TRB Standing Committees

ACS10 – Transportation Safety Management Systems

ACS20 – Safety Performance Analysis

Synthesis Report on Safety-Related Papers

presented at the 100th TRB Annual Meeting

Prepared by

Alfonso Montella, Mohamed Abdel-Aty, Mohamad Banihashemi, Frank Gross, Qiming Guo, Jaeyoung Lee, Filomena Mauriello, Raul Andres Pineda Mendez, Maria Rella Riccardi, Heesub Rim, Brendan Russo, Xueqian Shi, Raghavan Srinivasan, Jinghui Yuan, and Andrew Tarko

TRB Standing Committee ACS10 – Transportation Safety Management Systems

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: https://sites.google.com/view/trbcommitteeacs10

Membership as of December 2020

Chair

Stephanie Malinoff, Senior Director of Engagement and Technical Activi

TRB Staff Representatives

Mary Kissi, Bernardo Kleiner, Freda Morgan

Committee Research Coordinator

Brendan Russo, Northern Arizona University

Committee Communications Coordinator

Wendy Hansen, Penna Powers

Members

Timothy Barnett, Alabama Department of Transportation
Andrea Bill, University of Wisconsin, Madison
James Bradford, International Road Assessment Program
Salvatore Damiano Cafiso, University of Catania
Kevin Chang, University of Idaho
Alicia Chavez, National Study Center
Scott Davis, Thurston County Public Works
Ann Dellinger, Centers for Disease Control and Prevention (CDC)
Nathaniel George, Rummel, Klepper, and Kahl, LLP (RK&K)
Offer Grembek, University of California, Berkeley
Frank Gross, VHB
Wendy Hansen, Penna Powers
Kelly Hardy, American Association of State Highway and Transportation Officials
William Horrey, AAA Foundation for Traffic Safety
Steven Lavrenz, Wayne State University
Jaeyoung Lee, Central South University (CSU)
Daniel Magri, Louisiana Department of Transportation and Development
Stephanie Malinoff, University of Minnesota, Twin Cities
Joseph Marek, Clackamas County
Alfonso Montella, University of Naples Federico II
Kelly Morton, Federal Highway Administration (FHWA)
Jennifer Oxley, Monash University Accident Research Centre
Kelly Palframan, Focus Forensics
Bonnie Polin, Massachusetts Department of Transportation
Mark Poppe, J2 Engineering and Environmental Design
Kristy Rigby, Utah Department of Public Safety
Brendan Russo, Northern Arizona University
Kendra Schenk, Burgess and Niple, Inc.
Alazar Tesfaye, Colorado Department of Transportation
Esther Wagner, National Highway Traffic Safety Administration (NHTSA)
Nicole Waldheim, Cambridge Systematics, Inc.
Ling Wang, Tongji University
Keith Williams, National Highway Traffic Safety Administration (NHTSA)
Robert Wunderlich, Texas A&M Transportation Institute

TRB Standing Committee ACS20 – Safety Performance Analysis

TRB ANB25 (Highway Safety Performance) and TRB ANB20 (Safety, Data, and Evaluation) merged into ACS20 Safety Performance Analysis (draft committee name). 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: https://trbacs20.org/

Membership as of December 2020

Chairs

Karen Dixon, Texas A&M University
Kimberly Eccles, VHB

TRB Staff Representatives

Mary Kissi, Bernardo Kleiner, Freda Morgan

Secretaries

Tegan Enloe, City of Tigard
Derek Troyer, Ohio Department of Transportation

Committee Research Coordinator

Jianming Ma, Texas Department of Transportation

Committee Communications Coordinators

Christopher Monsere, Portland State University
Ida van Schalkwyk, Washington State Department of Transportation

Members

Mohamed Abdel-Aty, University of Central Florida
Mohamed Ahmed, University of Wyoming
Geni Bahar, NAVIGATS Inc.
Mohamadreza Banihashemi, GENEX Systems
Hillel Bar-Gera, Ben Gurion University of the Negev
Kate Bradbury, Jacobs
John Campbell, Exponent Inc.
Daniel Carter, North Carolina Department of Transportation
Cong Chen, USF Center for Urban Transportation Research
Tim Colling, Michigan Technological University
Michael Dimaiuta, GENEX Systems
Karen Dixon, Texas A&M Transportation Institute
Karim El-Basyouny, University of Alberta
Erin M. Ferguson, Kittelson & Associates Inc.
Brelend Gowan, Brelend C. Gowan, Attorney at Law & Legal Consultant
Feng Guo, Virginia Polytechnic Institute and State University
Douglas Harwood, MRIGlobal
Robert Hull, Cambridge Systematics Inc.
Michael Hunter, Georgia Institute of Technology
John Ivan, University of Connecticut
Thomas Jonsson, Norwegian University of Science and Technology
Keith Knapp, Iowa State University
Francesca La Torre, University of Florence
Sandra Larson, Stanley Consultants, Inc.
Dominique Lord, Texas A&M Transportation Institute
Craig A. Lyon, Persaud and Lyon Inc.
Jianming Ma, Texas Department of Transportation
John Mason, Pennsylvania State University, Harrisburg
Juan Medina, University of Utah
Yusuf Mohamedshah, Federal Highway Administration (FHWA)
Chris Monsere, Portland State University

Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ACS10-ACS20 related presentations and events at the 100th Annual Meeting of the Trransportation Research Board. With this aim, papers sponsored by the Committees ACS10 – Transportation Safety Management Systems and ACS20 – Safety Performance Analysis 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 ACS10[1]and ACS20[2] have been identified and classified in order to promote better interaction between ACS10, ACS20 and these other Committees. Indeed, highway safety is a worldwide major social challenge that 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, twenty-seven events sponsored by ACS10 and ACS20 are planned:

- Two Committee meetings (see Table 1);
- Seven Subcommittee meetings (see Table 2);
- Five workshops (see Table 3);
- Five lectern sessions (see Table 4); and
- Eight poster sessions (see Table 5).

The Committee meetings will be held on Monday morning, January 11, from 10:00 AM to 1:00 PM ET (ACS10) and Thursday afternoon, January 14, from 2:00 PM to 5:00 PM ET (ACS20).

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

a) Crash Data and Data Analysis (110 papers);
b) Network Screening (9 papers);
c) Safety Performance Functions (43 papers);
d) Crash Severity Prediction (45 papers);
e) Crash Modification Factors (18 papers);
f) Surrogate Measures of Safety (26 papers); and
g) Transportation Safety Management (32 papers).

[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 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 ACS10 and ACS20 Committee Meetings

Schedule	Title	Details
Monday, January 11 10:00AM – 1:00PM ET	Transportation Safety Management Systems Committee, ACS10	https://annualmeeting.mytrb.org/OnlineProgram/Details/14980
Thursday, January 14 2:00PM – 5:00PM ET	Safety Performance and Analysis Committee, ACS20	https://annualmeeting.mytrb.org/OnlineProgram/Details/14981

Table 2 ACS10 and ACS20 Subcommittee Meetings

Schedule	Title	Details
Wednesday, January 13 10:00AM – 11:30AM ET	Surrogate Safety Measures Subcommittee, ACS20(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15957
Wednesday, January 13 12:00PM – 1:30PM ET	Pedestrian and Bicycle Safety Analysis Subcommittee, ACS20(4), Joint Subcommittee of ACS20, ACH10, ACH20	https://annualmeeting.mytrb.org/OnlineProgram/Details/15958
Wednesday, January 06 4:00PM – 5:30PM ET	Emergency Response, AMR00(1), Joint Subcommittee of AMR00, ACS10, and ACP10	https://annualmeeting.mytrb.org/OnlineProgram/Details/15304
Thursday, January 07 10:00AM – 11:30AM ET	School Transportation Subcommittee, ACS10(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15946
Thursday, January 07 12:00PM – 1:30PM ET	Rural Road Safety Policy, Programming, and Implementation Subcommittee, ACS10(4), Joint Subcommittee of ACS10, ACS20, AKD30	https://annualmeeting.mytrb.org/OnlineProgram/Details/15950
Friday, January 08 10:00AM – 11:30AM ET	Safety Analytical Methods Subcommittee, ACS20(1)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15955
Friday, January 08 12:00PM – 1:30PM ET	Safety Performance and Analysis User Liaison Subcommittee, ACS20(2)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15956

