road network.

Authors	Ali Ghasemzadeh, University of Wyoming Mohamed Ahmed, University of Wyoming
Sponsoring Committee	Standing Committee on Surface Transportation Weather (AH010)
Session Number	318
Session Title	Weather Impacts on Safety and Surface Transportation
Paper Number	17-06764
Paper Title	Tree-Based Ordered Probit Approach to Identify Factors Affecting Work Zone Weather-Related Crash Severity in North Carolina Using the Highway Safety Information System Data Set
Abstract	Work zone crashes are still on the rise due to the aging of US roads and the increase in traffic demand. Investigation of crash characteristics and determining contributing factors in work zones is one of the most important issues in many traffic safety studies. The effect of work zones on traffic safety can be exacerbated by weather conditions. A sudden reduction in visibility may intensify the severity of work zone crashes. Although many studies have investigated work zone crashes, research that investigates the impact of adverse weather conditions on work zone crashes is lacking. In this study, The Highway Safety Information System database for North Carolina was used to identify the characteristics of work zone weather-related crashes. A Tree-based Ordered Probit, a relatively recent and promising combination of nonparametric machine learning (decision tree) and classical statistics (ordered probit) techniques, was utilized to gain a better understanding about the effects of various factors on different work zone crash related injury and crash severity in adverse weather conditions. The results showed that Tree- based Ordered Probit model has a better prediction accuracy compared to conventional Ordered Probit Model. Lighting conditions, number of vehicles involved in a crash, road characteristics, number of occupants, land use, presence of traffic control devices, and two types of crashes (sideswipe and rear-end crashes) were identified as the most important factors in work zone weather-related crash severity.

6 Crash Modification Factors

Tarek Sayed and Ahmed Osama, University of British Columbia

The Subcommittee identified fifteen papers dealing with crash modification factors and crash modification functions. Most of the papers employed the empirical Bayes approach (e.g. Zegeer et al., 17-03480; Le et al., 17-05379; Lyon et al., 17-00432). Cross-sectional regression methods were employed in some studies (e.g. Wu et al., 17-02498). A case-control method was compared to cross-sectional regression method in one study (Galgamuwa and Dissanayake, 17-01474). Both cross-sectional regression models and before-after empirical Bayesian analysis were performed in one study (Zegeer et al., 17-03480). A quasi experimental before-after treatment/control evaluation design was implemented in one study to develop collision modification factors for different treatment types (Sobhani et al., 17-06356). A before-after analysis with benefit-cost evaluation was applied in one study (Yassin et al., 17-04529). Other evaluation techniques were also proposed, such as Pratt et al., 17-04498, in which they combined collision modification factors from NCHRP Report 627 and HCM for evaluating freeway work zones; and Kitali et al., 17-05178, in which they used predicted crash counts from an estimated safety performance function to establish CMFs for distinctive crashes categories based on crash severity.

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 (Reyad et al., 17-00037). Crash modification functions were also proposed (e.g. Wu et al., 17-02498). Two papers compared crash modification functions to crash modification factors (Kitali et al., 17-05178; Zhao, 17-00046). An adjustment function to combine multiple CMFs was also proposed (Park and Abdel-Aty, 17-00439).

The evaluated countermeasures included pedestrian countdown signals (Kitali et al., 17-05178), red-light indicator lights (Himes et al., 17-03500), flashing yellow arrow (Schattler et al., 17-01020), box span signal configuration (Yassin et al., 17-04529), rumple strips and paved shoulders (Galgamuwa and Dissanayake, 17-01474), uncontrolled pedestrian crossing treatments (Zegeer et al., 17-03480), low-cost systemic safety improvements at signalized and stop-controlled intersections (Le et al., 17-05379), left-turn lanes on two-lane roads (Srinivasan et al., 17-03743), pavement resurfacing (Zhao, 17-00046), median, kerb extension, full-time fully controlled right turn signals, and part-time fully controlled right turn signals (Sobhani et al., 17-06356).

Authors	Passant Reyad Emanuele Sacchi, University of Saskatchewan Shewkar Ibrahim, City of Edmonton Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Session 589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00037
Paper Title	Traffic Conflict-based Before-After Study Using Comparison Groups and the Empirical Bayes Method
Abstract	Road safety evaluations rely mainly on the analysis of crash data that is challenged by well-recognized availability and quality issues. Recently, the statistical models used to predict the safety level of road sites, i.e., safety performance functions (SPFs), have been successfully developed using traffic conflict observations instead of crashes. As such, it is possible to adopt and transfer the statistical techniques used in crash-based road safety analysis to conflict-based analysis. The use of statistically rigorous techniques in crash-based before-after (BA) studies is essential in evaluating the effectiveness of road safety countermeasures. In particular, the use of Bayesian methods such as the empirical Bayes (EB) technique is vital to control for confounding factors that can operate simultaneously to the countermeasure and may affect road safety performance. The main objective of this paper is to estimate the treatment effectiveness of two traffic signal improvement projects in the City of Edmonton (Alberta, Canada) by means of a conflict-based BA study, using the comparison group and the EB methods. More than 300 hours of video data with traffic conflict observations were automatically collected and analyzed using computer vision techniques for two treatment and two control (untreated) intersections before and after the signal improvement projects. The results of the comparison group method showed statistically significant 24% reduction in rear-end average hourly conflicts while the EB method showed statistically significant 24.5% reduction in total average hourly conflicts.

Authors	Jiguang Zhao, CH2M
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-00046
Paper Title	Safety Performance Evaluation: Crash Modification Factor or Crash Modification Function?
Abstract	The treatment of shoulder rumble stripes, shoulder widening (from 0 to 2 feet) and pavement resurfacing (RSR) was deployed to over 400 centerline miles of rural two-lane highways in Missouri. The safety performance of the RSR treatment was evaluated with the empirical Bayesian before/after study method based on the roadway characteristics, traffic and crash data collected. Crash modification factors (CMF) for 20 categories of crash severity and/or collision types were calculated. Generally the RSR treatment is effective for improving safety performance of rural two-lane roads, especially for fatal and injury crashes. Meanwhile, the RSR treatment is more effective for run-off road and head-on crashes than for total crashes. A cumulative residual (CURE) analysis reveals that fixed-value CMFs for all annual average daily traffics (AADT) range are likely to conclude with biased estimation on the RSR's safety performance. The crash modification function (CMFunction) was introduced in this study and a sample size of 16 was selected to develop the CMFunction based on the sensitivity analysis results. CMFunctions were developed for two collision types under different severity levels. The CURE plot indicates that CMFunctions produce unbiased crash frequency prediction results and therefore are more reliable than fixed-value CMFs.

Authors	Craig Lyon, Persaud and Lyon Inc. Bhagwant Persaud, Ryerson University Kimberly Eccles, VHB
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-00432
Paper Title	Safety Evaluation of Two Curve Warning Treatments: In-Lane Curve Warning Pavement Markings and Oversized Chevron Signs
Abstract	The objective of this study was to undertake a rigorous before-after evaluation of the safety effectiveness—as measured by crash frequency—of in-lane pavement marking curve warnings and oversized chevrons in horizontal curves. These strategies were selected for the investigation for the Evaluation of Low Cost Safety Improvements Pooled Fund Study, which functions under the US Federal Highway Administration's Development of Crash Modification Factors program. Data from four states, Iowa, Kansas, Missouri and Pennsylvania were used to estimate crash modification factors (CMFs) for specific crash types including total, fatal+injury, run-off-road, night and night run-off-road using the empirical Bayes (EB) methodology. For in-lane curve warning pavement markings, results indicate that only the CMF estimates for total and night crashes are statistically significant at the 95-percent confidence limit. However, no CMF is recommended at this time since these results are based on few crashes in the after period and should be used with due caution. The sample size for oversized chevron signs was larger but still modest. None of combined results were statistically significant at the 95-percent confidence level. However, the estimated CMF of 0.73 for night crashes, the target crash type, has a relatively low p-value of 0.11. The disaggregate results for this crash type suggest, that sites where advisory speeds have been posted because of a combination of sharper curvature and higher design speeds may yield higher benefit from the installation of chevrons, especially larger chevrons, when compared to locations where advisory speeds are not required.

Authors	Juneyoung Park, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-00439
Paper Title	Alternative Approach for Combining Multiple Crash Modification Factors Using Adjustment Function and Analytic Hierarchy Process
Abstract	The safety effects of multiple treatments have recently emerged as an important issue of validation of the Highway Safety Manual (HSM) procedures to improve performance of the predictive process. In order to estimate more reliable combined safety effects of multiple crash modification factors (CMFs), several combining approaches have been suggested. However, there are still several critical issues for the existing combining methods such as over-estimation, region specific method, non-scientific approach, etc. Therefore, this study suggests a novel adjustment method to combine multiple CMFs to enhance the reliability of combining the safety effects of multiple treatments. Various combinations of CMFs for single and multiple treatments were estimated or obtained from previous studies by the authors and used for an exploratory analysis. Moreover, an alternative combining approach with the development of adjustment function was suggested through the comparison with the existing combining methods using the multi-criteria decision making process. The results show that the proposed alternative combining method provides better estimates than the existing methods and can account for different roadway types and severity levels. Thus, it can be recommended that the safety effects of multiple treatments are estimated using the proposed new combining approach to overcome the over-estimation issue and produce more reliable results.

Authors	Kerrie Schattler, Bradley University Eric Anderson, Strand Associates, Inc. Trevor Hanson, Illinois Department of Transportation
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-01020
Paper Title	Safety Performance of Flashing Yellow Arrow for Protected/Permissive Left-Turn Signal Control in Central Illinois
Abstract	In 2010, the Illinois Department of Transportation began implementing the flashing yellow arrow (FYA) at intersections operating with protected/permissive left-turn (PPLT) control. Research was conducted to evaluate the safety effectiveness of FYAs at 86 intersections and 164 approaches in central Illinois. The effectiveness evaluation was performed using three years of before- and after- FYA installation crash data and the empirical Bayes method. In the before condition, the left-turn signals operated with a circular green display indicating the permissive interval of PPLT control using a five-section signal head. In the after condition, the FYA replaced the circular green display for the permissive interval of PPLT using a four-section signal head. Supplemental traffic signs were mounted on the mast arm adjacent to the left-turn signal at over half of the FYA installations. This paper presents the results of the comprehensive safety evaluation of FYA for PPLT control. Analyses were also performed to assess the effects of the FYA supplemental signs and to assess the effects of the FYA overall on two subsets of drivers: older drivers (age 65+) and younger drivers (age 16 to 21 years) at-fault. The resulting mean crash modification factors for the targeted crash types ranged from 0.589 to 0.714. The findings of this research support the continued use of FYAs for PPLT control to improve safety at signalized intersections in central Illinois.

Authors	Uditha Galgamuwa, Kansas State University Sunanda Dissanayake, Kansas State University
Sponsoring Committee	Standing Committee on Geometric Design (AFB10)
Session Number	Session 298
Session Title	Geometric Design Research
Paper Number	17-01474
Paper Title	Estimating Crash Modification Factors Using Cross-Sectional and Case-Control Methods for Rumble Strips and Paved Shoulders
Abstract	This paper describes the application of case-control and cross-sectional methods to develop crash modification factors (CMFs) for lane departure countermeasures in two-lane rural undivided road segments in Kansas. Four commonly used countermeasures, namely 2-ft paved shoulders, centerline rumble strips, shoulder rumble strips, and shoulder & centerline rumble strips have been considered. The number of road segments used to analyze tangent and curved road segments were 22,061 and 6,442, with total lengths of 9,027 miles and 1,468 miles, respectively. CMFs were calculated for all crashes and fatal & injury lane departure crashes. Linear regression and logistic regression were used in developing models for cross-sectional and case-control methods respectively. Mean residuals and mean squared error (MSE) were used to validate the models developed for cross-sectional method. Classification tables were used to validate the models developed for case-control method. Three countermeasures were found to be effective in reducing all crashes and fatal & injury crashes except shoulder rumble strips in curved road segments. Even though same countermeasures were found to be effective in reducing lane departure crashes in both cross-sectional and case-control methods, CMFs developed using the cross-sectional method demonstrated a narrower range than CMFs developed using the case-control method indicating results from the cross-sectional method can be considered as more accurate and reliable than case-control method.

Authors	Lingtao Wu, Texas A&M Transportation Institute Dominique Lord, Texas A&M Transportation Institute Srinivas Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-02498
Paper Title	Developing Crash Modification Factors for Horizontal Curves on Rural Two-Lane Undivided Highways using a Cross-Sectional Study
Abstract	Horizontal curves have been identified as experiencing more crashes than tangent sections on roadways, especially on rural two-lane highways. The first edition of the *Highway Safety Manual* (*HSM*) provides crash modification function (CM-Function) for curves on rural two-lane highways. The CM-Function proposed in the *HSM* may suffer from both outdated data and analysis technique. Before-after studies are usually the preferred method for estimating the safety effects of treatments. Unfortunately, this method is not feasible for curves. Previous studies have frequently used regression models for developing CM-Functions for horizontal curves. As recently documented in the literature, some potential problems exist with using regression models for developing crash modification factors (CMFs). This study utilized cross-sectional study to develop curvature CM-Function. Curves located on Texas rural two-lane undivided highways were divided into a number of bins based on the curve radius. The safety was predicted with the assumption that these curves had been tangents. The observed number of crashes that occurred on the curves was compared with the "dummy" tangents and for different bins. The results showed that horizontal curve radius has a significant role in the risk of a crash. Based on these results, a new CM-Function was developed. The prediction performance of the *HSM* CM-Function and another function that was recently proposed in the literature were compared with the new CM-Function in this study. It was found that the new CM-Function documented in this study outperformed both.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-03743
Paper Title	Crash Modification Factors for Signal Installation With and Without Left-Turn Lanes on Two-Lane Roads in Rural and Suburban Areas
Abstract	The authors examined the safety effect of signalization with and without left turn lanes using data from 117 intersections on two lane roads in rural and suburban areas in North Carolina. They conducted a before-after study using the empirical Bayes method. Before signalization, all the 117 intersections were controlled by stop signs on the minor legs. The results of the safety analysis are provided for three and four leg intersections separately and for five types of crashes: total, injury and fatal, rear end, and two types of frontal impact crashes. It is clear that the introduction of signals without the addition of left turn lanes resulted in a reduction in total crashes, injury and fatal crashes, and frontal impact crashes (both types), and an increase in rear end crashes. When left turn lanes accompanied the signal installation, rear end crashes decreased as well. Injury and fatal crashes and rear end crashes benefited the most from the addition of left turn lanes. Overall, frontal impact crashes did not benefit from the addition of the left turn lanes.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 538
Session Title	Advances in Highway Safety Performance
Paper Number	17-03480
Paper Title	Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments
Abstract	The objective of this study was to develop crash modification factors (CMFs) for four treatment types: Rectangular Rapid Flashing Beacons (RRFBs), Pedestrian Hybrid Beacons (PHBs), Pedestrian refuge islands, and Advance Yield or STOP markings and signs. A total of 975 treatment and comparison sites were selected from 14 different cities throughout the U.S. Most of the treatment sites were selected at intersections on urban, multi-lane streets, since these are the situations which have a high risk for pedestrian crashes and where countermeasures are typically most needed. For each treatment site, relevant data were collected regarding the treatment characteristics, traffic, geometric, and roadway variables, and the pedestrian crashes and other crash types that occurred at each site. Cross-sectional regression models and before/after empirical Bayesian analysis techniques were used to determine the crash effects of each treatment type. All four of the treatment types were found to be associated with reductions in pedestrian crash risk, compared to the untreated sites. Pedestrian hybrid beacons were associated with the greatest benefit to pedestrian crash risk (55% reduction), followed by RRFBs (47% reduction), refuge islands (32% reduction), and advance yield/stop lines and signs (25% reduction). The results for RRFBs are based on a very limited sample, and must be used with caution.