Table 3 ACS10 and ACS20 Workshops

Schedule	Title	Details
Thursday, January 21 2:00PM - 5:00PM ET	(1016) Building a Purposeful Structure for Moving Research to Practice	https://annualmeeting.mytrb.org/OnlineProgram/Details/15155
Friday, January 22 10:00AM - 1:00PM ET	(1027) Safety Performance Decision Making: Advancing Research Through Implementation	https://annualmeeting.mytrb.org/OnlineProgram/Details/15154
Friday, January 22 10:00AM - 1:00PM ET	(1033) Breaking Down Silos to Embrace Life in a Multimodal Performance Based Solution	https://annualmeeting.mytrb.org/OnlineProgram/Details/15141
Friday, January 22 10:00AM - 1:00PM ET	(1035) A Disaster During Lockdown: An Exercise in Managing the Logistics, Potential Evacuations and Key Aspects of Multiple Disruptive Events	https://annualmeeting.mytrb.org/OnlineProgram/Details/15189
Friday, January 22 2:00PM - 5:00PM ET	(1044) New Developments in Safety on Low Volume Roads	https://annualmeeting.mytrb.org/OnlineProgram/Details/15160

Table 4 ACS10 and ACS20 Lectern Sessions

Schedule	Title	Details
Monday, January 25 10:00AM – 11:30AM ET	(1052) Regional Integration of Emergency Response into Connected Infrastructure Systems and Automation	https://annualmeeting.mytrb.org/OnlineProgram/Details/15524
Monday, January 25 4:00PM – 5:30PM ET	(1123) Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US	https://annualmeeting.mytrb.org/OnlineProgram/Details/15703
Thuesday, January 26 10:00AM – 11:30AM ET	(1143) Safety Performance and Analysis Doctoral Student Competition	https://annualmeeting.mytrb.org/OnlineProgram/Details/15773
Wednesday, January 27 10:00AM – 11:30AM ET	(1256) Perspectives in Traffic Safety Management During a Pandemic	https://annualmeeting.mytrb.org/OnlineProgram/Details/15722
Thursday, January 28 4:00PM – 5:30PM ET	(1408) Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce	https://annualmeeting.mytrb.org/OnlineProgram/Details/15709

Table 5 ACS10 and ACS20 Poster Sessions

Schedule	Title	Details
Tuesday, January 26 11:30AM – 1:00PM ET	(1169) Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15772
Tuesday, January 26 11:30AM – 1:00PM ET	(1183) Emergency Response, Incident Management, and Public Health	https://annualmeeting.mytrb.org/OnlineProgram/Details/15960
Tuesday, January 26 1:005PM – 2:30PM ET	(1202) Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15775
Wednesday, January 27 1:00PM – 2:30PM ET	(1295) Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15793
Wednesday, January 27 2:30PM – 4:00PM ET	(1304) Transportation Safety Management Systems from Start to Finish	https://annualmeeting.mytrb.org/OnlineProgram/Details/15681
Wednesday, January 27 2:30PM – 4:00PM ET	(1311) Case Studies in Performance Based Analysis of Geometric Design	https://annualmeeting.mytrb.org/OnlineProgram/Details/15555
Wednesday, January 27 4:00PM – 5:30PM ET	(1327) Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)	https://annualmeeting.mytrb.org/OnlineProgram/Details/15795
Thursday, January 28 10:00AM – 11:30AM ET	(1356) Pavement, Safety, and Traffic Management Developments for Low Volume Road Applications	https://annualmeeting.mytrb.org/OnlineProgram/Details/15838

2 Crash Data and Data Analysis

Mohamad Banihashemi, FHWA

"Crash Data and Data Anaysis" section contained many papers in wide variety of subjects in highway safety. Of over 283 papers submitted to the ACS10 and ACS20 Committees for 2021 Annual Meeting, there are 110 papers/presentations that fit in this major category, with several sub-categories listed below. Besides papers, there are several workshops and panel discussions that may have presentations fitting this category but for many of these presentations there is not enough information to confirm their categories. The Workshop/Panel Discussions are:

- Workshop 1027: Safety Performance Decision Making: Advancing Research Through Implementation;
- Workshop 1033: Breaking Down Silos to Embrace Life in a Multimodal Performance Based Solution;
- Workshop 1044: New Developments in Safety on Low Volume Roads
- Lectern Session 1408: Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce;
- Lectern Session 1123: Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US.

This is a unique session that touches a subject rarely brought up in the TRB. No specific information is available but most likely the data and analyses discussed in this session would be of interest to the researchers interested in "Data and Data Analysis."

The sub-categories of "Data and Data Analysis" and related papers are listed below:

Specific Models and Data, Real-time Crash Risk: This is the larget sub-category identified in this category of papers. There are about 32 papers related to this category in the Annual Meeting. These are papers that present either a relatively new type of modeling or focus on specific source or type of data.

Li, Pei and Mohamed Abdel-Aty (TRBAM-21-01697) have conducted real-time crash likelihood prediction using LSTM-CNN with attention mechanism. Kirsch, Jenna et al. (TRBAM-21-02828) have used crowd-sourced probe vehicle data, the impact of level of travel time reliability (LOTTR) on crashes. Zheng, Qikang et al. (TRBAM-21-04128) have investigated the predictability of crashes on different freeway segments using real-time crash risk models. Wang, Kang et al. (TRBAM-21-04294) have analyzed the segment type heterogeneity from crash characteristics, have proposed a method of variables selection and have built a nested logit model to quantitatively analyze the impact of crash contributing factors on the crash risk. Torkey, Alaa et al. (TRBAM-21-00742) have proposed a method of using sight distance and design consistency in the development of safety performance functions especially in countries having poor crash data. Junirman, Rizky and Hiroyuki Oneyama (TRBAM-21-01783) have conducted multivariate analysis using negative binomial regression to consider the effect of mixed traffic of motorcycles and other vehicles. Das, Subasish and Anandi Dutta (TRBAM-21-02366)

have used a robust clustering method known as cluster correspondence analysis to study light delivery vehicles crashes. Bhowmik, Tanmoy et al. (TRBAM-21-03184) have used Latent Segmentation Panel Multivariate Negative Binomial (LPMNB) to study the zonal level crash counts across different crash types. Kodi, John et al. (TRBAM-21-03255) have estimated the safety effects of adaptive signal control technology using the full bayesian approach. Appiah, Justice et al. (TRBAM-21-03763) studied the effect of road geometry and pavement surface condition on roadway departure crashes. Antwi Boasiako, Eugene et al. (TRBAM-21-03898) have used crash narrative review to find the association between vehicles-on-shoulder, congestion and crashes. Mishra, Raunak and Srinivas Pulugurtha (TRBAM-21-03723) have evaluated the safety effectiveness of Restricted Crossing U-turn (RCUT) intersections. Hu, Qinglin et al. (TRBAM-21-00299) have constructing three-Dimensional geometric profiles for local roads using open-source data and zero-inflated native binomial model to identify hazard curvature. Sagar, Shraddha et al. (TRBAM-21-00658) have studied the effect of socioeconomic and demographic factors on crash occurrence by using the quasi-induced exposure approach and binary logistic regression. Zhu, Yuan et al. (TRBAM-21-00981) have introduced a new web-based data visualization tool called Safety Analysis Visualization and Evaluation Tool (SAVE-T). Yocum, Rebeka et al. (TRBAM-21-01517) have introduced measures of wealth into the crash modeling conversation by determining the effect of wealth on crash frequencies. Agarwala, Ruchika and Vinod Vasudevan (TRBAM-21-02224) have adopted an exhaustive panel data modelling approach to relate household consumption expenditures to road traffic fatalities. Dai, Zhicheng et al. (TRBAM-21-02415) have developed a multivariate Poisson lognormal conditional autoregressive (CAR) model to examine the relationships between regional characteristics and traffic safety. Hodgson, Cody and Kevin Chang (TRBAM-21-02436) have used drone technology to collect school transportation data. Mohamadi Hezaveh, Amin et al. (TRBAM-21-02442) have studied the effect of “Travelers” on crashes. Rahman, Fahmida et al. (TRBAM-21-03068) have used Zero Inflated Negative Binomial model to investigate the effect of speed on crash prediction model of rural two-lane highways. Das, Subasish et al. (TRBAM-21-03150) have used motorcycle information, rider information, motorcycle information, and associated trip information to study the causation of motorcycle crashes. Mahmoud, Nada et al. (TRBAM-21-03294) have studied factors contributing to operating speed on different context classifications of arterial segments. Arabia Shioma, Shefa et al. (TRBAM-21-04448) have used the negative binomial and geographically weighted Poisson regression (GWPR) for understanding the effects of Built Environment-based (BE) Safety Measures assuming their spatial heterogeneity. Zhang, Zhihua et al. (TRBAM-21-01324) have used crowdsourced waze user reports to identify secondary crashes. Paleti, Rajesh et al. (TRBAM-21-01431) have incorporated the parsimonious parametric probability structure of hazard duration models and the flexibility of discrete choice models for incorporating time-varying covariates and unobserved heterogeneity in predicting crashes. Singh, Mankirat et al. (TRBAM-21-01915) have explored various spatio-temporal interactions in prediction of crash frequencies. Man, Cheuk Ki et al. (TRBAM-21-02446) have attempted to address the gap of spatial transferability of real-time crash prediction by combining Generative Adversarial Network (GAN) and transfer learning. Melempat-Kalapurayil, Hari-Krishnan et al. (TRBAM-21-02607) have used principal component analysis based agglomerative hierarchical clustering in crash data exploration. Asgharpour, Sina et al. (TRBAM-21-03372) have used a genetic algorithm-based clustered weighting method to deal with missing data. Kitali, Angela et al. (TRBAM-21-03548) have used a data-driven approach to automatically determine the spatiotemporal impact areas of primary incidents and detect secondary crashes. Agina, Samaa et al. (TRBAM-21-03543) have introduced an automated method for PSD assessment on two-lane highways using mobile Light Detection And Ranging (LiDAR) data.

Conventional Safety Analysis and Data: What are presented in these papers are closer to the conventional safety analysis. There are 16 papers presented in the Annual Meeting in this sub-category.

Intini, Paolo et al. (TRBAM-21-02219) have used grouped random parameter multinomial logit to identify crash types. Ma, Yadani et al. (TRBAM-21-01109) have used vehicle trajectory reconstruction via kalman filtering to identify left-turn conflicts at signal intersections. Xu, Xiaoyan et al. (TRBAM-21-02527) have used vehicle trajectories were reconstructed by discrete wavelet transform and Kalman filtering to examin causal factors of traffic conflicts at intersections. El Esawey, Mohamed et al. (TRBAM-21-00013) have used Empirical Bayes (EB) before-and-after safety evaluation and Variable Speed Limit System (VSLS) data to predict crashes frequency and rate. Das, Subasish et al. (TRBAM-21-01764) have used cluster correspondence analysis to study the relations between sun glare and Crashes. Torbic, Darren et al. (TRBAM-21-02711) have developed new intersection crash prediction models for the second edition of the Highway Safety Manual. Bhattacharyya, Abhinav et al. (TRBAM-21-02992) have developed Calibration Factors and Safety Performance Functions for rural two-lane two way roadways for New Jersey. Avelar, Raul et al. (TRBAM-21-03234) have used a multivariate approach to develope an index-based methodology to assess the quality of SPF calibration. Iqbal, Adika et al. (TRBAM-21-04402) have assessed the predictability of short segment crash analysis in the state of South Carolina for the statewide screening of midblock crash locations. Dimitrijevic, Branislav et al. (TRBAM-21-03591) have used roadway geometry characteristics, traffic flow characteristics, and weather condition data to conduct segment-level crash risk analysis for new jersey highways using Bayesian Logistics Regression, Decision Tree, Random Forest, Gradient Boosting Machine, K-Nearest Neighbor, and Gaussian Naïve Bayes models. McCarthy, Ross et al. (TRBAM-21-00051) have conducted Benefit-Cost analysis of pavement surface treatments using continuous friction measurements. Khattak, Muhammad et al. (TRBAM-21-00755) have investigated the impact of road cross-section elements on crash occurrence. Kitali, Angela et al. (TRBAM-21-04403) have developed a correlated bivariate negative binomial regression model, an uncorrelated bivariate negative binomial regression models, and a univariate negative binomial regression (UNR) model to explore separate modeling for Two- and Multiple-vehicle Crashes. Yeboah, Afia et al. (TRBAM-21-00969) have estimated ADT for low volume roadways bu using a linear regression model. Tsapakis, Ioannis et al. (TRBAM-21-02832) have used decision trees to improv stratification procedures and accuracy of annual average daily traffic (AADT) estimates. Williams, Michael et al. (TRBAM-21-03146) have provided an observational analysis of the safety effects of Edge Lane Road installations in the United States.Chakraborty, Meghna et al. (TRBAM-21-03405) have studied the relationship between Horizontal Curve Density and Safety Performance on rural two-lane highways using mixed-effects negative binomial regression models. Ma, Chaolun et al.

Connected and Automated Vehicle Safety and the use of Artificial Intelegence Techniques, including Machine Learning and Deep Learning: There are 16 papers presented in the Annual Meeting in this sub-category.

Shen, Sijun et al. (TRBAM-21-00588) have used Machine Learning Algorithms to predict crash spots. Formosa, Nicolette et al. (TRBAM-21-02470) have used Deep Learning to develop multiple Collision Avoidance Systems to identify the optimal factors to estimate the threat level under uncertainty. Khattak, Zulqarnain et al. (TRBAM-21-03292) have used Deep Learning approach based on 1D convolutional neural networks for detection of safety critical events using NDS data. Ma, Chaolun et