Authors	Scott Himes, VHB Frank Gross, VHB Kimberly Eccles, VHB Bhagwant Persaud, Ryerson University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-03500
Paper Title	Safety Evaluation of Red-Light Indicator Lights in Florida
Abstract	Red-Light Indicator Lights (RLILs) are auxiliary lights mounted on signal heads, mast arms, or poles and directly connected to a traffic-control signal. The RLIL activates at the onset of the red phase and allows an enforcement officer to observe red-light running from downstream of the intersection. This strategy is intended to reduce the frequency of crashes resulting from drivers disobeying traffic signals by providing a safer and more efficient means for police to enforce the red interval. Geometric, traffic, and crash data were obtained at treated four-leg signalized intersections in Florida. 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 four-leg signalized intersections with similar characteristics to the treated sites. The analysis also controls for changes in traffic volumes over time and time trends in crash counts unrelated to the treatment. Results indicate statistically significant crash reductions for most crash types. Disobeyed signal crashes have an estimated crash modification factor (CMF) of 0.71. Total crashes, fatal and injury crashes, right-angle, and left-turn crashes have estimated CMFs of 0.94, 0.86, 0.91, and 0.60, respectively. The benefit-cost ratio estimated with conservative cost and service life assumptions is 92:1 for four-leg signalized intersections. The results suggest that the treatment, even with conservative assumptions on cost, service life, and the value of a statistical life, can be cost effective. In addition to the crash-related benefits, RLILs can improve the efficiency and safety of red-light running enforcement efforts. While this study did not evaluate the efficiency and safety impacts with respect to enforcement, it should be noted that RLILs do allow police to observe violators from a downstream position, eliminating the need for a second observer (upstream) and the need to pursue a violator through the red-light.

Authors	Michael Pratt, Texas A&M Transportation Institute Srinivas Geedipally, Texas A&M Transportation Institute Kent Collins, Texas A&M Transportation Institute Jason Crawford
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-04498
Paper Title	Combining Safety Analysis Tools for Evaluation of Freeway Work Zones: A Case Study
Abstract	Predictive methods are available in the *Highway Safety Manual* (HSM) to estimate the safety performance of various types of roadway facilities, including freeways. These methods were developed to provide predictions of crash frequency in periods of normal roadway operation. Additionally, research has been conducted on various aspects of work zone safety. However, there is a need to combine insights gained from these separate efforts so work zones can be more effectively designed and monitored, and safety performance of work zones can be improved in a cost-effective manner. The freeway safety prediction methodology from Chapter 18 of the HSM has been combined with work zone crash modification factors that were documented in*NCHRP Report 627* for the purpose of obtaining refined predictions of crash frequency during ongoing construction activities. This combination improved the predicted crash frequencies that were obtained from a direct application of the HSM methodology, which does not in itself account for work-zone-specific issues. This combined analysis, along with traditional crash data analysis methods like crash trees, crash rate analysis, and hot spot analysis, allowed work zone safety to be monitored more effectively.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-04529
Paper Title	Safety Evaluation of Box Span Signal Configuration
Abstract	A research study was conducted to evaluate the safety benefits of the Box Span Signal Configuration for all drivers and for older drivers' age 65 years and above. The Box Span Signal Implementation was evaluated by performing a literature review, perception survey of Michigan drivers, and crash data analysis. Safety Performance Functions (SPF) were developed as part of the study. Crash Modification Factors (CMF) were developed through the before-after analysis of crash data. A benefit cost analysis was also performed to evaluate the safety benefits. The Box Span Signal Implementation, when replacing a diagonal span configuration, was found to significantly reduce Angle crashes by 12.4 percent for all drivers.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-05178
Paper Title	Developing Crash Modification Factors to Quantify Impacts of Pedestrian Countdown Signals to Drivers
Abstract	Pedestrian countdown signals (PCSs) are viable traffic control devices that assist pedestrians to cross intersections safely. Despite the fact that PCSs are meant for pedestrians, they also have an impact on driver behavior at intersections. This study focuses on evaluation of safety effectiveness of PCSs to drivers in the cities of Jacksonville and Gainesville, in Florida. A before-after study with empirical Bayes method was used in analyzing the vehicle crash data for the two cities, state maintained intersections with PCSs. Prior to establishing Crash Modification Factors (CMFs), full safety performance functions for different crash types and severities were estimated using the negative binomial regression model. From the predicted crash counts, the CMFs were established for distinctive categories of crashes based on crash severity types. The findings indicated that installing PCSs revealed a significant improvement of driver's safety by 8.8% reduction in total crashes, 4.8% reduction in fatal and injury crashes, and 7.1% reduction in property damage only crashes. In addition, rear-end crashes were observed to be reduced by 8.0% whereas a 4.6% reduction in angle crashes was observed. Also, discussed in this study, are the crash modification functions (CMFunctions) showing the relationship between the developed CMFs and average daily traffic volume in the major street at the intersection were developed. In summary, the results suggest usefulness of PCSs for drivers.

Authors	Thanh Le, VHB Frank Gross, VHB Timothy Harmon, VHB
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Standing Committee on Highway Safety Performance (ANB25)
Session Title	Advances in Highway Safety Performance
Paper Number	17-05379
Paper Title	Safety Effects of Low-Cost Systemic Safety Improvements at Signalized and Stop-Controlled Intersections
Abstract	Packages of intersection treatments, including signing, pavement marking and signal enhancements, were installed at many signalized and stop-controlled intersections in South Carolina. This study evaluated the overall safety effectiveness of the concurrent implementation of these systemic low-cost treatments as part of the FHWA Evaluation of Low Cost Safety Improvements Transportation Pooled Fund. The dataset included both urban and rural 3-legged and 4-legged intersections with two or four lanes on the major road. The study employed an empirical Bayes (EB) before-after analysis. The aggregate results indicate reductions for all crash types analyzed in this study. For signalized intersections, the crash modification factors (CMF) are 0.955, 0.893, 0.974, 0.883, and 0.969 for total, fatal and injury, rear-end, right-angle, and nighttime crashes, respectively. The CMFs for fatal and injury and right-angle crashes are statistically significant at 95-percent and the CMF for total crashes is statistically significant at 90-percent confidence levels. For stop controlled intersections, the CMFs are 0.917, 0.899, 0.933, 0.941 and 0.853 for total, fatal and injury, rear-end, right-angle, and nighttime crashes, respectively. All CMFs for stop-controlled intersections are statistically significant at the 95-percent confidence level. An economic analysis shows that systemic, low-cost intersection treatments are cost effective with conservative benefit-cost ratio estimates of 4.1 for total crashes at signalized intersections and 12.4 for total crashes at stop-controlled intersections.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-05863
Paper Title	Evaluating Safety Effects of Variable Speed Limit System using Empirical Bayesian Before-After Analysis
Abstract	Variable speed limits (VSL) have been increasingly used to improve traffic safety on freeway mainlines. The primary objective of this study was to evaluate the safety impacts of the VSL system implemented on Interstate 5 in Washington since 2010. An observational Empirical Bayesian (EB) before-after analysis was conducted based on 9787 crashes that occurred in the 72-month period. The analysis was conducted for all crashes, and crash severity levels. The EB before-after result implied that the total crash count was reduced by 29% with a standard deviation of 5% after the VSL system was applied in Washington. The counts of crashes with no injury and possible injury decreased more than crashes with severe injuries. The evaluation results of this study are particularly valuable for policy making associated with VSL system implementation projects.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 802
Session Title	Highway Safety Performance
Paper Number	17-06356
Paper Title	Evaluation of Key Engineering Treatments Addressing Major Pedestrian Casualty Crashes in Victoria, Australia
Abstract	Pedestrian injury and mortality are a global issue, with more than 270,000 pedestrians killed worldwide each year. In Victoria, 249 road fatalities were reported in 2014, 18% of which were pedestrians. These statistics convinced the Victorian road safety partners to develop a major program to reduce the number of severe pedestrian casualties. One of the main challenges in development of pedestrian safety programs is selection of engineering crash treatments leading to the most effective reduction in number of pedestrian crashes. This approach relies on accurate quantification of the effectiveness of such treatments. This study conducted a literature review of the effectiveness of different pedestrian treatments in Australia and in other countries. This literature review assessed the availability and accuracy of reported crash modification factors (CMF) for each treatment type. Then, four major treatment types which have not been evaluated accurately, were selected for evaluation. These treatment types included 'median', 'kerb extension', 'full-time fully controlled right turn signals' and 'part-time fully controlled right turn signals'. A quasi-experimental before-after treatment/control evaluation design was utilized to assess the effectiveness of these treatment types. Required data for treated and control sites were collected from Local Government Areas (LGAs) and VicRoads from Melbourne metropolitan area. A log-linear Poisson model was applied to estimate effectiveness of each treatment. The key findings were that median (flush or physical) CMF for all casualty crashes was 0.65, and for 0.45 for pedestrian casualty crashes. For kerb extensions the all casualty crash CMF was 0.46. For the full-time application of fully controlled right turns, the all casualty crash CMF was 0.48, and for part-time application of the same treatment the CMF was 0.89 (low significance). Site availability limitations meant that only one CMFs related to pedestrian crashes could be found. Some significant results were reported for fatal and serious injury crash CMFs. Nevertheless, the paper shows how these treatments address the main pedestrian movement types involved in serious pedestrian casualties. Outputs of this study will improves the cost-effectiveness and accuracy of pedestrian road safety treatment programs through updated and more accurate CMF values for the most effective and relevant pedestrian safety treatments. The findings will be useful to road agencies seeking to reduce incidence and severity of pedestrian casualties.

7 Surrogate Measures of Safety

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Matin Nabavi Niaki and Nicolas Saunier, Polytechnique Montreal

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

Of the topics covered in the papers, **freeway safety**, **intersection safety**, **pedestrians and non-motorized traffic**, and **connected vehicles** stand out. Seven papers involve **freeway safety** (Hamzeie et al., 17-00080; Zheng and Meng, 17-00621; Li et al., 17-01540; Liu et al., 17-01978; Khazraeian et al., 17-02775; Zhao and Lee, 17-03212; Mudgal and Hourdos, 17-05229), while eleven papers are related to **intersection safety** (Reyad et al., 17-00037; Tageldin et al., 17-00857; Sayed and Fyfe, 17-01651; Jahandideh et al., 17-01873; Zhang et al., 17-02090; Gonzales, 17-03647; Islam et al., 17-04116; Raker et al., 17-06177; Ghosh and Paul, 17-06588; Ma et al., 17-06687; Shen et al., 17-06897). **Pedestrians and non-motorized traffic** are covered by eight papers (Tageldin et al., 17-00857; Jahandideh et al., 17-01873; Zhang et al., 17-02090; Kassim et al., 17-03391; Gonzales, 17-03647; Islam et al., 17-04116; Sarwar et al., 17-05484; Raker et al., 17-06177) and **connected vehicles** by three (Sayed and Fyfe, 17-01651; Liu et al., 17-01978; Khazraeian et al., 17-02775).

Traffic conflicts are the most frequently used surrogate measure of safety, used in eighteen papers (Reyad et al., 17-00037; Zheng and Meng, 17-00621; Tageldin et al., 17-00857; Li et al., 17-01540; Sayed and Fyfe, 17-01651; Jahandideh et al., 17-01873; Liu et al., 17-01978; Zhang et al., 17-02090; Khazraeian, 17-02775; Zhao and Lee, 17-03212; Charly and Mathew, 17-04012; Islam et al., 17-04116; Babu et al., 17-04210; Li et al., 17-05537; Raker et al., 17-06177; Ghosh and Paul, 17-06588; Ma et al., 17-06687; Shen et al., 17-06897). **Time-to-collision (TTC)** and **post-encroachment time (PET)** are the most commonly used traffic conflict indicators (Zheng and Meng, 17-00621; Tageldin et al., 17-00857; Li et al., 17-01540; Sayed and Fyfe, 17-01651; Jahandideh et al., 17-01873; Zhao and Lee, 17-03212; Charly and Mathew, 17-04012; Islam et al., 17-04116; Babu et al., 17-04210; Li et al., 17-5537; Ghosh and Paul, 17-06588). Additionally, Shen et al., 17-06897 analyzes the **red-light running** behavior of drivers at signalized intersections.

Speed-related measures (including acceleration and deceleration) are also used by a number of researchers. Seven papers use such measures (Hamzeie et al., 17-00080; Richard et al., 17-00544; Stipancic et al., 17-01683; Babu et al., 17-04210; Mudgal and Hourdos, 17-05229; Sarwar et al., 17-05484; Ghosh and Paul, 17-06588).

In terms of data sources and techniques, various methods are utilized. **Field observations**, including video, GPS, or detector-collected data, are used in seventeen papers (Reyad et al., 17-00037; Richard et al., 17-00544, Zheng and Meng, 17-00621; Tageldin et al., 17-00857; Li et al., 17-01540; Sayed and Fyfe, 17-01651; Stipancic et al., 17-01683, Jahandideh et al., 17-01873; Wu et al., 17-02271; Zhao and Lee, 17-03212; Stylianou et al., 17-03330; Kassim et al., 17-03391; Gonzales, 17-03647; Mudgal and Hourdos, 17-05229; Li et al., 17-05537; Raker et al., 17-06177; Shen et al., 17-06897). **Simulation** methods and tools, including VISSIM and the Surrogate Safety Assessment Model (SSAM), are used in eight papers (Sayed and Fyfe, 17-01651; Khazraeian, 17-02775; Zhao and Lee, 17-03212; Charly and

Mathew, 17-04012; Islam et al., 17-04116; Babu et al., 17-04210; Li et al., 17-05537; Ma et al., 17-06687). **Naturalistic driving** data, much of which comes from the SHRP 2 program, is utilized in four papers (Hamzeie et al., 17-00080; Richard et al., 17-00544; Sarwar et al., 17-05484; Ye et al., 17-06198).