al. (TRBAM-21-04119) have used Machine Learning techniques to predict the occurrence of distraction-affected crashes with phone use data. Melendez, Benjamin Meet al. (TRBAM-21-01848) have evaluated the safety impact of narrow AV-Exclusive lanes. Rahman, Md Hasibur et al. (TRBAM-21-02905) have evaluated the safety performance of various communication parameters of Dedicated Short-Range Communications for vehicle ad-hoc network and intelligent driver model in the CAV environment. Ben Khedher, Moataz Bellah e al. (TRBAM-21-00971) have used different techniques including machine learning techniques, i.e. data splitting, and graphical tools to study crash frequency on two lane rural roads. Patil, Shubham et al. (TRBAM-21-01259) have used Deep Learning techniques to develop a new safety framework that includes the collision instincts caused by the surrounding vehicles using time-to-collision measure. Joo, Yang-Jun et al. (TRBAM-21-02229) have proposed a new framework to analyze lane changing risk on freeways with the mix of human driven vehicles and autonomous vehicles considering the forecastability in adjacent vehicles. Abu Sayed, Md et al. (TRBAM-21-02668) have used seven machine learning techniques; (1) multinomial naive bayes, (2) logistic regression, (3) Support Vector Machine, (4) Random Forest, (5) K-nearest neighbor, (6) Gated recurrent Unit and (7) NoisyOR to identifying underreported work zone crashes. Osman, Osama et al. (TRBAM-21-03024) have used three deep learning models of multilayer perceptron neural networks, long-short-term memory networks, and convolutional neural networks to predict crashs involving Advanced Driver Assistance Systems in real time to avoid them. Ashraf, Md Tanvir et al. (TRBAM-21-03336) have used AV crash reports from the California DMV and applied the Decision Tree and Association Rule methods to extract the pre-crash rules of AV involved crashes. Mokhtarimousavi, Seyedmirsajad et al. (TRBAM-21-03739) have utilized a Negative Binomial regression and a Support Vector Regression models trained by Artificial Bee Colony optimization algorithm to model work zone crash frequencies. Mokhtarimousavi, Seyedmirsajad et al. (TRBAM-21-03834) have used three machine learning algorithms, Support Vector Machine, Artificial Neural Network, and K-Nearest Neighbour to classify work zone crash severities. Dadvar, Seyedehsan and Mohamed Ahmed (TRBAM-21-04068) have examined 234 CA DMV AV-related crashes and have applied classification tree using Chi-square Automatic Interaction Detector method to classify these crashes. Shen, Xiaoyan et al. (TRBAM-21-00754) have used 3 Machine Learning decision tree C5.0, support vector machine and multilayer perceptron to extract the probable risk factors of road transport accidents of hazardous materials.

Pedestrians and Bicyclists safety combined with Wrong-Way Driving crashes: This sub-category has 11 papers presented in the Annual Meeting.

Meng, Fanyu et al. (TRBAM-21-04363) have proposed a procedure to extract pedestrian trajectories from travel-diary survey data based on a crowdsourced dataset. They then aggregated these data to 209 neighborhoods and developed a Bayesian spatially varying coefficients model to investigate the spatially non-stationary relationships between the number of pedestrian–motor vehicle crashes and related risk factors. Saeidi Razavi, Ray and Peter Furth (TRBAM-21-03931) have estimated the crash risk of bicyclists on exclusive path conflicting with left-turning vehicles having protected-only left turn phase. Shujuan, Ji et al. (TRBAM-21-01987) have studied bike crashes by using geographically weighted poisson regression under linear model of coregionalization assistance. Rahman, Mashrur et al. (TRBAM-21-00955) have used Negative Binomial models to predict pedestrian crashes. Maddox, Spencer et al. (TRBAM-21-01654) have conducted pedestrian-vehicle conflict analysis using automated video processing. Hossain, Moinul et al. (TRBAM-21-04058) have studied the pedestrian safety hazard due to jaywalking and cell phone induced distractions using bayesian networks.

Abou-Senna, Hatem et al. (TRBAM-21-04213) have conducted categorical principal component analysis of pedestrian crashes, using location characteristics, pedestrian factors, driver/vehicle characteristics, environmental-related factors and crash characteristics as categories. Ugan, Jorge et al. (TRBAM-21-03023) have tried to improve the safety performance functions for bicycle crashes at urban corridors by utilizing crowdsource data from STRAVA and on-street speed management countermeasures data. Hosseini, Parisa et al. (TRBAM-21-01970) have used text mining of crash report narratives using machine learning to identify wrong-way driving (WWD) crashes. Chang, Qing et al. (TRBAM-21-03488) have used a before-and-after evaluation of traditional traffic control devices for preventing wrong-way driving (WWD) at freeway off-Ramp crashes. Zhou, Huaguo et al. (P21-21214) have ranked different interchange types on wrong-way driving (WWD) crashes to undersyand the impact of geometric design elements on deterring these crashes at interchange terminals.

Analysis of Spatial and Naturalistic Driving Data (including SHRP 2 Data): There are 10 papers related to this sub-category.

Prevedouros, Panos et al. (TRBAM-21-01590) have analyzed near-misses using NDS data from on-board cameras in taxicabs. Bharadwaj, Nipjyoti et al. (TRBAM-21-03149) have used SHRP 2 NDS data to examine vehicle kinematics of rear-end safety-critical events. Ahmad, Numan et al. (TRBAM-21-02508) have pre-crash NDS data to categorize various driving errors and violations and explore their contribution to speed volatility and crash outcomes. Fahmid, Hossain and Juan Medina (TRBAM-21-03366) have presented a verification of usRAP risk assessments for run-off road and head-on crashes. Thay also have compared between risk estimations from usRAP and actual crash rates. Ahmad, Numan et al. (TRBAM-21-02508) have used NDS data to classify human factors into six driving errors and violations and explore pathways from driving errors and violations to crashes. Pei, Yingying et al. (TRBAM-21-03435) have conducted a macro-level safety analysis of crashes and violations using a bayesian bivariate negative binomial spatial conditional autoregressive (BNB-CAR) model. Khattak, Asad J. et al. (TRBAM-21-04104) have studied the heterogeneity in naturalistic driving errors, violations, and crash risk in diverse environmental context using SHRP 2 NDS data. Van Schalkwyk, Ida et al. (P21-20305) have estimated the societal cash benefits of existing and potential new installations of centerline and/or shoulder rumble strips on WA two lane rural highways. Roland, Jeremiah et al. (TRBAM-21-02286) have studied the effects of negative sampling on understanding network-level accident occurrences and spatio-temporal accident prediction. Cui, Haipeng et al. (TRBAM-21-02807) have studied the interactions between spatial and temporal correlations of crash observations using a full bayesian space-time random effect approach. They have proposed a Bayesian Spatiotemporal Interaction (BSTI) approach for crash frequency modeling with an Integrated Nested Laplace approximation (INLA) method to greatly expedite the estimation process. Diaz-Corro, Karla et al. (TRBAM-21-01773) have assessed the crash occurrence using historical crash data and a random effect negative binomial model to identify factors that influence crash occurrence within a Traffic Analysis Zone (TAZ) by accounting for serial and spatial correlation in longitudinal crash data.

Emergency Medical Services (EMSs) and Emergency Responder Workforce (Lecturn Session 1408): There are 9 papers/presentations related to these subjects in the Annual Meeting.

Li, Xiaobing et al. (TRBAM-21-00412) have conducted an integrated spatio-temporal analysis of emergency medical service response characteristics for stroke events by examining EMS delay

characteristics for patients with suspected strokes. Li, Xiaobing et al. (TRBAM-21-00501) have analyzed the EMS responses and compared between crash- and health-based emergency medical service response across Alabama. Hannoun, Gaby Joe and Monica Menendez (TRBAM-21-03691) have introduced a smart system for EMS by leveraging the modular vehicular technology initially developed for transit systems. The proposed system relies on the design of vehicular modules that can couple and decouple to transfer patients from a module to another during transport. Hosseinzadeh, Aryan et al. (TRBAM-21-00614) have used Machine Learning to model and compare EMS response time using four machine learning approaches, as well as regression analysis. Gudishala, Ravindra et al. (TRBAM-21-02851) have proposed generic metrics and a formula for measuring resiliency of a transportation network in the context of freeway incident diversionary behavior.

Brown, Michael (P21-21302), Candice McDonald (P21-21303), Gaynell Rochester (P21-21304), and Robert Lawrence (P21-21305) are leaders from Police, Fire, EMS and towing services to discuss their unique perspective on Emergency Responder Workforce related issues from recruitment and retention to safety and mental health (Session 1408: Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce).

Effect of Driver Behavior and Other Observed Performances on Safety: There are 11 papers related to this sub-category.

Sun, Changxin et al. (TRBAM-21-01839) have conducted statistical analysis and regional comparison of data collected from high-risk population groups and high-risk behaviors by 3 regions in China. Thay also calculated the road accident risk degree (RARD) and the combined workload index (WLX) and discussed in traffic laws and management. Goetz, Jackson and Kirolos Haleem (TRBAM-21-00071) have investigated the safety impact of distracted driving (“texting while driving”) for different roadway configurations and various lighting conditions using a driving simulator setting. Park, Subin et al. (TRBAM-21-00094) have proposed a novel safety indicator based on in-vehicle hazardous driving event data that is obtained from on-board devices, called digital tachographs (DTG), in Korea. Hunter, Margaret et al. (TRBAM-21-01539) have developed a proactive approach to evaluating intersection safety using hard-braking data to screen potential locations of rear-end crashes. Chen, Qinghong et al. (TRBAM-21-02212) have used vehicular trajectory data to explore risky factors and unobserved heterogeneity during lane-changing by using binary logit models and mixed binary logit models. Chen, Qinghong et al. (TRBAM-21-02215) have employed a naturalistic vehicle trajectory dataset to analyse risky factors and unobserved heterogeneity for different lane-changing vehicle patterns. Monyo, Denis et al. (TRBAM-21-03992) have developed a two-step approach involving a latent class clustering analysis and the penalized logistic regression to investigate factors that influence driving errors made by older drivers on interchanges. Sky Guo, Xiaoyu et al. (TRBAM-21-04183) have applied Random Forest algorithm to examine if the frequency of phone use while driving is a significant factor for predicting the number of distraction-affected crashes. Megat-Johari, Nusayba et al. (TRBAM-21-02354) have used logistic regression models to assess driver compliance with the law while considering important contextual factors. Megat-Johari, Megat-Usamah et al. (TRBAM-21-02355) have used a series of negative binomial models to examine total, speeding-related, and nighttime crashes based upon historical messaging data while controlling for other site-specific factors. Pawar, Nishant et al. (TRBAM-21-01268) have assessed the driving behavior, overtaking and crash probabilities of drivers during a car-following situation under three different time pressure conditions. of No Time Pressure (NTP), Low Time Pressure (LTP), and High Time Pressure (HTP).

COVID-19 and Highway Safety: There are 5 papers related to this sub-category.

Koloushani, Mohammadreza et al. (TRBAM-21-03025) have investigated in four counties of Florida to understand how changes in travel policies may affect traffic safety. Pierre, Roodson et al. (TRBAM-21-03793) have investigated changes in florida traffic crash trends due to COVID-19 Pandemic. Chatmon, Morgan et al. (TRBAM-21-00273) have studied the impact of COVID-19 on traffic crash trends in Tennessee. Romeo-Garcia, Amy et al. (TRBAM-21-01852) have studied the impact of COVID-19 on traffic crash trends in Florida. Hui, Matthew et al. (TRBAM-21-03043) have studied how during COVID-19 incident-based traffic safety metrics changed over time on state highways in the San Francisco bay area and Los Angeles regions.

Workshop 1027: Safety Performance Decision Making: Advancing Research Through Implementation

This workshop will build on the 2019 TRB Annual Meeting podium session, Using the Highway Safety Manual in the Real World, and the 2020 Use of Safety Performance in Day-to-Day Decision-Making workshop. The workshop will advance the science of safety analysis, decision making and putting research into practice. A key objective is to identify gaps that may lead to future research, resource development or training needs. This workshop will present interactive case studies, discuss unique aspects of safety performance calculations, outcomes and use in day-to-day transportation decision making and offer suggestions for addressing needs and communicating results to obtain outcomes.
Sponsored by:

- Standing Committee on Safety Performance Analysis (ACS20)
- Standing Committee on Performance Effects of Geometric Design (AKD10)

There is not enough information available to determin whether any of the workshop presentations fall into the category of “Data and Data Analysis.”

Welcome Bonnie Polin, Massachusetts Department of Transportation	P21-21268
Setting the Stage Wemple Elizabeth, HDR Priscilla Tobias, Arora and Associates, P.C.	P21-21269
Safety Performance and Decision Making for Suburban Corridor Robert Miles, Utah Department of Transportation	P21-21270
Suburban Corridor Safety Performance Breakout Activity David Petrucci, Federal Highway Administration (FHWA) Mouyid Islam, University of South Florida John Nitzel, Jacobs	P21-21271
Suburban Corridor Safety Performance Facilitated Report Jacob Farnsworth, Kimley-Horn and Associates, Inc.	P21-21272
Suburban Corridor Safety Performance Process and Approach Case Study: West South Blvd, Montgomery, Alabama	P21-21273

Michael Dimaiuta, GENEX Systems	
Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual, NCHRP 17-84 Darren Torbic, Texas A&M Transportation Institute	P21-21274
FHWA Safety Analysis Resources Jerry Roche, Federal Highway Administration (FHWA)	P21-21275
Safety Performance and Decision-Making Process and Approach Best Practices James Bonneson, Kittelson & Associates, Inc. (KAI) Kim Kolody, Jacobs	P21-21276
AASHTO Perspective on Quantitative Safety Performance Decision Making Stephen Read, Virginia Department of Transportation	P21-21277

Workshop 1033: Breaking Down Silos to Embrace Life in a Multimodal Performance Based Solution

Transportation professionals around the world are challenged to improve the safety and mobility of their transportation network to serve multimodal users. This workshop will begin with brief discussions of perspectives and issues associated with 'silos' within the transportation industry, such as institutional, organizational, planning/design, and operations/safety/design, as well as highlighting success stories how agencies have broken down these types silos. This will be followed by breakout sessions, where participants will engage in continuing identifying ongoing 'silos' and their associated challenges, what were done to break these down, as well as identifying needs and gaps to obtain answers to ongoing questions.
Sponsored by:

- Standing Committee on Performance Effects of Geometric Design (AKD10)
- Standing Committee on Pedestrians (ACH10)
- Standing Committee on Bicycle Transportation (ACH20)
- Standing Committee on Highway Capacity and Quality of Service (ACP40)
- Standing Committee on Access Management (ACP60)
- Standing Committee on Safety Performance Analysis (ACS20)
- Standing Committee on Public Engagement and Communications (AJE40)
- Standing Committee on Tort Liability and Risk Management (AJL70)
- Standing Committee on Urban Freight Transportation (AT025)

There is not enough information available to determin whether any of the workshop presentations fall into the category of “Data and Data Analysis.”

Background and Overview Hermanus Steyn, Kittelson & Associates, Inc. (KAI)	P21-21301
Overview of AASHTO Vision for Green Book 8th Edition (GB8) R. Marshall Elizer, Washington State Department of Transportation	P21-20549
Overview of AASHTO Vision for Green Book 8th Edition (GB8)	P21-20555

James Rosenow, Minnesota Department of Transportation	
FHWA's Breaking Down Silos and Managing Risk Through Performance Modelling George Merritt, Federal Highway Administration (FHWA)	P21-20551
Navigating modal advocates and local politics to deliver great multimodal projects Michael Carroll, City of Philadelphia	P21-20553
Tort Liability when you Step outside the Silos Paul Dorothy, S-E-A Limited	P21-20556
Bridging the Gap between Planning and Design: The Oregon DOT Performance - Based Design and Decision Process Richard Crossler-Laird, Oregon Department of Transportation	P21-20558
Closing Remarks of Workshop: Jeffrey Shaw, Federal Highway Administration (FHWA)	P21-20560

Workshop 1044: New Developments in Safety on Low Volume Roads

Most highway safety initiatives focus on the safety of high traffic volume highways and city streets, with little effort and funding devoted to low-volume rural roads. This workshop will provide a forum to exchange experience, best practice, and emerging technologies, including toolkits, smartphone applications, intelligent transportation systems, and novel driver education, specific to low volume road safety management. Case studies of successful implementation will be shared. The primary objective of the workshop is to improve safety on low volume roads by:

- Introducing best practices, new and innovative technologies, and lessons learned from using them, and
- Promoting national awareness and interest.