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00037
Paper Title	Traffic Conflict-based Before-After Study Using Comparison Groups and the Empirical Bayes Method
Abstract	Road safety evaluations rely mainly on the analysis of crash data that is challenged by well-recognized availability and quality issues. Recently, the statistical models used to predict the safety level of road sites, i.e., safety performance functions (SPFs), have been successfully developed using traffic conflict observations instead of crashes. As such, it is possible to adopt and transfer the statistical techniques used in crash-based road safety analysis to conflict-based analysis. The use of statistically rigorous techniques in crash-based before-after (BA) studies is essential in evaluating the effectiveness of road safety countermeasures. In particular, the use of Bayesian methods such as the empirical Bayes (EB) technique is vital to control for confounding factors that can operate simultaneously to the countermeasure and may affect road safety performance. The main objective of this paper is to estimate the treatment effectiveness of two traffic signal improvement projects in the City of Edmonton (Alberta, Canada) by means of a conflict-based BA study, using the comparison group and the EB methods. More than 300 hours of video data with traffic conflict observations were automatically collected and analyzed using computer vision techniques for two treatment and two control (untreated) intersections before and after the signal improvement projects. The results of the comparison group method showed statistically significant 24% reduction in rear-end average hourly conflicts while the EB method showed statistically significant 24.5% reduction in total average hourly conflicts.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00080
Paper Title	Assessing the Interrelationship Between Speed Limits, Geometry, and Driver Behavior
Abstract	Prior research has shown crash risk to be affected by increases in both mean speed and speed variance. However, challenges arise empirically when analyzing the speed-safety relationship given difficulties in integrating crash and speed data temporally and spatially. This study involves a detailed assessment of driver speed selection and crash risk in response to changes in the speed limit while controlling for important roadway, environmental, and driver characteristics. Speed profiles are examined over 20-second time periods immediately preceding crash and near-crash events. Regression models are estimated to assess three measures of interest: the average speed of individual drivers on freeways with different posted speed limits and geometric characteristic; the variance in travel speeds of individual drivers over these same freeway segments; and the probability of a driver being involved in a crash or near-crash event as it relates to roadway geometry, traffic congestion, mean speed and speed variance. Significant correlation was observed with respect to speed selection behavior among the same individuals and particularly within a single driving event. Mean speeds are shown to increase with speed limits. However, these increases are less pronounced at higher speed limits. Drivers tend to reduce their travel speeds along horizontal or vertical curves, under adverse weather conditions, and particularly under heavy congestion. Increases in average travel speed and the variability in travel speeds are both found to increase crash risk. Crash risk also increases on vertical curves and ramp junctions, as well as among the youngest and oldest age groups of drivers.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00544
Paper Title	Using Naturalistic Driving Data to Develop a Typology of Speeding Episodes
Abstract	Speeding-related crashes continue to be a serious problem in the United States. A recently completed NHTSA project, *Motivations for Speeding*, collected data to address questions about driver speeding behavior. This naturalistic driving study used 1-Hz GPS units to collect data from 88 drivers in Seattle and 76 drivers in rural Texas to record how fast vehicles traveled on different roadways. The current project further developed this data set to redefine speeding in terms of speeding episodes. Analyses of the speeding episodes identified six types of speeding. These include two types of speeding that occur around speed-zone transitions (speeding up and slowing down), Incidental speeding, Casual speeding, Cruising speeding, and Aggressive speeding. In this paper, we focus on the urban Seattle driving environment and the relative risk for the various types of speeding identified.

Authors	Lai Zheng, Harbin Institute of Technology Xianghai Meng, Harbin Institute of Technology
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-00621
Paper Title	Validating the Return Level Derived from PET Extremes as a Surrogate Measure of Safety
Abstract	Research on surrogate measures of safety is a promising direction that benefits both practical engineering and theoretical research in road safety area. This study aims at proposing as well as validating the return level derivated from PET extremes as a surrogate measure of safety. The procedures of deducing the return level from exceedance statistics and the generalized Pareto distribution are introduced at first, and then the safety implication of return level derivated from negated PET extremes is preliminarily analyzed. Two case studies are conducted to test the validation of the return level, and one is the case of lane changing events on 29 basic segments of freeways while the other is the case of merging events on eight merging areas of freeways. The validation results show that return levels are strongly correlated with observed crash counts from the points of view of both Pearson's product-moment correlation and Spearman's rank correlation. It is also found that an exponential regression model could be established to convert return levels into crash counts, and this satisfies the convertible condition of a surrogate measure of safety. With regard to these two arguments, it is concluded that the return level proposed in this study is a valid surrogate measure of safety.

Authors	Ahmed Tageldin, University of British Columbia Tarek Sayed, University of British Columbia Khaled Shaaban, Qatar University
Sponsoring Committee	ANF10, Pedestrians
Session Number	806
Session Title	Pedestrian Safety and Behavior
Paper Number	17-00857
Paper Title	Comparison of Time Proximity and Evasive Action Pedestrian Conflict Measures: Case Studies from Five Cities
Abstract	There has been a growing interest in using traffic conflicts for studying safety from a broader perspective than relying only on collision data. The analysis of traffic conflicts is typically performed through the calculation of traditional conflict severity measures such as Time-To-Collision (TTC), Post Encroachment Time (PET), among others. These measures rely on road users getting within specific temporal and spatial proximity from each other and therefore assume that proximity is the surrogate for severity. However, this assumption may not be valid in some driving environments where close interactions between road users are common and sudden evasive actions are frequently used to avoid collisions. Therefore, it is suggested that evasive action-based conflict indicators can assess traffic conflicts in some less organized traffic environments. This paper focuses on the severity evaluation of pedestrian conflicts. The objective of this paper is to compare the use of time proximity and evasive action-based conflict indicators in evaluating the severity of pedestrian conflicts in different traffic environments. Pedestrian evasive actions are mainly reflected in variations of the spatio-temporal gait parameters (e.g., step frequency and step length). Video data from intersections located in five major cities; Shanghai, New Delhi, New York, Doha and Vancouver are used in this study. The video data is analyzed using automated computer vision techniques to extract pedestrian involved conflicts and to calculate various conflict indicators. The results showed that evasive action-based indicators are more effective in identifying and measuring the severity of pedestrian conflicts than time proximity measures in traffic environments such as Shanghai and New Delhi (less organized traffic). However, the evasive action measures did not show the same potential in Vancouver and Doha where time proximity measures were shown to be more effective.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-01540
Paper Title	Evaluation of impacts of different car-following types on rear-end crash risks at freeway weaving sections using vehicle trajectory data
Abstract	The primary objective of this study is to evaluate the impacts of four different car following types on rear-end crash risks at freeway weaving sections using trajectory data. The time-to-collision (TTC) was introduced as the surrogate safety measure to determine the rear-end crash risks. Then, the trajectory data at a freeway weaving section was used for the case-controlled analysis. Three logistic regression models were developed with different TTC thresholds to quantify the impacts of different car following types. The explanatory factors were also analyzed to investigate possible reasons for the results of logistic regressions. Results showed that the rear-end crash risks of Type3 (truck follows car, T-C) was 3.167 times higher than those of Type1 (car follows car, C-C) when TTC threshold is 2 s. While the odds ratios of Type2 (car follows truck, C-T) and Type4 (truck follows truck, T-T) were both smaller than 1, which indicated the safer condition. The analysis of explanatory factors also showed Type3 had the largest speed differences and smallest net gaps. This was consistent with vehicle operation features at a weaving section and was also the reason for the larger rear-end crash risks. The results of this study reflect the mechanism of rear-end crash risks of different car-following types at the freeway weaving section.

Authors	Tarek Sayed, University of British Columbia Martin Fyfe, University of British Columbia
Sponsoring Committee	ANB10, Transportation Safety Management
Session Number	245
Session Title	Transportation Innovations May Improve Safety
Paper Number	17-01651
Paper Title	Safety Evaluation of Connected Vehicles for a Cumulative Travel Time Adaptive Signal Control Microsimulation Using the Surrogate Safety Assessment Model
Abstract	Connected vehicles are on the cutting edge of automotive technology with applications expected to improve mobility and safety. Several studies have evaluated the mobility benefits of connected vehicle technology but there is little research on its impact on safety. The main objective of this study was to investigate the ability to evaluate the safety of a connected vehicle application of a Cumulative Travel Time (CTT) algorithm applied to a signalized intersection by using surrogate safety measures through a combination of the micro-simulation model VISSIM and the Surrogate Safety Assessment Model (SSAM). As well, the study investigates the impacts of calibrating the micro-simulation model using real-world vehicle trajectory and conflict data. The CTT algorithm was applied to a signalized intersection and evaluated under three calibration scenarios: uncalibrated, first step calibrated for desired speed and vehicle arrival types, and second step calibrated for conflicts observed in the field. A comparison of safety based on the number of conflicts at different time-to-collision thresholds is provided for the varying scenarios. Results show that the combination of VISSIM and SSAM provide an appropriate tool to evaluate the safety of a connected vehicle application of a CTT algorithm. Calibrating the micro-simulation model has an impact on the results of the safety evaluation. However, it is inconclusive whether the results are realistic with the lack of a real-world CTT implementation.

Authors	Joshua Stipancic, McGill University Luis Miranda-Moreno, McGill University Nicolas Saunier, Ecole Polytechnique de Montreal
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-01683
Paper Title	The Impact of Congestion and Traffic Flow On Crash Frequency and Severity: An Application of Smartphone-Collected GPS Travel Data
Abstract	Mobility and safety are the two greatest priorities within any transportation system. Ideally, traffic flow enhancement and crash reduction could occur simultaneously, though their relationship is likely complex. The impact of traffic congestion and flow on road safety requires more empirical evidence to determine the direction and magnitude of the relationship. This study is an ideal application for instrumented vehicles and surrogate safety measures (SSMs). The purpose of this paper is to correlate quantitative measures of congestion and flow derived from GPS smartphone data to collision frequency and severity at the network scale. GPS travel data was collected in Quebec City, Canada and the study sample contains over 4000 drivers and 20,000 trips. The extracted SSMs, congestion index (CI), average speed ($\bar{V}$), and coefficient of variation of speed (CVS), were compared to crash data over a five year period from 2006 to 2010 using Spearman's correlation coefficient and pairwise Kolmogorov-Smirnov tests. Correlations with crash frequency were weak to moderate. CI was shown to be positively correlated with crash frequency, and the relationship with crash severity was found to be non-monotonous. Higher congestion levels were related to major injury crashes, while low congestion was related to minor and fatal crashes. Surprisingly, $\bar{V}$ was found to be negatively correlated with crash and had no conclusive statistical relationship with crash frequency. CVS was observed to be positively correlated with crash frequency, and statistically related to increased crash severity. Future work will focus on developing a network screening model that incorporates these SSMs.

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Sponsoring Committee	ANF10, Pedestrians
Session Number	806
Session Title	Pedestrian Safety and Behavior
Paper Number	17-01873
Paper Title	Modeling the Risk Intensity of Crossing Pedestrians in Intersections Based on Selected Critical Time to Collision
Abstract	The collision between a vehicle and a pedestrian usually ends to injury or death of pedestrian. Sometimes pedestrians put themselves in danger by engaging in risky and unsafe behaviors. While crossing the streets, pedestrians may get into collisions by inaccurate judgments about the gap between themselves and an approaching vehicle. The aim of the current study is to investigate and identify factors affecting on pedestrians' risk intensity based on selected critical time to collision. An observational survey of road crossings was conducted at six intersections located in Qazvin city. In both signalized and unsignalized intersections, time to collision of 800 pedestrians were recorded in each crossing lane. Using the cumulative percentage graph of recorded time to collisions, a ranking pattern for pedestrian risk condition has been proposed. Using an Ordered Logit Model, the risk taking behavior of pedestrians has been modeled based on their risk intensity. Results of this study showed that the average time to collision chosen by pedestrians crossing intersections is about 6.2 seconds. Among individuals in the survey, 54% of men and 39% of women had taken risk by accepting TTC less than 3 seconds (critical TTC). It is also indicated that factors such as accompanied pedestrian, dressing type, pedestrian speed, crossing type, speed of approaching vehicles, Curbside Parking have significantly affect pedestrians risk taking behaviors or selecting time to collision. Elasticity analysis showed that the pedestrian speed and time to collision in the second lane are the most effective variables in risk taking of pedestrians.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-01978
Paper Title	Investigating Subsequent Safety Surrogate Measurement Affected by Connected Vehicles Technologies
Abstract	The envisioned Connected Vehicle (CV) safety systems are expected to improve the safety performance of a highway facility via assisting drivers in (re)acting properly under risky traffic conditions. This research aims to disclose and quantify the cause-and-effect mechanism between such a behavior impact of CV and the traffic safety. To this end, a synthetic approach has been adopted to integrate the CV-affected behavior parameters into state-of-the-art traffic flow models. The models are used to reproduce vehicle trajectories under the CV environment. Such a trajectory data is the basis for computing the surrogate safety measurement, which depicts the systematic safety performance of a highway facility. The effectiveness of the CV is revealed in a case study performed at a freeway site in the greater Cincinnati area, Ohio. The case study finds that the CV-affected perception-reaction time, desired headway and desired speed are responsible for the reduction of the traffic conflict frequency and decrease of the conflict intensity. The quantitative contribution of these behavior parameters has also been determined based on statistical analysis. The findings lay out a solid foundation to promote successful deployment of the CV safety technologies into the existing highway transportation systems.

Authors	Yaohua Zhang, University of Connecticut Nalini Ravishanker, University of Connecticut John Ivan, University of Connecticut Sha Mamun, University of Connecticut
Sponsoring Committee	ABJ80, Statistical Methods
Session Number	288
Session Title	Statistical Methods In Transportation
Paper Number	17-02090
Paper Title	Where Can Conflicts Be Surrogates for Crashes? An Investigation Based on a Semi-Parametric Statistical Approach
Abstract	There is growing interest among traffic engineers for using so-called surrogate measures of safetyas an alternative to crash counts, especially in contexts where the temporal and/or spatial crash occurrence rate is extremely low. In order to facilitate this paradigm shift, it is useful to demonstrate significant association between conflicts and crashes, and to study how this association might vary by location. We investigate a semiparametric statistical approach called the tau-path method that enables us to rank locations by decreasing magnitude of the association between crash and conflict counts. We demonstrate the method in the context of pedestrian safety at intersections in central Connecticut with variation in several characteristics including crossing distance, pedestrian signal phasing type, presence or absence of on-street parking and surrounding land use. Locations with high association between conflicts and crashes were more likely to have exclusive pedestrian phasing and on-street parking. Among these locations, those with high conflict and crash counts were more likely to have on-street parking and be in non-residential areas. The tau-path method can be easily applied to other road safety contexts beyond investigating conflict counts as surrogates for crash counts. This approach is also relevant to more general data mining settings where there is a need to identify a subpopulation in which there is a strong association between a pair of variables of interest.

Authors	Yina Wu, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai, University of Central Florida Jaeyoung Lee, University of Central Florida Juneyoung Park, University of Central Florida
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-02271
Paper Title	Rear-End Crash Risk Algorithm Under Fog Conditions Based on Kinematics Analysis
Abstract	This research examines car-following behavior under fog condition. By utilizing both real-time traffic and weather data, a general algorithm about the car-following behavior in fog situation when the front car's brake light comes on is presented in this study. Three different situations are identified and derived based on the relationship between gap, visibility, and speed. For each situation, the minimum comfortable and safe required gaps are computed to determine the comfort deceleration levels of the following car. In order to validate the proposed algorithm, both hypothetical and field data are employed. The result using the hypothetical data indicates that larger minimum comfortable and safe required gaps are needed with higher speed and lower visibility. In addition, based on the proposed algorithm, more dangerous car-following behavior can be observed under fog condition than under clear condition. The result shows that there is higher probability of rear-end crashes under fog conditions.

Authors	Samaneh Khazraeian, Florida International University (FIU) Mohammed Hadi, Florida International University (FIU) Yan Xiao, Florida International University (FIU)
Sponsoring Committee	AHB15, Intelligent Transportation Systems
Session Number	527
Session Title	Advances in Connected Vehicle Systems
Paper Number	17-02775
Paper Title	Assessment of the Benefits of Queue Warning in a Connected Vehicle Environment based on Surrogate Safety Measures
Abstract	Queue warning systems (QWS) have been implemented to increase traffic safety by informing drivers about the queued traffic ahead, so that they can react in a timely manner to the presence of queue. Existing QWS rely on fixed traffic sensors to detect the back of queue. It is expected that if the transmitted messages from the connected vehicles (CV) are utilized for this purpose, the detection can be faster and more accurate. In addition, with connected vehicles, the delivery of the messages can be done using on-board units instead of dynamic message signs (DMS), providing more flexibility on how far upstream of the queue the messages are delivered. This study investigates the accuracy and benefits of the QWS based on connected vehicle data. The study evaluates the safety benefits of the QWS under different market penetrations of CV in future years based on safety surrogate measures estimated using simulation modeling combined with the Surrogate Safety Assessment Model (SSAM) tool. The results from this study indicate that a relatively low market penetration, around 3% to 6%, for the congested freeway examined in this study, is sufficient for accurate and reliable estimation of the queue length. Even at 3% market penetration, the CV-based estimation of back of queue identification is significantly more accurate than that based on detector measurements. It is also found that CV data allows faster detection of the bottleneck and queue formation. Further, it is concluded that the QWS improved the safety condition of the network by reducing the number of rear-end conflicts. The safety impacts become significant when the compliance percentage with the queue warning messages is more than 15%.

Authors	Peibo Zhao, University of Windsor Chris Lee, University of Windsor
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-03212
Paper Title	Analysis and Validation of Surrogate Safety Measures for Rear-End Collision Risk by Types of Lead and Following Vehicles on Freeways
Abstract	As truck volume increases due to a growth in freight travel demand, interactions between cars and trucks become more frequent on roadways. This trend has a negative effect on road safety as the likelihood of collision between cars and trucks is likely to increase. In this regard, this study analyzes rear-end collision risk in car-heavy vehicle mixed traffic flow on a freeway using two surrogate safety measures - time-to-collision (TTC) and post-encroachment-time (PET). The study estimated surrogate safety measures for different types of lead and following vehicles (car or heavy vehicle) using the individual vehicle trajectory data. The vehicle trajectory data were collected from a segment of the US-101 freeway in Los Angeles, U.S.A. It was found that the distributions of TTC and PET were significantly different among different types of lead and following vehicles. Also, the mean values of TTC and PET were longer for heavy vehicles-following-cars than cars-following-cars and cars-following-heavy vehicles. The study also validated TTC using the simulated traffic data for a few minutes before the time of crashes that occurred on a section of the Gardiner Expressway in Toronto, Canada. It was found that TTC reflects higher collision risk in the time intervals closer to the crash time and it reflects higher collision risk for the crash case than the non-crash case. The findings suggest that the difference in rear-end collision risk among different vehicle pair types should be considered in safety assessment of car-heavy vehicle mixed traffic flow.

Authors	Katerina Stylianou, University of Cyprus Loukas Dimitriou, University of Cyprus Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-03330
Paper Title	Investigating Rear-End Collision Potential at Signalized Urban Networks Based on Disaggregated Spatial Sensor Data
Abstract	Rear-end collisions are one of the most frequently occurring crashes. An understanding of the contributing factors and their significant association with rear-end collisions is of practical importance. The objective of this study is to discover the underlying patterns in rear-end collision potentials at a microscopic level in an urban environment. In this study the disaggregated data utilized were obtained by inductive loop detectors in the urban network of Nicosia, Cyprus. A risk index based on stopping distance was derived, which was used to classify rear-end collision potentials by using individual speed and headway. For a more detailed analysis, alternative Multinomial Logit (MNL) Models are developed to identify the significant contributing variables for rear-end collision classes. The proposed rear-end collision potential classification results showed that 70% of the car-following events were considered as potentially unsafe. An explanatory analysis for external contributing factors, was performed and indicated that lane of travel and leading vehicle size are found to have an effect on individual driving characteristics. The MNL estimation results facilitated the thorough investigation of the statistically significant elements that explain rear-end collision classification. Only six models provided statistically significant coefficient of the variables, with a McFadden R2 ranging between 0.17-0.19 indicating an acceptable goodness-of-fit. The results showed the complexity of the contribution of factors on rear-end collision occurrence suggesting that different combinations of external factors influence rear-end collision potential classes, as defined here, in different manners. A more thorough investigation was developed by employing a multi-step hourly model of a selected form which presented similar results as the diurnal one.

Authors	Ali Kassim, Carleton University Karim Ismail, Carleton University Suzanne Woo, City of Ottawa
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-03391
Paper Title	Investigation of the Effect of Super-Sharrows on Cyclist and Vehicle Behavior
Abstract	This study examines the potential effect of special painting of shared lane markings, on a number of operational and safety performance parameters for cyclists and motor vehicles. These performance parameters were used to assess the current as well as post-treatment behavior when cyclists and motor vehicles are in close proximity. The performance parameters are: [i] rate of lane change maneuvers performed by vehicles in the presence as well as absence of cyclists and [ii] lateral spacing between cyclists, vehicles, and curb edge. Video data was collected for a period of 8 hours/day for one weekday and one weekend in both pre- and post-treatment conditions. A total of 2,437 cyclists and 33,205 motor vehicles were observed in both conditions for four different phases. The first phase captures pre-treatment conditions. The subsequent three phases capture the post-treatment conditions at different points in time. This was done to enhance the data sample and capture any time variation of the effect. The average lateral distances between bicycle and curb was 0.59 m and between bicycle and vehicle was found to be 2.07 m for the phase 1. For phase 2 “immediately after the implementation” was found to be 0.62 m and 2.03 m, respectively. For phase 3 “education phase” was found to be 0.64 m and 2.02 m. While, for phase 4 “one year after super-sharrows implemented” was found to be 0.69 m and 2.05 m. There was a statistically significant change in rates of lane-change maneuvers: [i] from right lane to left lane with and without the presence of cyclists and [ii] from left lane to right lane without cyclist presence. There was a statistically significant reduction in the number of cyclists who rode on the sidewalk.

Authors	Eric Gonzales, University of Massachusetts, Amherst
Sponsoring Committee	ANF10, Pedestrians
Session Number	806
Session Title	Pedestrian Safety and Behavior
Paper Number	17-03647
Paper Title	Evaluation of a Pedestrian Safety Outreach Campaign in New Jersey Using Surrogate Safety Measures
Abstract	This paper presents a study to compare the rates of risky pedestrian and driver behaviors before and after two phases the North Jersey Transportation Planning Authority's (NJTPA) state-wide pedestrian safety education and enforcement campaign called Street Smart NJ. The first phase was a four-week pilot program in four Northern New Jersey communities (Newark, Jersey City, Woodbridge, and Hackettstown) during November 2013. The second phase was an additional four-week program in eight Northern New Jersey communities (Elizabeth, Jersey City, Metuchen, Newark, Passaic, Red Bank, Toms River, and Woodbridge). Since crashes rarely occur, the program's effectiveness has been evaluated by observing pedestrian and driver behaviors as surrogate measures of safety. Three types of unsafe behaviors (which by regulation are citable violations) were identified for observation: 1) pedestrians jaywalking and crossing against the signal, 2) failure of turning motorists to yield to pedestrians crossing parallel to their vehicles' approach, and 3) failure of motorists turning right on red or passing stop signs to properly yield to pedestrians. The results show that in most cases, statistically significant reductions in safety proxy measures were observed following the Street Smart NJ campaign, which represents an improvement in safety behavior. Statistically significant improvements in behavior were more consistently observed in more urban communities and at more conventional crossing intersections. This paper presents the data collection and statistical analysis methods, and provides an interpretation of the results.

Authors	Anna Charly, Indian Institute of Technology, Bombay Tom Mathew, Indian Institute of Technology, Bombay
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04012
Paper Title	Estimation of Modified Time to Collision as Surrogate for Mid-block Crashes under Mixed Traffic Conditions
Abstract	Quantification of safety is necessary to assess the crash risk of a road facility and evaluate the effect of implemented accident countermeasures. Traditional safety quantification procedure uses accident data, which in spite of being a direct measure of safety, has limitations such as recording errors, missing data, small sample size and reactive approach. In this context, surrogate safety measures offer flexibility to assess safety as well as evaluate effectiveness of countermeasures. With advancement in micro simulation models these measures can be tested on road in their planning stage and can be implemented in Collision Avoidance Warning Systems in new generation vehicles for driver support. This demands a surrogate measure that has been validated and evaluated on different roads under different conditions to estimate conflicts with minimum error. The present study proposes a methodology to identify possible conflicts using width characteristics of vehicles and estimate an existing surrogate measure-Modified Time to Collision (MTTC)-under mixed traffic conditions with due consideration of all vehicle types and their characteristics. The proposed methodology has been implemented in a real case study using a micro simulation model and has been evaluated against real world accident data. Sensitivity of MTTC threshold is studied to arrive at an appropriate critical threshold. Results indicate a strong temporal and spatial correlation between the estimated conflicts and real accidents for a considerable time of the day. The study considers diverse driver and vehicle characteristics. The limitations of MTTC as a surrogate for mid-block crashes has been studied and discussed.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04116
Paper Title	Safety Assessment of Heterogeneous Traffic at Urban Intersections Using Simulated Conflicts
Abstract	In this paper, an attempt was made to investigate the potential of traffic conflicts, identified from microscopic simulation model as explanatory variables in crash prediction models for intersections having heterogeneous traffic. Such traffic streams are characterized by absence of lane discipline and the presence of non-motorized vehicles. Hence, role of non-motorized traffic in influencing safety at such intersections was also investigated. Simulated conflict based crash prediction models were developed for intersections of Dhaka city, the capital of Bangladesh. Intersections were modeled in a suitably calibrated simulation platform, VISSIM, for 8 hours of peak hour traffic and the resulting trajectory file of every hour analyzed in SSAM to identify the corresponding simulated hourly conflicts. It was found that hourly simulated conflicts had a significant statistical relationship with hourly crash count but the fit of the simulated conflict based crash prediction model was poorer compared to traffic volume based model.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-04210
Paper Title	Comparative Assessment of Safety Indicators for Vehicle Trajectories on the Highway
Abstract	Safety measurement and analysis have been a challenging and well-researched topic in transportation. Surrogate safety indicators have been used as risk measures in simulation models for safety assessment; in control formulations for driver assistance systems; in data analysis for naturalistic driving studies. Even though these surrogate indicators are of functional significance, their validity as a risk measure has been widely challenged, especially in interactions including intelligent vehicles. Hence in this paper we qualitatively and quantitatively compare different relevant safety indicators: iTTC, PET, PICUD, warning Index and Safety field strength. The qualitative analysis obtains theoretical insights and they are then complemented with quantitative evaluation on risk measure using trajectory simulation of typical safety critical scenarios. Our results highlight the limitations of surrogate indicators and advantageous of safety field strength as a risk measure.

Authors	Abhisek Mudgal, Texas A&M Transportation Institute John Hourdos, University of Minnesota, Twin Cities
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	537
Session Title	Crash-Based Research: Wrong-Way Driving, Work Zones, Debris, Taxis, and Other Crash Situations
Paper Number	17-05229
Paper Title	Impact of Variable Speed Limits on Freeway Rear-End Collisions
Abstract	The highest crash area (HCA) is a section of westbound Interstate-94 (I-94) located on the southern edge of Minneapolis, Minnesota where one crash (primarily rear-end) happens every two to three days and near-crashes about four times as many. Crashes are primarily caused by traffic breakdown leading to shock waves that take the upstream drivers by surprise. To absorb the shock waves and thus make the corridor safer, the Minnesota Department of Transportation (MnDOT) installed an advisory Variable Speed Limit (VSL) system on an I-94 corridor between Minneapolis and St. Paul. This paper analyzes the HCA corridor to find if there was any significant change in traffic safety or crashes (primarily rear-end ones) after VSL was activated on September 27, 2012. A before-and-after comparison of crash counts was performed. Traffic speed at the onset of congestion was used as a surrogate measure for smoother traffic conditions that reduce the chance for rear-end crashes. Rear-end crashes or near-crashes (together called incidents) were extracted from video data and those along with loop detector data were used to estimate virtual trajectories of vehicles involves in a crash. The usefulness and timeliness of speed displayed by the VSL signs were analyzed using VSL activation data. While in 2013 traffic became smoother, the incident/crash rate did not decrease significantly. Study of virtual trajectories revealed that only during 32% of the incidents, the drivers received an advisory speed just before the incidents and only about 60% of those cases the displayed speed was useful for avoiding a crash.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-05484
Paper Title	Preliminary Investigation of the Effectiveness of High Visibility Crosswalks on Pedestrian Safety Using Crash Surrogates
Abstract	Using the SHRP2 naturalistic driving study (NDS) data, this paper provides a preliminary evaluation of the effectiveness of high-visibility crosswalks (HVC) in terms of improving pedestrian safety at uncontrolled locations. This is accomplished by analyzing the driving behavior of SHRP2 participants at three uncontrolled locations in the Erie County, New York test site. In this context, crash surrogates (i.e., speed, acceleration, throttle pedal actuation, and brake application) are used, in order to evaluate the participants' driving behavior, primarily on the basis of data before and after the HVC installation. The before/after analysis allows the assessment of HVC effectiveness in terms of driver behavior modification. Mixed logit and random parameters linear regression models are estimated, and panel effects and unobserved heterogeneity are accounted for. A number of factors are explored and controlled for (e.g., vehicle and driver characteristics, roadside environment, weather conditions, etc.), and the preliminary exploratory results show that HVCs have the potential to improve pedestrian safety and positively modify driving behavior.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-05537
Paper Title	Vehicular Safety and Operations Assessment of Reserved Lanes using Microscopic Simulation
Abstract	Evaluation of roadway safety via the analysis of vehicular conflicts using microscopic simulation shows increasing preference among transportation professionals, mostly due to significant advances in computational technology that allows for better efficiency when compared with other safety modeling approaches. In addition, since traffic simulation is intrinsic to the methodology, one may assess various impacts of safety treatments without disrupting vehicle movements and before proceeding with real-world implementations. In this study, a microscopic model, using VISSIM, is developed to reproduce the traffic network of an urban high occupancy vehicle (HOV) arterial in Québec. The model is calibrated to reflect the observed real-world driving behavior. The vehicle conflicts are assessed using the Surrogate Safety Assessment Model (SSAM) developed by FHWA. The experimental results indicate that the existing study area has a significant safety problem, mostly due to high interactions between buses and passenger cars. Alternative geometric and control designs are tested to ameliorate traffic safety. It is shown that the proposed alternative geometric design efficiently eliminates many vehicular traffic conflicts, and also that the alternative traffic control solution significantly reduces the public transit delay while ameliorating traffic safety. It is expected that this methodology can be successfully applied to other similar reserved lanes facilities.

Authors	John Raker, Ohio Northern University Madeleine Hirsch, Texas A&M Transportation Institute Karen Dixon, Texas A&M Transportation Institute Raul Avelar, Texas A&M Transportation Institute
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	590
Session Title	Vulnerable Road Users: Analysis of Pedestrian and Bicycle Crashes
Paper Number	17-06177
Paper Title	Pedestrian and Bicyclist Influence at Stop-Controlled Intersections
Abstract	The purpose of this research was to observe if increased volumes of pedestrians and bicyclists generate more crash conflicts at four-way stop controlled intersections. A crash conflict is defined in this study as "when a pedestrian, bicyclist, or vehicle makes an abrupt stop or swerve in order to avoid a crash." This hypothesis is based around the theory that crash conflicts and crashes have a positive linear correlation, meaning the more crash conflicts that occur, the more crashes there will be. The authors' collected data from nine different sites in two different cites, creating over 20 hours of video footage from which all the necessary variables were found. Along with this data, the team utilized crash data from the years 2011 to 2014. When the observational data was analyzed, the authors noticed a trend in crash conflicts and traffic volume, which resulted in additional analysis on whether or not there is a threshold at which pedestrians and bicyclist activity is no longer correlated with conflicts in an intersection. There is a peak that occurs in a traffic volume of 600-700 vehicles per hour in which conflicts with pedestrians and bicyclists present begin to become less frequent. Although the team was unable to determine the exact threshold in which pedestrians and bicyclists stop being an intrusion to stop controlled intersections, all of the data that was collected leads the team to believe that such a threshold exists in the traffic volume. This finding is based upon statistical analysis of different correlations between crash conflicts and actual crashes, as well as the graphs showing conflicts and their cause and the graphs displaying number of conflicts and traffic volume. This paper concludes with recommendations about how to better manage four-way stop-controlled intersections and improve awareness.