Sponsored by:

- Standing Committee on Low-Volume Roads (AKD30)
- Standing Committee on Transportation Safety Management Systems (ACS10)
- Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))

There is not enough information available to determin whether any of the workshop presentations fall into the category of "Data and Data Analysis."

Aerial Inspection of LVR Condition Surya Sarat Chandra Congress, Texas A&M University, College Station	P21-20559
Enhanced Rural Roads Safety with Unmanned Aerial Systems Austin Woody, University of Wyoming	P21-20561
Safety and Condition Assessment of LVRs in New Zealand Neil Bennett, Roads Consulting Limited	P21-20562

Practical Approach to Safety Problem Identification and Mitigation on County Roads Mario Romero, Purdue University	P21-20564
Application of Emerging Technologies in Road Safety Data Collection Lars Forslöf, Roadroid CEO/Inventor	P21-20566
Challenges and Promising Approaches for LVR Network Screening, a Critical Step in the HSIP Programs Ahmed Al-Kaisy, Montana State University	P21-20567
Safety Toolkit for Indian Tribes Sahima Nazneen, University of Wyoming Trenna Terrill, University of Wyoming	P21-20568
Panel Discussion with all participants involved	P21-20803

Lectern Session 1123: Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US

This panel will feature the voices of leading and emerging planning, engineering, policy, and public health researchers who will share knowledge on the ways in which Black, Indigenous, and People of Color (BIPOC) people experience restrictions, risks, indignities, and inequities while navigating pedestrian, bicycle, transit, and other transportation systems. They will highlight the social, political, economic, and health impacts of racial disparities in transportation and examine the ways in which our approaches to transportation research, planning, policy, and design can and must be reimagined to achieve greater mobility, health, and quality of life for all road users.

This is a unique session that touches a subject rarely brought up in the TRB. No specific information is available but most likely the data and analyses discussed in this session would be of interest to the researchers interested in “Data and Data Analysis.”

Authors / Panel Members	Celeste Chavis, Morgan State University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10) Subcommittee on Pedestrian Research (ACH10(1)) Subcommittee on Pedestrian and Autonomous Vehicle Interactions (ACH10(2)) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Subcommittee on Mainstreaming Global Research and Multi-faceted Data Collection on Gender Issues in Transportation (AME20(1)) Standing Committee on Transportation and Public Health (AME70)
Session Number	Lectern Session 1123
Session Title	Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US
Paper Number	P21-20643
Paper Title	**NA**
Abstract	NA

Authors / Panel Members	Lincoln Edwards, University of Arizona
Sponsoring Committee	Standing Committee on Pedestrians (ACH10) Subcommittee on Pedestrian Research (ACH10(1)) Subcommittee on Pedestrian and Autonomous Vehicle Interactions (ACH10(2)) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Subcommittee on Mainstreaming Global Research and Multi-faceted Data Collection on Gender Issues in Transportation (AME20(1)) Standing Committee on Transportation and Public Health (AME70)
Session Number	Lectern Session 1123
Session Title	Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US
Paper Number	P21-20644
Paper Title	**NA**
Abstract	NA

Authors / Panel Members	Keshia Pollack Porter, Johns Hopkins University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10) Subcommittee on Pedestrian Research (ACH10(1)) Subcommittee on Pedestrian and Autonomous Vehicle Interactions (ACH10(2)) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Subcommittee on Mainstreaming Global Research and Multi-faceted Data Collection on Gender Issues in Transportation (AME20(1)) Standing Committee on Transportation and Public Health (AME70)
Session Number	Lectern Session 1123
Session Title	Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US
Paper Number	P21-20645
Paper Title	**NA**
Abstract	NA

Authors / Panel Members	Richard Ezike, The Urban Institute
Sponsoring Committee	Standing Committee on Pedestrians (ACH10) Subcommittee on Pedestrian Research (ACH10(1)) Subcommittee on Pedestrian and Autonomous Vehicle Interactions (ACH10(2)) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Subcommittee on Mainstreaming Global Research and Multi-faceted Data Collection on Gender Issues in Transportation (AME20(1)) Standing Committee on Transportation and Public Health (AME70)
Session Number	Lectern Session 1123
Session Title	Arrested Mobility: Exploring the Impacts of Over-policing (i.e., policy, police and polity) BIPOC Mobility in the US
Paper Number	P21-20646
Paper Title	**NA**
Abstract	NA

Lectern Session 1143: Safety Performance and Analysis Doctoral Student Competition

There is not enough information available to determin whether any of the workshop presentations fall into the category of "Data and Data Analysis."

Authors	MD Sultan Ali, Florida International University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21278
Paper Title	**Assessing the Safety Impacts of Transit Signal Priority Using Full Bayes Before-After Study**
Abstract	NA

Authors	Mohamed Essa, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21279
Paper Title	**Real-time Safety and Mobility Optimization of Traffic Signals in a Connected Vehicle Environment**
Abstract	NA

Authors	Henrick Haule, Florida International University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21280
Paper Title	**Evaluating the Safety Impacts of Ramp Metering on Freeways**
Abstract	NA

Authors	Ricardo Jacome, Mid-America Transportation Center
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21281
Paper Title	**On-Road Coordinates for Autonomous Vehicle Guidance**
Abstract	NA

Authors	Pei Li, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21283
Paper Title	**The Application of Novel Connected Vehicles Emulated Data on Real-Time Crash Potential Prediction for Arterials**
Abstract	NA

Authors	Seyedeh Maryam Mousavi, Texas A&M University, College Station
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21285
Paper Title	**Examining the Effects of Non-Infrastructure Variables on The Safety Performance of Mixed Traffic Environments at a Signalized Intersection**

Abstract	NA

Authors	Duc Phan, La Trobe University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21286
Paper Title	**Can Walking and Cycling for Train Access Improve Road Safety? A Case Study in Victoria, Australia**
Abstract	NA

Authors	Beijia Zhang, Auburn University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20) Standing Committee on Statistical Methods (AED60)
Session Number	Lectern Session 1143
Session Title	Safety Performance and Analysis Doctoral Student Competition
Paper Number	P21-21287
Paper Title	**A Comprehensive Study of Driver Behaviors at Unsignalized Intersections Using SHRP2 Naturalistic Driving Study Data**
Abstract	NA

Poster Session 1183: Emergency Response, Incident Management, and Public Health

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Qinglin Hu, University of Alabama Abbey Gregg, University of Alabama
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Poster Session 1183
Session Title	Emergency Response, Incident Management, and Public Health
Paper Number	TRBAM-21-00412
Paper Title	**An Integrated Spatio-temporal Analysis of Emergency Medical Service Response Characteristics for Stroke Events Across Alabama**
Abstract	Stroke treatment must be given within the first few hours of symptom onset, so rapid Emergency Medical Services (EMS) response is essential for positive patient outcomes. Examining EMS response characteristics across temporal and geographical perspectives is critical for improving Alabama's stroke death rate from its current 49th place in the U.S. We examined EMS delay characteristics for patients with suspected strokes from 2018-2019 across Alabama, with particular attention paid to rural and urban differences. We used EMS call data from the Alabama Department of Public Health and defined possible stroke cases as calls where a stroke scale completed by EMS was positive or indeterminate. Time between EMS dispatch and destination arrival was coded as EMS delay. This study incorporates global and local spatio-temporal weighted ordered logistic regression models to evaluate significant non-stationary correlations of factors with EMS delay by accounting for unobserved heterogeneity. There were 17,088 possible stroke cases, and 74% of these calls had total response times within 60 minutes. Longest EMS delay was observed in rural counties. EMS response characteristics, such as pre-arrival instructions and advanced vehicle navigation were associated with shorter delays, while long travel distance and on-scene/transport times were associated with longer EMS delays. The impact of response characteristics on stroke-event based EMS delay varied significantly across rural and urban counties and time (i.e., between 2018 and 2019). The revealed spatio-temporal correlations are useful for EMS personnel in applying effective localized rural and urban EMS response improvement strategies.