Authors	Mengqiu Ye, Louisiana State University Osama Osman, Louisiana State University Sherif Ishak, Louisiana State University
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-06198
Paper Title	Accounting for Driver Distraction and Socioeconomic Characteristics in a Crash Risk Index: A Naturalistic Driving Study
Abstract	Distracted driving has long been acknowledged as one of the main contributors to crashes in the US. According to past studies, driving behavior proved to be influenced by the socioeconomic characteristics of drivers. However, only few studies attempted to quantify that influence. The study proposed a Crash Risk Index to estimate the crash risk associated with the socioeconomic characteristics of drivers and their tendency to experience distracted driving. The analysis is conducted using data from the SHRP 2 Naturalistic Driving Study (NDS). The proposed Crash Risk Index (CRI) is developed based on a grading system of three measures: the crash risk associated with performing secondary tasks during driving, the effect of socioeconomic attributes (e.g. Age) on the likelihood of engagement in secondary tasks, and the effect of specific categories within each socioeconomic attribute (e.g. Age>60) on the likelihood of engagement in secondary tasks. Logistic Regression analysis was performed on the secondary tasks, socioeconomic attributes, and the specific socioeconomic characteristics. The results identified the significant secondary tasks with high crash risk and the socioeconomic characteristics with significant effect on determining drivers' involvement in secondary tasks among each tested parameter. These results were used to quantify the grading system measures and hence estimate the proposed CRI. This index indicates the crash risk associated with a driver given specific socioeconomic characteristics and considering the possible secondary tasks this driver's socioeconomic category may engage in. The proposed CRI and the associated grading system are plausible methods for estimating auto insurance premiums.

Authors	Indrajit Ghosh, Indian Institute of Technology, Roorkee Madhumita Paul, Indian Institute of Technology, Roorkee
Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-06588
Paper Title	Development of New Speed-Related Proximal Indicator for Safety Assessment at Uncontrolled Intersections
Abstract	Traffic conflict analysis has been traditionally performed using Post Encroachment Time (PET) and based on its predetermined threshold critical conflicts are identified. Identification of critical conflicts based on a time-based threshold could be misleading because drivers in a traffic stream do not always follow the posted speed limit. Moreover, PET alone can assess the probability of collision. This study is focused on proposing a new methodology to identify the critical conflicts in terms of severity. A new proximal safety indicator has been developed by incorporating conflicting speed of through moving vehicles alongside PET. Four uncontrolled intersections have been selected from the NCR of India. A speed parameter termed as critical speed is introduced to identify the critical conflicts in terms of severity of resulting collision. It is calculated based on the concept of braking distance. In general, more critical conflicts are observed when the conflicting speed of through vehicles is high. For all the vehicle categories on two cross roads, the maximum proportion of critical conflicts is observed between right turning HV and through moving 2W along the major road. The conflicting speed of through moving 2W is also observed to be the highest among all vehicle categories. Safety evaluation of such uncontrolled intersections can be carried out using the proposed indicator. It is suggested to verify the appropriateness of the proposed methodology using the crash data available for the study sites.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-06687
Paper Title	Developing Safety Heatmap of Uncontrolled Intersections Using Both Conflict Probability and Severity
Abstract	This paper presents a method to assess the safety of uncontrolled intersections considering two major properties of traffic conflicts: conflict probability and severity. This method assesses both the safety level of the entire intersection and also the distribution of safety within it. Intersections are modeled by a two-dimensional Cartesian coordinate system and the internal space of intersections is divided into cells. First, vehicle movement characteristics of an uncontrolled intersection are modeled. Second, conflict probability of each cell within the intersection is estimated considering approaching probability and lateral migration probability of vehicles. The quantification of conflict severity is based on kinetic energy loss of potential crashes. Grey cluster analysis is used to combine conflict probability and severity to model the safety assessment of each cell. Third, the application of the method is discussed, and an overall safety index of intersections is proposed considering weighted safety level and relative value of areas of different safety levels. Finally, a case study, which includes three different designs, is presented along with safety heatmaps to demonstrate the results. The results not only demonstrate the validity of the model, but also indicate that the proposed method can be applied to: i) safety evaluation of build-up intersections; ii) dangerous position management within an intersection; iii) safety assessment of designed intersections, and iv) safety level comparison among different intersections or various designs for a single intersection. Using this method, engineers and planners can better evaluate and improve the safety of existing or future uncontrolled intersections.

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Sponsoring Committee	ANB20, Standing Committee on Safety Data, Analysis and Evaluation
Session Number	589
Session Title	It's All About Relationships: Understanding Conflicts and Surrogates for Highway Safety Analysis
Paper Number	17-06897
Paper Title	Estimation of Crossing Conflict at Signalized Intersection Using High-Resolution Traffic Data
Abstract	This paper aims to explore the possibility of using high-resolution traffic signal data to evaluate intersection safety. Traditional methods using historical crash data collected from infrequently and randomly occurred vehicle collisions cannot provide an accurate and timely evaluation of intersection safety. By contrast, the proposed method estimates potential traffic conflicts using high-resolution traffic signal data collected from the SMART-Signal system, which has been deployed at over 100 intersections in the Twin Cities area. The potential conflicts estimated in this research include both red-light running events, when stop-bar detectors are available and crossing (i.e. right-angle) conflicts. Using the estimated traffic conflicts and the field collected crash occurrence data, a crash prediction model will be built and calibrated. The proposed work will provide a low-cost and easy-to-use toolbox for traffic engineers to evaluate traffic safety performance at signalized intersections, without relying on vehicle crash event data, which usually have a long data collection period.

8 Transportation Safety Management

Frank Gross, VHB

Thirty-nine papers describing different aspects of transportation safety management will be presented at the 2017 TRB Annual Meeting, which are briefly discussed below.

A single paper by Munnich (17-02042) discusses **roadway safety policy and leadership**.

Seven papers discuss **system planning**. Poppe (17-02245) explores the use of CMF-corrected crash prediction models to identify sites with promise. Cai et al. (17-01200) performed a comparative analysis of zonal systems for macro-level crash modeling. Ambros et al. (17-01987) describes a method and two case studies to simplify road network safety screening. Ambros et al. (17-01991) explore an alternative approach to the iRAP star rating. Fawcett et al. (17-04196) employ the Full Bayes approach to road safety hotspot identification. Farhan (17-04598) uses a sketch planning approach to highway safety manual based crash prediction methods. Islam et al. (17-06667) describe a performance-based approach to transportation safety planning.

Several papers discuss the development, implementation, and evaluation of **data-driven safety plans and programs**. Ambros et al. (17-01992) describe an approach to improving safety through self-explaining roads. Chen et al. (17-05511) developed a web-based tool to track highway safety planning progress in California. Tsyganov and Read (17-00833) discuss a systemic safety analysis of extended highway corridors. Chen (17-01087) presents a novel approach to monitoring road safety development at the regional level. Mineer et al. (17-01642) describe the application of the Roadway Safety Analysis Methodology (RSAM) in Utah. Richer et al. (17-06147) present a technical analysis of Vision Zero in Los Angeles, California. Shaw et al. (17-06706) describe the use of Strategic Highway Safety Planning, Vision Zero, and the Safe System Approach in Wisconsin and Victoria, Australia.

Three papers address **data collection and management issues** related to effective safety management and data-driven decision-making. Ulak et al. (17-05135) conducted a GIS-based spatial and statistical analysis of severe crash hotspot accessibility to hospitals. Anderson et al. (17-00466) present the findings from a coordinated multiagency fatal crash review. Gan et al. (17-01430) describe a prototype system for collecting safety data from police crash reports.

Two papers describe opportunities to employ advanced tools in **countermeasure selection**. Yang et al. (17-00869) employ a multiobjective evaluation approach to countermeasure selection, considering operations, safety, and environmental factors. Black et al. (17-06325) discuss Vision Zero as it relates to evaluating potential engineering solutions.

Several papers explored the **safety effects of factors such as operations, environment, economics, and development**. Cui and Levinson (17-01070) analyzed the effects of crash costs on route choice and accessibility. Goodall (17-06790) studied the probability of secondary crash occurrence on freeways using private-sector speed data. Cafiso et al. (17-01563) performed a safety assessment of an ITS application for providing travel time information. Wang et al. (17-00248) studied the implementation of active traffic management strategies for safety of a congested expressway weaving segment. Ko et al. (17-01381) conducted a comparative analysis of fatal crashes in Texas and

California, identifying implications for traffic safety improvement. Dadashova et al. (17-02571) evaluate the potential impact of decreasing commercial motor vehicle volume on roadway safety. Chambers et al. (17-05118) conduct an empirical before-after evaluation of a variable speed limit system. Kocatepe et al. (17-06321) relate socioeconomic characteristics and crash proneness through a case study in Florida.

Two papers discussed specific **driver behavior issues**. Al-Taweel et al. (17-04306) study the relationship between crash severity, change in velocity, and driver's reaction. Penmetsa et al. (17-04950) explore risk perceptions of drivers and how it changes with crash history or prior convictions.

One paper discussed the broader area of **traffic safety culture**. Islam et al. (17-04744) measure and explore the effect of respondents' socio-demographic characteristics on traffic safety culture.

Connected and automated vehicles (C/AV) and other technologies have a promising future in improving traffic safety, including mitigating crash severity and decreasing the possibility of crashes by offering warnings to drivers and/or assuming vehicle control in dangerous situations. A paper by Sayed and Fyfe (17-01651) presents a safety evaluation of connected vehicles for a cumulative travel time adaptive signal control microsimulation. Liu et al. (17-03107) explain the use of unmanned aerial vehicle and imaging systems for accident scene reconstruction.

Four papers focus on **school transportation safety** (17-01245; 17-01759; 17-04672; 17-05398). These papers deal with issues related to: connected vehicle systems, bicycling to school, changes in trips over time, and the relationship between speed and safety in school zones.

Two papers focus on **Emergency Medical Service (EMS)** (Kumar et al., 17-01660; Hu et al., 17-05293). These papers deal with issues related to access to trauma centers as well as trends in EMS response time, treatment, and transport.

Authors	Ling Wang, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida
Sponsoring Committee	ANB10
Session Number	245
Session Title	Transportation Innovations May Improve Safety
Paper Number	17-00248
Paper Title	Implementation of Active Traffic Management Strategies for Safety of a Congested Expressway Weaving Segment
Abstract	In weaving segments, traffic merges, diverges, and weaves in a limited space. These traffic maneuvers might result in a high crash hazard. In order to improve the safety of a congested weaving segment, various Active Traffic Management (ATM) strategies were tested in microsimulation. The strategies included ramp metering (RM), variable speed limit (VSL), and an integrated RM and VSL (RM-VSL). Overall, the results showed that the ATM strategies were able to improve the safety of the studied weaving segment. The modified ALINEA RM algorithms, which took both lane occupancy and safety into consideration, outperformed the traditional ALINEA algorithm from a safety point of view. The 45 mph VSLs, which were located at the upstream of the studied weaving segment, significantly enhanced the safety without notably increasing the average travel time. In order to reduce the average travel time of the modified ALINEA RM and maintain its impact on safety, the modified ALINEA RM was adjusted according to queue length and was integrated with the 45 mph VSL strategy. The results proved that the consolidated RM-VSL strategy yields slightly better safety, but provides much lower average travel times than the modified ALINEA without queue control.

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Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-00466
Paper Title	Findings from Coordinated Multiagency Fatal Crash Review
Abstract	North Carolina traffic safety leaders have embraced a multi-agency, collaborative review of all fatal collisions in the state. Survey responses from the North Carolina State Highway Patrol demonstrate that quarterly Fatal Crash Reviews conducted in every troop across the state have substantially improved the crash investigation process following a deadly collision. The formal review process has transformed crash investigation in North Carolina by facilitating collaboration and accountability between agencies and troopers, setting higher expectations for quality data and investigation, augmenting data-driven enforcement planning, and shifting the overall organizational culture of the NCSHP. The investigative insights from the fatal reviews have influenced legislative action in the North Carolina General Assembly.

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Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-00869
Paper Title	Multiobjective Evaluation in Countermeasure Selection at Two-Way Stop-Controlled Intersections Considering Traffic Operation, Safety, and Environment
Abstract	This study aims to develop a procedure to conduct multi-objective evaluation in traffic countermeasure (CM) selection process at two-way stop-controlled (TWSC) intersections. To illustrate the procedure, the economic benefits of three vehicle safety related CMs were calculated considering not only the safety impacts but also the operational and environmental impacts. First, for each countermeasure, VISSIM simulation models were developed to obtain the average delay, vehicle emission and fuel consumption for the intersection both before and after the treatment. The traffic operational impacts were calculated as the change in delay costs. The environmental impacts were calculated as the change in vehicle emission and fuel consumption costs. Next, the safety impacts were calculated as the crash reduction benefits for different CMs using safety performance functions (SPFs) and crash modification factors (CMFs). Finally, the life cycle cost (LCC) method was used to combine the different components in the total benefit. The Monte Carlo (MC) simulation method was used to conduct uncertainty analysis by using random sampling from probability descriptions of uncertain input variables to generate a probabilistic description of results. The findings showed first, that the operational and environmental impacts accounted for a large proportion of the total impacts, which can significantly affect the selection of CMs. Second, the rankings of the CMs differ depending on whether the safety impacts alone are considered, or whether the safety, operational and environmental impacts are considered together. The study illustrates the detailed process of evaluating projects considering multiple objectives. This process offers policy and decision makers a solid and practical reference of how to conduct multi-objective evaluation. The findings also explain how different objectives can countervail with each other in improving motorist safety at TWSC intersections.

Authors	Mengying Cui, University of Minnesota, Twin Cities David Levinson, University of Minnesota, Twin Cities
Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-01070
Paper Title	The Safest Path: Analyzing the Effects of Crash Costs on Route Choice and Accessibility
Abstract	The "safest path" is proposed to optimize the on-road safety of individuals and minimize the cost of crashes. In this study, the framework of a link-based crash cost analysis is built and applied to assess the crash cost of each link segment on the road network of the Minneapolis - St. Paul area based on Safety Performance Functions from the perspective of travelers. The safest path is then found for all OD pairs to compare flow patterns and accessibility distributions with those based on the traditional shortest travel time path. While, the safest path does not coincide with the shortest path, the accessibility distributions have similar patterns.

Authors	Salvatore Damiano Cafiso, University of Catania Carmelo D'Agostino, University of Catania Mariusz Kiec, Cracow University of Technology Sylwia Pogodzinska, Cracow University of Technology
Sponsoring Committee	ANB10
Session Number	245
Session Title	Transportation Innovations May Improve Safety
Paper Number	17-01563
Paper Title	Safety Assessment and Management of ITS Application in Travel Time Information System
Abstract	The present research work reports an evaluation of road safety on the road sections included in the Intelligent Traffic Control System of the Podhale Region (ISSRRP) in Poland. This Travel Time Information System consists of Remote Traffic Microwave Sensor, cameras, Automatic Number Plate Recognition located in the National roads with Variable Message Sign (VMS) and mobile app to suggest alternative routes in the Regional road network. The target of paper is to analyze the changes in safety due to driver distraction and behavior in the National road sections and to check the overall safety performance of the network including also the links of regional roads where traffic is moved. The assessment of road safety considering the before and after period of 3 years, was performed by using the empirical Bayes analysis and a safety management approach was proposed taking into account Safety Performance Functions (SPFs). Results, pointed out no changes in the safety performance of National road network after the introduction of ISSRRP, but a potential negative impact of the system on the overall safety performance of the National and Regional network if a proactive safety management is not applied.