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Qinglin Hu, University of Alabama Abbey Gregg, University of Alabama
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Poster Session 1183
Session Title	Emergency Response, Incident Management, and Public Health
Paper Number	TRBAM-21-00501
Paper Title	**Analysis and Comparison Between Crash- and Health-based Emergency Medical Service Response Across Alabama**
Abstract	Emergency Medical Services (EMS) can respond to multiple types of urgent requests from patients demanding urgent healthcare. The total time duration of EMS responding to those requests consists of multiple delays at several stages (e.g., response-to-scene, on-scene, transport). Additionally, the corresponding delay at each stage may correlate with different characteristics (e.g., number of crews/patients, signal priority, acuity). Furthermore, those characteristics can have diversified correlations with EMS response for different urgent requests. To capture the diversified correlations for crash-based and health-based EMS requests, this paper collected EMS call data (2018-2019) from the Alabama Department of Public Health and defined crash-based EMS responses as people who are injured in traffic accidents and health-based EMS response as people who either have heart-related health issues or stroke. To account for unobserved heterogeneity due to limited available data, we use random parameter parametric survival models to explore potential varying correlations of the characteristics associated with delays at different stages for three EMS response types. The results indicate that 108,304, 110,262, and 24,421 EMS responses were requested for traffic crashes, heart problems, and stroke, respectively. The modeling results show that at different stages of EMS responses, the associated characteristics are diversified. More importantly, the associations of the same characteristics with delays are significantly distinct for the three studied EMS response types at different response stages. For example, advanced vehicle technologies are found to have positive associations at response-to-scene stage, but negative associations at transport stage for crash-based EMS responses. More implications are discussed in the paper.

Authors	Gaby Joe Hannoun (gabyjoe.hannoun@gmail.com), New York University, Abu Dhabi Monica Menendez, New York University, Abu Dhabi
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Poster Session 1183
Session Title	Emergency Response, Incident Management, and Public Health
Paper Number	TRBAM-21-03691
Paper Title	**Modular technology for Emergency Medical Services**
Abstract	While advancements in vehicular and wireless communication technologies are shaping the future of our transportation system, emergency medical services (EMS) are not receiving enough research attention. Their operations are still plagued by response delays that can often be life-threatening. Dispatching and redeployment systems identify the best practices regarding the allocation of the resources to emergencies and stations. The existing systems are unfortunately insufficient, and there is a growing need to embrace new technological solutions. This research introduces a smart system for EMS by leveraging the modular vehicular technology initially developed for transit systems. The proposed system relies on the design of vehicular modules that can couple and decouple to transfer patients from a module to another during transport. A fleet of medical transport vehicles is deployed to cooperate with the life support vehicles by providing for example transport and hospital admission tasks, thus allowing life support vehicles to answer pending emergency calls earlier. This is especially useful when there is a large demand for EMS (e.g. under the COVID-19 pandemic). This paper develops a mathematical programming model to determine the optimal assignment decisions. A comparative analysis is executed and results show that reductions in response times and arrival times to hospital can be achieved with the modular technology, with average improvements of up to 17.51% and 40.88% respectively, for the tested scenarios.

Authors	Aryan Hosseinzadeh (Aryan.Hosseinzadeh@louisville.edu), University of Louisville Mohamadreza Haghani, University of Louisville Robert Kluger, University of Louisville
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Poster Session 1183
Session Title	Emergency Response, Incident Management, and Public Health
Paper Number	TRBAM-21-00614
Paper Title	**Exploring Influencing Factors on Crash-related Emergency Response Time: A Machine Learning Approach**
Abstract	Crashes lead to three million injuries in the United States every year who needs immediate care and swift transfer to the emergency department of hospitals. Reducing ambulance response time can save lives. Therefore, identifying the factors associated with emergency medical services response time can help to shape policy and operational changes. The objective of the current study is an investigation to find what impacts emergency response time in motor vehicle crashes among individual-related and crash-related variables. It followed with a more in-depth investigation of each factor in Jefferson County, Kentucky. The study employed a linked dataset of police-reported crash data, EMS runs from Computer-Aided Dispatch and Patient Care Reports. In this study, EMS response time was modeled and compared using four machine learning approaches, as well as regression analysis. The most successful approach in terms of root mean square error and goodness of fit was chosen to represent contributing factors. The results show EMS travel distance, the discrepancy between police and dispatch location, crash type, time of day, number of injuries and injury location code were important factors in EMS response time. The study outcome can be used to guide practice and help EMS reduce the time to care for motor vehicle crashes.

Authors	Ravindra Gudishala (Ravindra.Gudishala@arcadis.com), Arcadis Saurabh Bawankule, Arcadis US Inc Chester Wilmot, Louisiana State University Brian Wolshon, Louisiana State University
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Poster Session 1183
Session Title	Emergency Response, Incident Management, and Public Health
Paper Number	TRBAM-21-02851
Paper Title	**Freeway Incident Diversion Behavior as a Measure of Transportation Network Resiliency**
Abstract	Disruption caused by an incident reduces the performance of transportation networks. In this case, road users try to redistribute themselves onto alternate serviceable routes. Assuming that no external assistance is provided to the network for recovery, redistribution behavior of the road users helps the network in mitigating performance lost due to incident. The main objective of the study was to propose generic metrics and a formula for measuring resiliency of a transportation network in the context of freeway incident diversionary behavior and the secondary objective was to apply and check its workability on the data collected for LA DOTD's (Louisiana Department of Transportation and Development) diversionary behavior study. Other objective includes understanding and interpreting the motorist's adaptive behavior in resiliency context. The findings from the study indicate that resiliency is not a fixed value for facility but varies depending on the severity of the incident, the opportunities in the network for diversion, by the behavior of road users, and actions of network managers.

Poster Session 1169: Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)

Authors	Fanyu Meng, Southern University Jie Zhang, Southwest Jiaotong University S.C. Wong, University of Hong Kong Pengpeng Xu, University of Hong Kong Ni Dong (dongni@home.swjtu.edu.cn), Southwest Jiaotong University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04363
Paper Title	**TOWARDS ACTIVITY-BASED EXPOSURE MEASURES IN SPATIAL ANALYSIS OF PEDESTRIAN-MOTOR VEHICLE CRASHES**
Abstract	Background: Although numerous efforts have been devoted to exploring the effects of area-wide factors on the frequency of pedestrian crashes in neighborhoods over the past two decades, existing studies have largely failed to provide a full picture of the factors that contribute to the incidence of zonal pedestrian crashes, due to the unavailability of reliable exposure data and use of less sound analytical methods. Methods: Based on a crowdsourced dataset in Hong Kong, we first proposed a procedure to extract pedestrian trajectories from travel-diary survey data. We then aggregated these data to 209 neighborhoods and developed a Bayesian spatially varying coefficients model to investigate the spatially non-stationary relationships between the number of pedestrian–motor vehicle (PMV) crashes and related risk factors. To dissect the role of pedestrian exposure, the estimated coefficients of models with population, walking trips, walking time, and walking distance as the measure of pedestrian exposure were presented and compared. Results: Our results indicated substantial inconsistencies in the effects of several risk factors between the models of population and activity-based exposure measures. The model using walking trips as the measure of pedestrian exposure had the best goodness-of-fit. We also provided new insights that in addition to the unstructured variability, heterogeneity in the effects of explanatory variables on the frequency of PMV crashes could also arise from the spatially correlated effects. After adjusting for vehicle volume and pedestrian activity, road density, intersection density, bus stop density, and the number of parking lots were found to be positively associated with PMV crash frequency, whereas the percentage of motorways and median monthly income had negative associations with the risk of PMV crashes. Conclusions: The use of population or population density as a surrogate for pedestrian exposure when modeling the frequency of zonal pedestrian crashes is expected to produce biased estimations and invalid inferences. Spatial heterogeneity should also not be negligible when modeling pedestrian crashes involving contiguous spatial units.