Authors	Tarek Sayed, University of British Columbia Martin Fyfe, University of British Columbia
Sponsoring Committee	ANB10
Session Number	245
Session Title	Transportation Innovations May Improve Safety
Paper Number	17-01651
Paper Title	Safety Evaluation of Connected Vehicles for a Cumulative Travel Time Adaptive Signal Control Microsimulation Using the Surrogate Safety Assessment Model
Abstract	Connected vehicles are on the cutting edge of automotive technology with applications expected to improve mobility and safety. Several studies have evaluated the mobility benefits of connected vehicle technology but there is little research on its impact on safety. The main objective of this study was to investigate the ability to evaluate the safety of a connected vehicle application of a Cumulative Travel Time (CTT) algorithm applied to a signalized intersection by using surrogate safety measures through a combination of the micro-simulation model VISSIM and the Surrogate Safety Assessment Model (SSAM). As well, the study investigates the impacts of calibrating the micro-simulation model using real-world vehicle trajectory and conflict data. The CTT algorithm was applied to a signalized intersection and evaluated under three calibration scenarios: uncalibrated, first step calibrated for desired speed and vehicle arrival types, and second step calibrated for conflicts observed in the field. A comparison of safety based on the number of conflicts at different time-to-collision thresholds is provided for the varying scenarios. Results show that the combination of VISSIM and SSAM provide an appropriate tool to evaluate the safety of a connected vehicle application of a CTT algorithm. Calibrating the micro-simulation model has an impact on the results of the safety evaluation. However, it is inconclusive whether the results are realistic with the lack of a real-world CTT implementation.

Authors	Calvin Thigpen, University of California, Davis Rachel Hartsough, City of Davis, California
Sponsoring Committee	ANB10
Session Number	329
Session Title	School Transportation Research
Paper Number	17-01759
Paper Title	Barcodes, Virtual Money, and Golden Wheels: How Schools in Davis, California, Encourage Bicycling to School
Abstract	While most of the literature on children bicycling to school focuses on the influence of infrastructure interventions, relatively few studies have robustly evaluated the influence of encouragement efforts. We analyze bicycle rack count data collected in the city of Davis, CA, where the city and local volunteers have recently undertaken three encouragement efforts: the Active4.me scanning program, the Monkey Money incentive system, and the national Bike-to-School Day celebration. After accounting for the schools' physical environment and characteristics, as well as the influence of weather and the natural environment, we find that all three of the encouragement efforts increase levels of bicycling to school. We conclude by suggesting that these encouragement programs have the potential for lasting influence by providing children with the skills and confidence to bicycle now and later in life and note the potential for further state support for the parent volunteers who operate these encouragement programs.

Authors	Jiri Ambros, Transport Research Centre (CDV), Czech Republic Veronika Valentová, Ondrej Gogolin, Transport Research Centre (CDV), Czech Republic Richard Andrasik, Transport Research Centre (CDV), Czech Republic Jan Kubecek, Transport Research Centre (CDV), Czech Republic Michal Bíl, Transport Research Centre (CDV), Czech Republic
Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-01992
Paper Title	Improving the Self-explaining Performance of Czech National Roads
Abstract	Improving the road network according to principles of self-explaining roads is a promising way of increasing level of safety; however there are no universal guidelines on how to measure and improve the self-explaining performance of existing roads. In order to apply this approach on Czech national roads, a presented study was conducted, consisting of five steps: (1) automated segmentation into tangents and horizontal curves; (2) collection of floating car data and calculation of speed; (3) development of multivariate speed models for estimation of speed also on segments not covered by floating car data; (4) network-wide application of the models and evaluation of speed consistency, i.e. differences of speed on tangents and following curves; (5) identification of substandard curves, categorization and proposal of optimization in terms of consistent placement of traffic control devices or reconstructions. The paper describes all the steps, as well as several checks conducted along the way, such as comparison of profile speed and floating car speed, interpretation of regression models or validation of predicted speed consistency against long-term average of crash frequency. The methodology was certified for practical use and will be applied by Czech national road agency.

Authors	Mark Poppe, Arizona Department of Transportation
Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-02245
Paper Title	Observations on the Use of CMF-corrected Crash Prediction Models to Identify Sites with Promise
Abstract	The Highway Safety Manual (HSM) provides guidance on the application of crash prediction models for: network screening, evaluation of alternative designs, and evaluation of implemented safety improvements. A variety of models are available. They may be classified as network screening level (or simple models), project level (or CMF-corrected models), and evaluation level models. Identifying sites with promise using crash prediction models is often based on assessing the difference between the expected number of crashes (Ne) at a site and the predicted number of crashes (Np) for similar sites within the population. A large difference between Ne and Np may denote a safety problem and be used to identify and rank sites with promise. The HSM indicates that CMF-corrected models may be used for network screening purposes. However, issues arise in the analysis regarding the definition of "similar sites." When using CMF-corrected models, the definition of "similar sites" changes with changes in the CMF adjustments particular to each site. Use of (N e – Np) for identifying and ranking sites with promise does not work well when using a CMF-corrected estimate of Np . A large composite CMF will increase Np and thereby decrease the value (Ne – N p). But a large composite CMF may point to a site with promise. This paper examines this phenomenon in detail, reviews a case study, and suggests that simple models may be preferable for identifying sites with promise.

Authors	Alexei Tsyganov, Virginia Department of Transportation Stephen Read, Virginia Department of Transportation
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-00833
Paper Title	Systemic Safety Analysis of Extended Highway Corridors
Abstract	The present paper discusses the Virginia Department of Transportation (VDOT) approach for systemic safety assessment of extended highway corridors. This procedure, named "Corridor Safety Assessment (CSA)," was developed to assist the Highway Safety Improvement Program (HSIP) in identifying appropriate systemic safety treatments and promote a mobile evaluation methodology that maximizes the safety of the field review team and the amount of roadway covered. The CSA process utilizes a joint analysis of crash statistics, roadway features, and findings of experts' field observations which maximizes validity of safety assessment and recommendations. The method includes a detailed procedure for complex safety assessment of the travel environment, considering impacts of the roadway, roadside, and traffic control features. This approach provides data for selection of applicable safety improvement countermeasures including both long-term high-cost, as well as immediate low-cost treatments. Analysis of the variety of risk factors also allows to select effective systemic improvement strategies. Formalizing the use of video and GPS logging provided an efficient way to collect information. To ensure linear references for data obtained from video records and the GPS data, a special technique to tie video frames and highway mileage was developed. Additionally, linear references of the obtained findings permit planning and programming level cost estimates of the recommended safety improvements.

Authors	Faan Chen, Tongji University
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01087
Paper Title	Monitoring Road Safety Development at Regional Level: A Novel Approach Integrating Weighting, Aggregating, and Grouping
Abstract	Persistent monitoring of progress made, evaluating the results of interventions and recalibrating to achieve continuous improvement over time is widely recognized as an indispensable part towards the successful development of road safety. In doing so, a systematic and more importantly easy to use/adapt monitoring framework is urgently needed; especially in the context of the ASEAN where there is a lack of well-resourced teams, with multidisciplinary safety professionals and specialists in individual countries who are able to carry out this work effectively. This paper developed an easy to reproduce monitoring framework based on a updated and refined Road Safety Development Index, by means of a novel approach, RSR (Rank-sum ratio)-based model, for monitoring/reporting road safety developments at regional level. For case study, the road safety achievements in eleven Southeast Asian countries are reported. The countries are finally grouped into several classes based on an overview of their progress and achievements regarding to road safety. The results allow the policymakers to better understand their own road safety progress toward the desired impact; more importantly, so that necessary interventions can be made and quick remedial action can be taken, to keep the action plans on schedule if things are not progressing as desired. This would avoid reinventing the wheel and trial and error approaches to road safety, making the implementation of action plans more effective. The comparison and analysis of the results verify the robustness of the proposed model, and imply the feasibility of using this approach as a valuable tool for monitoring the road safety developments of countries, or of sub-national jurisdictions by policymakers, decision makers and practitioners.

Authors	Qing Cai, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01200
Paper Title	Comparative Analysis of Zonal Systems for Macro-level Crash Modeling: Census Tracts, Traffic Analysis Zones, and Traffic Analysis Districts
Abstract	Macro-level traffic safety analysis has been undertaken at different spatial configurations. However, clear guidelines for the appropriate zonal system selection for safety analysis are unavailable. In this study, a comparative analysis was conducted to determine the optimal zonal system for macroscopic crash modeling considering census tracts (CTs), state-wide traffic analysis zones (STAZs), and a newly developed traffic-related zone system labeled traffic analysis districts (TADs). Poisson lognormal models for three crash types (i.e., total, severe, and non-motorized mode crashes) are developed based on the three zonal systems without and with consideration of spatial autocorrelation. The study proposes a method to compare the modeling performance of the three types of geographic units at different spatial configuration through a grid based framework. Specifically, the study region is partitioned to grids of various sizes and the model prediction accuracy of the various macro models is considered within these grids of various sizes. These model comparison results for all crash types indicated that the models based on TADs consistently offer a better performance compared to the others. Further, the models considering spatial autocorrelation outperform the ones that do not consider it.

Authors	Kelly Palframan, Focus Forensics Bryan Katz, Toxcel, LLC
Sponsoring Committee	ANB10
Session Number	329
Session Title	School Transportation Research
Paper Number	17-01245
Paper Title	Multistage Approach for Integrating Enhanced School Bus Warnings into Connected Vehicle Systems
Abstract	The concept of connected vehicles is becoming more of a reality as researchers and software developers put more effort into developing and testing the hardware and software that the DSRC network will use to communicate between road users. As that progresses, researchers have begun to expand the variety of applications in which the system supports. This paper explores a multi-stage approach for implementing an application that focuses on improving safety around school buses and school bus stops in the near-term, intermediate-term, and long-term stages. The paper details the mechanisms of how three different notification types could be implemented over time: 1) warning approaching vehicles that students are waiting at a school bus stop ahead, 2) warning approaching vehicles that there is a stopped school bus ahead and out of their sightline, and 3) alerting emergency service providers that a school bus has experienced an emergency situation. As the connected vehicle system develops over time and expands through the stages of primarily vehicle-to-infrastructure communication (near-term), to vehicle-to-vehicle communication (intermediate-term), and ultimately to autonomous driving (long-term), the data needs and methods of communication will need to adapt to each stage's unique demands and capabilities. Through the lens of a school bus related application, this paper provides the foundation for navigating these transitional stages and making the most of the technology as it becomes available.

Authors	Myunghoon Ko, Texas A&M Transportation Institute Lingtao Wu, Texas A&M Transportation Institute Troy Walden, Texas A&M Transportation Institute
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01381
Paper Title	Comparative Analysis of Fatal Crashes in Texas Versus California and Implications for Traffic Safety Improvement
Abstract	Texas and California are the top two states in traffic fatal crashes and fatalities in the United States. In 2014, Texas recorded 464 more deaths than California. The numbers of fatalities in Texas relative to California are the greatest since Fatality Analysis Reporting System (FARS) provided collecting fatal crash data in 1994. Historically, Texas had experienced fewer fatalities than California until 2007. Since that time, Texas has surpassed California in the recorded number of traffic fatalities, and the difference between the states has been continuously growing. The primary goal of the study is to identify systemic and environmental factors that might have influenced the changes in traffic safety of California and Texas. Fatalities at both states significantly decreased in 2008 to 2010 and then rebounded. One of distinctive changes in transportation before and after the 2008 financial crisis was that more people used public transportation modes instead of privately-owned cars. This change partially contributed to lower fatal crashes and fatalities at both states, especially at California. Texas had fewer fatalities during the morning and afternoon commuting hours until 2007. In 2014, however, there were 130 more deaths in Texas than California during the hours. Since 2008, oil prices significantly increased and remained high. It resulted in the energy industry boom conditions, especially at Texas. Consequently, fatalities in the large truck involved crashes in Texas significantly increased. For fatal crashes related to strict traffic laws (e.g., universal helmet, cellphone ban) and proactive traffic enforcement (e.g., sobriety checkpoint, red light running and speed cameras), California has fewer fatalities at the crashes due to traffic violations. In addition, the probability of a traffic law violation being encountered by an officer in California was significantly higher than that of one being encountered in Texas. Finally, the results on systemic and environmental factors to the changes of traffic fatalities provide an important information to improve statewide management of traffic safety, countermeasures, programs and policy development not only in Texas and California, but also other states in the United States.

Authors	Albert Gan, Florida International University (FIU) Priyanka Alluri, Florida International University (FIU) Haifeng Wang, Florida International University (FIU)
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01430
Paper Title	A Prototype System for Collection of Safety Data from Police Crash Reports
Abstract	Police crash reports include useful additional information that is not available in crash summary records. This information may include police sketches and narratives and is often needed for detailed site-specific safety analysis. In addition, some agencies also routinely review police reports to correct miscoded and missing crash types. As a result, safety analysts often spend much of their time to review police reports on a regular basis. However, reviewing police crash reports and recording review information in Florida has not been an easy process. This paper introduces a newly developed web-based system designed for the Florida Department of Transportation (FDOT) to facilitate the process of reviewing police crash reports and recording review results. The system allows projects to be set up for specific study locations and target review questions. The review questions can be set up for different data entry formats, including dropdown list, checkbox, radio button, single and comment box. A user-friendly interface is provided to allow the users to review the police reports specified in a project and to save the review results together with their respective crash records in the database. The results can then be downloaded to a local drive for further safety analysis. The system reduces the police report review processing time by multiple folds and helps cut down on the project backlogs at FDOT safety offices. The system can serve as a prototype and be adapted for other transportation agencies to facilitate their review of police crash reports and collection of safety data.

Authors	Samuel Mineer, Grant Schultz, Brigham Young University Mitsuru Saito, Brigham Young University
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01642
Paper Title	Application of the Roadway Safety Analysis Methodology in Utah
Abstract	The Utah Department of Transportation (UDOT) continues to advance the safety of the state roadway network through their participation and endorsement of the “Zero Fatalities: A Goal We Can All Live With™” campaign to increase awareness of the importance of highway safety. As a continuing effort by UDOT to advance the safety of their roadway network, a research team from Brigham Young University (BYU) conducted research to apply and automate recently completed safety analysis tools in the state. This effort resulted in the creation of the Roadway Safety Analysis Methodology (RSAM), developed to apply and automate the work accomplished in recently completed highway safety research in Utah. The purpose of this paper is to report the results of applying the RSAM in Utah. The RSAM allows for an evaluation of highway safety in a statewide network, prioritizing the roadways experiencing more crashes than what would be expected. Utilizing the automation tools and graphical user interfaces (GUIs) in the RSAM, statistical models are utilized that allow users to evaluate the safety issues of roadways within their jurisdiction. By using the RSAM, UDOT Safety Programs engineers, Region directors, and other interested users have access to tools that will allow them to make informed decisions related to prioritizing highway safety projects and programs within the state of Utah. As the RSAM continues to develop and to be refined, other states can apply the methodology and statistically based tools to their jurisdictions and improve their decision making tools related to safety on their highways.

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Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01660
Paper Title	Trend Analyses of Emergency Medical Services for Motor Vehicle Crashes: Michigan Case Study
Abstract	Timely response of an EMS personnel at a crash site may help prevent loss of a life and thereby impact the quality of life for an individual at risk. With that said, availability and access to quantitative data involved in the EMS activities becomes critical. This study was conducted to review the EMS data collected by The Michigan Department of Community Health (MDCH), Emergency Medical Services (EMS) Section from a 5-year period starting 2010. The specific intent was to identify current EMS response, treatment, and transport trends. Among the results noted in this paper, it was identified that on average, total time involved from the dispatch call to the drop off of a patient from a motor vehicle crash in the state of Michigan were 56.99 minutes and 42.97 minutes for rural and urban areas, respectively. The results from this study could be utilized to guide and direct future EMS initiatives relating to motor vehicle crashes. The analysis might also be beneficial in predicting the types of injuries that occur in specific types of vehicle crashes. Several challenges and recommendations are also provided in this paper.

Authors	Jiri Ambros, Transport Research Centre (CDV), Czech Republic Jiri Sedonik, Transport Research Centre (CDV), Czech Republic Zuzana Krivankova, Transport Research Centre (CDV), Czech Republic
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01987
Paper Title	How to Simplify Road Network Safety Screening: Two Case Studies
Abstract	Network screening is the first step of rational road safety management; according to state-of-the-art it utilizes crash prediction models or safety performance functions. However their development is demanding, since they require knowledge of traffic volume data for all evaluated segments and intersections. In addition the whole screening process, as well as tits output, is separated into segments and intersections, which may not be the most practical from the perspective of road agency as the end user. In this regards using number of intersection per segment length is a potential simplification, which allows omitting separate modeling for intersections; however its performance has been tested rarely. The aim of the paper is to follow the original UK application of the concept, while extending it not only geographically, but also in various road conditions (regional and national road network samples) and adding assessment of method consistency, which is important for quality of network screening. The method was found feasible: predictions from simplified model were closely correlated with predictions, based on combination of segment and intersection models; and consistency, in terms of overlap between two rankings of final segment lists, was also satisfactory. The simplified approach may thus increase efficiency of network screening and enable wider practical application for Czech regional agencies.

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Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-01991
Paper Title	Exploring Alternative Approach to iRAP Star Rating Validation
Abstract	Star Rating protocol, applied by International Road Assessment Program (iRAP), awards 1 to 5 stars depending on the level of safety which is 'built-in' to the road. Although this procedure is known and used world-wide, there have been only few validation studies, showing the relationship between Star Ratings and crashes. In addition, the past studies relied on crash rates or crash costs per kilometer, derived from Police-reported data only; this approach is not the best, since it incorrectly assumes a linear relationship between crash frequency and the measure of exposure, and does not control for confounding effect of regression to the mean. Objective of the paper objective is to fill the gap and conduct validation study using state-of-the-art empirical Bayes approach, combining observed crash frequency with expected crash frequency based on crash prediction model. For the purpose of this exploratory study Star Ratings from Hungarian rural road network were used. The proposed approach proved to be feasible, with results confirming the relationship between increasing Star Ratings and decreasing crash frequencies. The described design should be followed by further and improved validation studies.

Authors	Lee Munnich, University of Minnesota, Twin Cities
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-02042
Paper Title	Roadway Safety Policy and Leadership: A Case Study of Six Midwest States
Abstract	This study examined various factors determining policy and political leadership in adopting evidence-based policy countermeasures and integrated performance-based approaches such as Towards Zero Deaths (TZD) to reduce road fatalities and serious injuries. Specifically, it sought to increase understanding of the policy context for safety and engage policy and political leaders and institutions at the state and local level in applying these approaches. The study focused on six states in the Midwest region – Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin – and engaged legislators and policy safety policy leaders to better understand the challenges and opportunities for improving roadway safety through public policy. In comparing the extent of policy adoption and political leadership from one state to another, the study developed, applied, and tested an assessment tool of TZD and roadway safety programs for each of the six states under review.

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Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-02571
Paper Title	Evaluation of Potential Impact of Decreasing Commercial Motor Vehicle Volume on Roadway Safety in Spain
Abstract	Spain's Ministry of Transportation (MFOM) envisions to increase the railway share of goods transportation from 4.1% to 8-10% by 2020 in order to improve the roadway safety as well as decrease greenhouse emissions. This in turn implies that the volume of commercial motor vehicle (CMV) will potentially decrease. This paper was developed with the purpose of evaluating the impact of this potential decrease in CMV miles on road safety. For this purpose, the research team studied the data collected (2010) from two major freight corridors in Spain: Almería (south-east) -Barcelona (north-east) and Madrid (center) - Irún in the Vasque Country (north). To carry out the empirical study, the factors affecting the prediction of the road safety indicator were identified through negative binomial regression models. In order to estimate the effect of the CMV removal from the traffic flow, simulation scenarios with new traffic volume data were generated, assuming that CMV traffic decreases of 5%, 10% and 15%. We also considered the potential changes in the remaining traffic volume after the CMV volume decrease. It is assumed that the remaining traffic will either remain the same or increase due to induced traffic (i.e. rebalance of transportation supply and demand, or the attraction of more users to the roads because of reduced CMV traffic). New crash data was simulated using the potential scenarios where the CMV and remaining traffic volume change their values. Comparing the results of the simulated and observed crash data the authors observed that decreasing CMV volume may have both positive and negative impact on road safety. The direction of this impact is site-specific and significantly depends on the facility type. The research team also observed that the effect of the induced traffic is another important factor that should be taken into account when decreasing the truck volume.

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Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-03107
Paper Title	Use of Unmanned Aerial Vehicle and Imaging System for Accident Scene Reconstruction
Abstract	Accident scene reconstruction can provide detailed and accurate information for accident analysis to improve traffic safety, the current methods of investigating accident (e.g. total station and laser scanning) always need highway closure, and the working process is time-consuming. Unmanned aerial vehicle (UAV) can monitor accident scene from different angles or at different altitudes without interrupting the traffic, therefore, UAV is introduced for accident scene reconstruction. First, the method framework of accident scene reconstruction was proposed, in which UAV was used to take pictures of accident scene, and imaging system was adopted to reconstruct 2D and 3D accident scene. Then, the method's 3D reconstruction, point cloud generation and model optimization were presented. Next, a UAV flight experiment was conducted for 2D and 3D scene reconstruction, and two evaluation indexes, signal-to-noise ratio (PSNR) and structural similarity (SSIM), were introduced to assess the image quality of accident scene reconstruction. The case study demonstrates that the accident scene reconstruction is satisfactory, the proposed method is efficient and has its unique advantages of mobility, broad view and low cost compared with traditional methods. In addition, the challenges and future work of using this method for accident scene reconstruction were discussed.

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Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-04196
Paper Title	Full Bayes Approach to Road Safety Hotspot Identification with Prediction Validation
Abstract	In this paper, we outline a new approach for accident hotspot identification based on a recent collaboration between researchers at Newcastle University, UK, and industrial partners at PTV Group, Germany. The primary aim of this work is the development of a user-friendly software tool for assessing the likelihood of accidents within a pool of potential road safety hotspots, in the future, to enable a proactive – rather than reactive – approach to road safety scheme implementation. A fully Bayesian hierarchical model is constructed to estimate site-specific regression-to-mean (RTM) and trend effects. For example, given a time series of accident counts at each potential hotspot, we allow for a global network temporal trend with the possibility of site-specific deviations from this, dampenend by a zero-inflation component to prevent an exaggeration of local trends – a particularly important device for short-run time series. We also employ a negative binomial distribution with monotonically increasing variance for historic observations to account for increasing uncertainty in intrinsic site changes as we move further into the past, and to lend predictions of future accident counts more weight from more recent observations. The Bayesian posterior predictive distribution is exploited to formulate these predictions. We validate this model using two large datasets – one from the city of Halle, Germany, and one from the Northumbria region of England – and we conclude that our model predicts future accident counts with a high degree of accuracy.

Authors	HAYDER AL-TAWEEL, Monash University William Young, Monash University Amir Sobhani, VicRoads
Sponsoring Committee	ANB10
Session Number	245
Session Title	Transportation Innovations May Improve Safety
Paper Number	17-04306
Paper Title	Understanding the Relationship Between Crash Severity, Change in Velocity, and Driver's Reaction
Abstract	A driver's reaction may influence the risk and severity of road crashes. Even though many studies have analyzed the factors influencing drivers' injury severity, little is understood about the relationship between driver's reaction, delta–v and driver's injury severity. This study develops a modelling framework to better understand this relationship. Three models, replicating driver's reaction, change in velocity (delta-v) and the driver's injury severity, are developed to analyze the hierarchy of factors influencing these three components of a crash. The data used for this estimation consists of two-vehicle crashes extracted from the United States National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) for the period between 2009 and 2014.The results show that as drivers' age increases the possibility of a reaction before the crash. This possibility is also increased when there are adverse surface conditions, non-straight horizontal curves, non-level vertical curves and on local roads. Reacting before a crash reduces the delta-v of the crashes and consequently the injury severity of the driver. The modelling results confirm that a higher delta-v is associated with higher occupant injury severity. Future research should focus on a more in depth understanding of factors influencing driver inattention to reduce occupant injury severity. In addition, the results of this research suggests that improving vehicle technologies such as 'Auto Emergency Braking System', can reduce severity of road crashes.

Authors	Muhammad Farhan, University of Dammam
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-04598
Paper Title	A Sketch Planning Approach to Highway Safety Manual Based Crash Prediction Methods Using Road Safety Audit Data in Saudi Arabia
Abstract	A comprehensive traffic safety study for the two main corridors was conducted in Eastern Province of Saudi Arabia recently. The main aim of the study was to analyze the causes of various traffic safety related issues in the Eastern Province of Saudi Arabia. This was done in particular with regards to traffic crashes with fatalities; some of the methods employed included collecting data on traffic volumes, highway speeds, travel times, traffic crashes, and conducting the Road Safety Audit. These methods helped develop several countermeasures which targeted to reduce crashes and the severity levels associated with them, and hence improve the overall traffic safety situation in the area. This paper explains a sketch planning approach for the application of Highway Safety Manual based crash prediction methods using Road Safety Audit Data, to help estimate reduction in crashes due to proposed improvements. The selection of the two corridors was to best represent the transportation network in the Eastern Province which consists of several different types of facilities including urban, suburban, and rural roads. The comprehensive road safety audit was performed on two corridors and the data collected thereof was archived into reporting templates. After thorough evaluation of the collected data in the safety audit process, improvements to root causes of traffic safety concerns were recommended; the highway Safety Manual based crash prediction methods were applied to see the effectiveness of the improvements suggested. Reports were prepared for each of the data collection items. While the results show reduction in traffic crashes based on improvements to the corridors, this approach could contribute in its true essence when applied in combination with several other traffic safety improvement strategies.

Authors	Kevin Manaugh, McGill University Elizabeth Pis, McGill University
Sponsoring Committee	ANB10
Session Number	329
Session Title	School Transportation Research
Paper Number	17-04672
Paper Title	Exploring Changes in Children's Trips to School over Time in Montreal, Canada, region
Abstract	Daily trips to school can offer many benefits to children, including an opportunity to engage in physical activity, spend time outdoors, and interact with peers without parental supervision. However, the rate of motorized trips for school age children has continued to rise over the past few decades. This has implications for local air quality and broader environmental concerns, as well as public health and safety issues. Several elements of policy and street design have been linked to this decline, including dispersed development patterns and school consolidations making distances impractical to walk or cycle. In addition, parental fears of traffic and crime may be leading many households to prefer to drop children off at school. This study, using four waves of the Montreal-region Origin-Destination survey examines the personal, household, and built-form determinants of active transport to school for children aged 6-16 between the years 1998 and 2013. Binary logistic regression identifies age of child, car use in the home, percentage of four-way intersections as having an impact on active transport to school. In addition, some of these effects are observed to increase in magnitude over time.

Authors	Tazul Islam, City of Edmonton Laura Thue, City of Edmonton Jana Grekul, University of Alberta
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-04744
Paper Title	Understanding Traffic Safety Culture: Implications for Increasing Traffic Safety
Abstract	Despite the success of various engineering, education and enforcement measures, fatalities and injuries from traffic collisions have remained as one of the major global problems. Recently, it has been advocated that addressing this massive problem requires a fundamental transformation in the traffic safety culture of road users. Consequently, measuring and understanding traffic safety culture has gained growing attention in the field of traffic safety. To this end, this study, believed to be the first of its kind in Canada, aimed to (i) measure traffic safety culture related to distracted driving, impaired driving and speeding, (ii) investigate how perceptions of these major issues are associated with self-reported behaviour and support for related enforcement and policy, and (iii) explore the effect of respondents' socio-demographic characteristics on traffic safety culture. A telephone survey based on a stratified random sample of approximately 1000 residents in the Edmonton region of Alberta, Canada, was conducted in 2014. Descriptive analysis, multivariate confirmatory factor analysis and structural equation modeling were performed. The descriptive statistics show the prevalence and often the acceptance of distracted driving, specifically hands-free cell phone use, and speeding on freeways. Detailed results demonstrate statistically significant correlations among perceived threat to personal safety, acceptability of behaviours, self-reported behaviours, support for enforcement and support for law and policy. In addition, perceived threat to personal safety was found to have a statistically significant influence on self-reported behaviour, and support for enforcement, law and policy. Finally, various socio-demographic characteristics have a significant effect on the perceived threat of traffic behaviours to personal safety. The results from this study can be used to better guide educational campaigns to transform traffic safety culture from one that is risk receptive to one that is protective.

Authors	Praveena Penmetsa, University of North Carolina, Charlotte Srinivas Pulugurtha, University of North Carolina, Charlotte Ajinkya Mane, University of North Carolina, Charlotte
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-04950
Paper Title	Risk Perceptions of Drivers: Does It Change with Crash History or Prior Convictions?
Abstract	This paper examines whether risk perceptions of drivers towards a traffic rule violation change with prior crash history or prior violations history. The data from the Naturalistic Driving Study (NDS), consisting of several surveys answered by voluntarily participated drivers across the United States, was used for research and analysis. The change in risk perception of participants is generally significant with involvement in two or more crashes. Participants between 16 to 19 years had a significant increase in the risk perception after involving in an injury severity crash. Participants between 16 to 19 years who were found at fault in a crash had significantly less risk perception than participants of the same age group who were not found at fault in a crash. Similarly, participants between 45 to 54 years had a significant change in the risk perceptions, but participants who were found at fault had high risk perceptions than who were not found at fault. Participants above 55 years and who were involved in injury severity crash found traffic rule violations less risky than participants of the same age group who were involved in damage only but not reported crashes. Overall, the results from this study help in understanding how drivers risk perceptions change after involving in crashes or convicted of violations. They assist in better educating drivers to increase the risk perceptions towards traffic rule violations so as to improve safety on roads.

Authors	Alexander Chambers, California Polytechnic State University Anurag Pande, California Polytechnic State University Robert Bertini, USF Center for Urban Transportation Research
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-05118
Paper Title	Empirical Before and After Evaluation of a Variable Speed Limit System from a Safety Management Perspective
Abstract	Active traffic management (ATM) strategies involving ramp metering and variable speed limits (VSL) are implemented on freeways as lower cost solutions for addressing safety, reliability and other performance issues. These strategies are particularly attractive on freeways with limited to no scope for capacity expansion. In an era of big data with many data sources for agencies, it is key to understand how best to utilize the information available to improve safety and operations. This paper explores the application of VSL on Oregon Route 217 in the Portland area from a safety management perspective by studying multiple traffic, incident, emergency response, and crash data sources to evaluate their potential for aiding in the assessment of safety impacts . Toward that end, this research addressed issues relevant to safety evaluations including applying the Highway Safety Manual (HSM) safety management approach in practice with multiple crash data sources. Among the crash data sources, the trade-offs between timeliness, level of granularity, and completeness were noted. Gaining experience and examining the ability to detect changes in safety and operational conditions via different data sources will benefit agencies in lessening response times to problems, and will allow them to be more proactive in applying safety solutions. The conclusions from the study point to the value of a safety management approach to safety wherein a corridor's crash experience is monitored continuously. The study also includes recommendations to update some the information gathered by more immediate data sources to make timely safety evaluations more accurate. These procedures can be used by other agencies considering implementation of ATM strategies, including VSL.

Authors	Mehmet Ulak, Florida State University Ayberk Kocatepe, Florida State University Eren Ozguven, Florida A&M University - Florida State University Mark Horner, Florida State University Lisa Spainhour, Florida State University
Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-05135
Paper Title	GIS-Based Spatial and Statistical Analysis of Severe Crash Hotspot Accessibility to Hospitals
Abstract	Previous studies have examined the hospital accessibility problem, and exhaustively investigated several aspects of roadway crashes such as their severity, frequency, influential factors, and clustering behavior. However, even though studies have looked at crashes and hospital accessibility separately, the relationship between them, in terms of accessibility of severe crash hotspots to hospitals with emergency services, still remains unclear. In this study, we investigate this accessibility using a geographic information systems (GIS)- and statistics-based analysis to detect high risk locations. We also examine several environment-, traffic-, and human-related factors to identify the determinants of the crashes that constitute the hotspots via a hierarchical multinomial logistic regression analysis. Results show that several roadway segments portend an elevated threat of injury and fatalities on drivers and passengers not only due to a higher probability of being severely injured, but also because of their low accessibility with respect to hospitals having emergency service. Regression analysis, on the other hand, illustrates and verifies that particular spatial, traffic-, and roadway related factors such as intersection presence or speed limits imperil traffic safety substantially. The knowledge gained from this study can help agencies and officials pinpoint and investigate high risk locations to enhance the safety of roadway users.

Authors	Wei Hu, University of Tennessee, Knoxville Qiao Dong, School of Transportation, Southeast University Baoshan Huang, University of Tennessee, Knoxville
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-05293
Paper Title	Access to Trauma Centers for Fatal Crashes in the United States
Abstract	Existing research indicates that around 90% of all US residents have access to at least one level I or II trauma center within 60 minutes. However, a limitation of these estimations lies in that they are based on where people live and not where people are injured, which may overestimate the access to trauma center for seriously injured patients in fatal crashes. In this study, the Fatality Analysis Reporting System (FARS) data from 2013 to 2014 were collected and analyzed to quantify the access of injured patients to trauma centers for fatal crashes across states. Two types of distance, linear distance and route distance, were calculated using ArcGIS. The Northeast region had the nearest average linear and route distance between fatal crash and trauma center (25.3 km and 31.7 km, respectively), followed by the Midwest (44.4 km and 54.1 km), the South (47.3 km and 57.0 km), and the West (50.9 km and 67.5 km). The estimated transport time to the nearest level I/II trauma center was also calculated and compared to the recorded transport time. The comparison results revealed that the different states adopted different trauma triage protocols, resulting in different utilization rate of the level I/II trauma center among states. A linear regression analysis demonstrated that the longer the average route distance, the less the seriously injured patients in fatal crashes were taken to level I/II trauma center directly.

Authors	Danyang Sun, University of Alberta Karim El-Basyouny, University of Alberta Shewkar Ibrahim, City of Edmonton
Sponsoring Committee	ANB10
Session Number	329
Session Title	School Transportation Research
Paper Number	17-05398
Paper Title	Speed and Safety Assessment of School Zones: Case Study of City of Edmonton, Canada
Abstract	This paper describes a study undertaken to assess the speed and safety effects of reducing speed limits from 50-to-30 km/h in school zones in Edmonton, Canada. A longitudinal (before-and-after) study was conducted to evaluate the changes in collisions and vehicular speeds. Statistical analyses were employed to test the significance of the impacts. The results indicated that mean speeds and 85th percentile speeds were reduced by 12.2 and 12.0 km/h, respectively. More so, the analysis revealed speed variation was smaller in the after period. Moreover, speed distribution plots were depicted to compare the speeds before and after the speed limit change. The results indicated that the speed distributions shifted to the left, showing significant reductions in all speed ranges, especially when considering locations with high speeds. The findings from the speed analysis indicated a positive safety effect from introducing school zones. To corroborate this finding, a simple before-and-after collision analysis was conducted. The evaluation results revealed that fatal/injury collisions were statistically significantly reduced by 41.2%, and injuries to vulnerable road users were statistically significantly reduced by 71.4%. Consequently, the results of this study provide strong evidence that reducing speed limits to 30 km/h in school zones can bring about significant safety effects by reducing vehicular speeds and fatal/injury crashes. The results also showed that for every 1 km/h reduction in mean speed, fatal/injury crashes were reduced by 4%, which is consistent with findings from previous research.

Authors	Katherine Chen, University of California, Berkeley Sang Hyouk Oum, University of California, Berkeley Jill Cooper, Safe Transportation Research and Education Center
Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-05511
Paper Title	Developing a Web-Based Tool to Track Highway Safety Planning Progress in California
Abstract	A Strategic Highway Safety Plan (SHSP) is a comprehensive, statewide, data-driven safety plan that coordinates activities across agencies to reduce traffic fatalities and serious injuries on all public roads. In 2015, California updated its SHSP with the input of hundreds of stakeholders. The challenge with implementing a multi-year effort across many primary actors is tracking decisions and progress in an efficient manner, as well as, having a state's safety program be accountable and transparent to its stakeholders. The Safe Transportation Research and Education Center at UC Berkeley developed a tracking tool for California's updated SHSP. The steering committee and other key stakeholders involved in the SHSP implementation phase provided substantial input. The SHSP Tracking Tool is a user-friendly, low-cost, easily maintained resource that multiple stakeholders update. Written in PHP on a single-page website, the SHSP Tracking Tool is a mechanism that allows users to contact leaders, track progress, run reports, and review performance measures on all SHSP projects. Moving forward, the tool will also serve as a primary repository of SHSP internal documents and a community forum to evaluate progress and advance the efforts of California's SHSP safety stakeholders. Further, it reflects federal and state transportation calls to ensure safety efforts are data- and performance-driven. It can be adapted for any state's SHSP.

Authors	Chelsea Richer, Fehr & Peers Dana Weissman, Fatemeh Ranaiefar, Fehr & Peers Nat Gale, City of Los Angeles Department of Transportation
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06147
Paper Title	Vision Zero Technical Analysis in Los Angeles, California: Data-Driven Effort to Eliminate Traffic Fatalities
Abstract	In August 2015, Los Angeles Mayor Eric Garcetti issued Executive Directive 10, Vision Zero Initiative, establishing a goal of zero traffic deaths in Los Angeles by 2025. In response to this directive, the Los Angeles Department of Transportation (LADOT) completed an in-depth, data-driven process to build the foundation of a city-wide Vision Zero initiative. This study documents the innovations developed to analyze collision data, pair countermeasures to specific data-driven trends, and prioritize high-collision locations. A team of planners, engineers, statisticians, and data analysts worked together to create a process grounded in national best practices and tailored to meet the specific needs of LADOT. This study can be used as a guide to help cities develop their own robust data-driven Vision Zero process, to develop an understanding of collision patterns across the city, pair countermeasures in locations where the greatest collision reduction could be obtained, and prioritize the most critical intersections. More immediately, this study positions LADOT to develop an Action Plan, including prioritized locations and project descriptions for the first several years of Vision Zero infrastructure investment and any related projects through LADOT's normal course of work.

Authors	Ayberk Kocatepe, Florida State University Mehmet Ulak, Florida State University Eren Ozguven, Florida A&M University - Florida State University Mark Horner, Florida State University Reza Arghandeh, Florida State University
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06321
Paper Title	Socioeconomic Characteristics and Crash Proneness: Case Study in Florida Using Two-Step Floating Catchment Area Method
Abstract	The objective of this study is to investigate the spatial crash proneness among different population groups using a Gaussian-based two-step floating catchment area (2SFCA) method. This is performed by developing a special form of crash-to-population ratio that incorporates the crash hotspots as well as the socioeconomic data. While identifying the crash hotspots, four different age groups are considered: 17 and younger, 18 to 21, 22 to 64 and 65 and older. For each age group, different crash hotspots are identified based on the number of severely injured occupants of that age group involved in crashes. Using these age-specific crash hotspots, further socioeconomic analysis is conducted weighting the distances between crash hotspot locations and population block groups. This analysis included data on the ethnicity, poverty, education level, and vehicle ownership. Results indicate that several high and low crash prone areas are correlated with the socioeconomic characteristics of those areas. The developed approach has the potential to improve understandings of the relationships between socioeconomics and crash proneness.

Authors	Timothy Black, Public Health Foundation Enterprises Jacqui Swartz, Public Health Foundation Enterprises Tim Fremaux, City of Los Angeles Department of Transportation
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06325
Paper Title	Vision Zero and Beyond: A Simple Yet Powerful Data Strategy for Evaluating Potential Engineering Solutions
Abstract	As cities adopt Vision Zero goals to eliminate traffic fatalities, many find they are limited in resources to carry out such an ambitious program. With constraints in time, funding, and staffing, many cities are taking a data-driven approach to reduce fatalities as quickly and cost-effectively as possible. The Los Angeles Department of Transportation (LADOT), in collaboration with the Los Angeles County Department of Public Health (LACDPH), developed a simple—yet powerful—database and analysis tool that now plays a key role in how Los Angeles prioritizes projects, applies for grant funding, and designs for safety on our streets. Moving beyond the macro-level Vision Zero strategy development, this tool provides a more targeted approach to estimating the safety benefit of specific engineering countermeasures. Providing highly customizable queries, the process proposed in this paper can be implemented quickly and applied to improve the work transportation planners and engineers already do on a daily basis, such as apply for grants to fund basic safety improvements.

Authors	Mouyid Islam, CH2M Dante Perez-Bravo, CH2M Kimberly Kolody, CH2M
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06667
Paper Title	Performance-based Assessment to Transportation Safety Planning for Metropolitan Travel Improvement Study
Abstract	Nebraska sets the ambitious 'toward zero deaths' goal as part of the Strategic Highway Safety Plan (SHSP). Improving highway safety by reducing fatalities and serious injuries on all public roads is integral to the transportation safety management in Nebraska. With the vision of Metropolitan Improvement Study (MTIS) for Omaha, Nebraska and Council Bluffs, Iowa by Nebraska Department of Roads (NDOR) and Metropolitan Area Planning Agency (MAPA), quantitative safety performance stands as an important milestone and key decision making factor. This study focuses on the process and outcome of performance-based safety evaluation of freeways and major arterials for the MTIS by applying the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) and the Federal Highway Administration (FHWA) Crash Modification Factor Clearinghouse. An HSM predictive network screening method was applied to identify the locations with potential for safety improvements. A detailed analysis of the most recent five years of historical crash data was performed to understand the contributing factors. With this knowledgebase, strategies to mitigate severe crashes were determined. This leads to predictive safety performance of six strategy packages for the design year 2040. This paper focuses on a performance-based approach to compare safety performance to transportation planning alternatives. Thus, this study establishes a framework to implement the quantitative safety evaluation process envisioned in HSM in the direction 'towards zero deaths.' Moreover, this study paves an avenue to make informed decisions by the safety professionals, designers, planners, and policy makers at state and local levels.

Authors	John Shaw, Iowa State University Carlyn Muir, Monash University David Noyce, University of Wisconsin, Madison
Sponsoring Committee	ANB10
Session Number	328
Session Title	Transportation Safety Management: Creating Safer Systems
Paper Number	17-06706
Paper Title	A Tale of Two States: Strategic Highway Safety Planning, Vision Zero, and the Safe System Approach in Wisconsin and Victoria, Australia
Abstract	The 2014 publication of Toward Zero Deaths: A National Highway Safety Strategy was an important milestone in American efforts to improve highway safety. This approach has both similarities and differences in comparison to the Safe System approach advocated as international best-practice by the International Transport Forum of the Organization for Economic Cooperation & Development. To explore how these differences influence safety strategy implementation at the state level, we compared the strategic safety plans for the states of Wisconsin, USA and Victoria, Australia. These state level plans have many technical similarities in spite of the fact that their philosophical underpinnings differ. Perhaps the most important effect of the Safe System approach is that it has allowed Victoria state government to benefit from long-term advocacy efforts by physicians and other road safety stakeholders. This combination has, in recent years, accelerated the pace of highway safety investments in Victoria and resulted in the implementation of substantive legal and behavioral safety strategies that are currently not being considered in Wisconsin.

Authors	Noah Goodall, Virginia Department of Transportation
Sponsoring Committee	ANB10
Session Number	397
Session Title	Transportation Safety Management: From Start to Finish
Paper Number	17-06790
Paper Title	Probability of Secondary Crash Occurrence on Freeways Using Private-Sector Speed Data
Abstract	A percentage of crashes on freeways are suspected to be caused in part by the congestion or distraction from earlier incidents. Identifying and preventing these secondary crashes are major goals of transportation agencies, yet the characteristics of secondary crashes—in particular the probability of their occurrence—are poorly understood. Many secondary crashes occur when a vehicle encounters non-recurring congestion, yet previous efforts to identify incident queues and their secondary crashes have relied either on deterministic queuing theory, or on data from uniformly-spaced, dense loop detectors. This study is the first analysis of secondary crash occurrence integrating incident timelines and traffic volumes with widely-available (and legally obtained) private sector speed data. Analysis found that 9.2% of all vehicle crashes were secondary to another incident, and that 6.2% of these crashes were tertiary to another primary incident. Secondary crashes occurred on average once every 10 crashes and 54 disabled vehicles. The findings support a fast incident response, as the probability of secondary crash occurrence increases approximately one percentage point for every additional 2-3 minutes spent on-scene in high volume scenarios.

9 Interacting Committees

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

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.

AH010, Surface Transportation Weather

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

AHB15, Intelligent Transportation Systems
The Intelligent Transportation Systems (ITS) Committee is concerned with ITS systems-level issues. Such issues include conceptual system planning and design, integration of technologies and approaches from various sub-disciplines within ITS, applications to all modes of ground transportation and to facilitate intermodal integration, and evaluation of the overall impacts of ITS on the developers, users, and operators of all parts of the ground transportation system. Activities focus on the broad planning, policy, economic, social, technological, and institutional aspects of the development and implementation of ITS. The Committee also facilitates coordination of ITS- related issues with other standing committees of TRB.

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.

AHB65, Operational Effects of Geometrics

This committee is concerned with geometric design as related to traffic operations and safety.

ANB60, Safe Mobility of Older Persons

Stimulate quality research and evaluation, provide a forum for interested researchers and practitioners to disseminate research and related information to those involved and interested in improving the safety and mobility of older drivers.

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.

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.

AP018T, Task Force on Transit Safety and Security

This committee focuses on the research, methods, practices, data and technologies important to the topic of public transportation system safety and security as they affect all modes and phases of infrastructure development and service operation. Research efforts initiated through the Task Force foster the development and professional growth of practitioners and researchers in the field of transit safety management, application, and research.