Authors	Ray (Mohammad) Saeidi Razavi (mohammad.saeidi.1982@gmail.com), Northeastern University Peter Furth, Northeastern University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-03931
Paper Title	**Risk from Left Turns Across Multiple Lanes to Bicyclists in a Separated Path: A Case for Protected-Only Left Turns**
Abstract	At signalized intersections, permitted left turns (i.e., on a green ball, after yielding) across multiple through lanes and across a separated bike lane or bike path present a substantial threat to bicyclist safety. A conflict study of two such intersections found that when cyclists cross while one or more vehicles is waiting to turn left and there is no opposing through traffic to block it, the chance of a motorist yielding safely (i.e., waiting in the left turn lane) was only 9%, and the chance of their yielding at all – including yielding only after beginning the turn, then stopping in the opposing through lanes – was still only 37%. Non-yielding rates were worse for bikes arriving during green, for bikes riding on the right side of the road and therefore facing a left cross conflict, and for bikes facing a queue with multiple left turning vehicles. Of 112 cyclists who arrived on green when there was at least one left-turning car but no opposing through traffic blocking it, 73 had to slow or stop to avoid a collision. While these conflicts could be essentially eliminated using protected-only left turn phasing (turn on green arrow), existing criteria prefer permitted left turns to reduce vehicular delay. A case study shows how, by considering multiple signalization alternatives, it can be possible to convert left turns to protected-only phasing without imposing a substantial delay burden on vehicles or other road users. Keywords: Bicycle Safety, Left Turn Phasing, Permitted Turns, Signalized Intersections

Authors	Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Yongfeng Tang, Tongji University Mohammed Quddus, Loughborough University Qingya Zhou, Guangzhou Urban Planning and Design Survey Research Institute Xinyi Hou, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01968
Paper Title	**Spatial Models for High-Accurate Hot Zone Identification for E-bikes**
Abstract	Show Abstract The use of electric bicycles (e-bikes) has growing rapidly in recent decades, resulting in a significant rise in e-bike crash rates. Therefore, improving the safety of e-bikes is essential to maintain the rapid growth of this sustainable mode of transport. One policy prescription is to focus on area-wide traffic safety management by identifying hot zones for e-bike crashes and their contributory factors. In macro-level safety modelling, the primary explanatory variable – the area of a zone, vary greatly in sizes. This phenomenon poses realistic challenges to the accuracy of macro-level statistical models. Yet, limited studies examined the influence of discrepancy in zone sizes on macro-level safety analysis related to e-bikes. To fill the research gap, this study aims to examine the influence of the size of an area on macro-level modelling. Spatial data on e-bike crash, road network, land use and socio-economic for 213 administrative units in Shanghai were collected. Then three Poisson log-normal Conditional Autoregressive models were developed with different modelling strategies to address the impact of area scale. In Model 1, area was modelled as a regular independent variable. While in Model 2, area was considered as an exposure variable. Finally, in Model 3, independent variables and dependent variable were divided by area. The results indicated Model 2 outperforms other two models. To identify hot zones, Potential for Safety Improvement estimates of three models were aggregated separately. The findings from this study can provide guidelines in considering the influence of area scale in macro-level modelling and hot-zone identification.

Authors	Shujuan Ji, Chang'an University Yuanqing Wang (wyqing@chd.edu.cn), Chang'an University Yao Wang, Chang'an University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01987
Paper Title	**Geographically Weighted Poisson Regression under Linear Model of Coregionalization Assistance: Application to a bicycle crashes study**
Abstract	Cycling benefits individuals and society. However, cyclists are vulnerable road users and its safety concern arises macro-level spatial crash studies. This study intends to investigate the spatial effects of population, land use and bicycle lane infrastructures on the bicycle crashes. This was done by dealing with the issue of spatial correlation and spatial non-stationary simultaneously by developing semi-parametric Geographically Weighted Poisson Regression (sGWPR) model. It is a model combined both constant and geographically varying parameters. For determining which parameters are fixed and non-stationary, previous study suggested monitoring Akaike Information Criterion (AICc) to make decision whether a parameter should vary geographically or not. Yet, only relying on AICc might bury some spatial associations. In this study, we propose Linear Model of Coregionalization (LMC) to assist the decision. Here, we use bicycle crash data across the metropolitan area of Greater Melbourne to establish sGWPR models suggested by AICc and LMC. Comparing the two sGWPR models, we found the sGWPR model under LMC results has better performance, and 30% improvement in the mean squared prediction error (MSPE). It also uncovers more details about spatial relationship between bicycle crashes and bicycle lane intersection density (BLID), which is not suggested under AICc results. The parameters of BLID, a new measurement of bicycle lane facilities proposed by us, are positive and vary over space in majority analysis zones in Greater Melbourne. Keywords: semi-parametric GWPR, spatial non-stationary, spatial correlation, macro-level

Authors	Paolo Intini (paolo.intini@poliba.it), Politecnico di Bari Nicola Berloco, Politecnico di Bari Achille Fonzone, Edinburgh Napier University Grigorios Fountas, Edinburgh Napier University Vittorio Ranieri, Polytechnic University of Bari Pasquale Colonna, Politecnico di Bari
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02219
Paper Title	**Grouped random parameter multinomial logit for studying the influence of traffic, geometric and context variables on urban crash types**
Abstract	Previous research has shown that different factors may influence the occurrence of crashes of different types. In this study, a dataset including information from crashes occurred at segments and intersections of urban roads in Bari, Italy was used to estimate the likelihood of occurrence of various crash types. The crash types considered are: single-vehicle, angle/head-on, rear-end and sideswipe. Models were estimated through a mixed logit structure considering various crash types as outcomes of the dependent variable and several traffic, geometric and context-related factors as explanatory variables (both site- and crash-specific). To account for systematic, unobserved variations among the crashes occurred on the same segment or intersection, the grouped random parameters approach (estimating segment- or intersection-specific parameters) was employed. This approach allows assessing the variability of results across the observations for individual segments/intersections. Segment type, bus lanes were included as explanatory variables in the model of crash types for segments. Traffic volume per entering lane, total entering lanes, total number of zebra crossings, balance between major and minor traffic volumes at intersections were included in the model of crash types for intersections. Area type was included in both segment and intersection models. Typical traffic at the moment of the crash and the period of the day were included in both segment and intersection models. Significant variations in the effect of several predictors across different segments or intersections were identified. The applicability of the study framework is demonstrated, in terms of identifying high-risk or anomalous sites with respect to specific crash types.

Authors	Mashrur Rahman, University of Texas, Austin Kara M. Kockelman (kkockelm@mail.utexas.edu), University of Texas, Austin Kenneth Perrine, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-00955
Paper Title	**Predicting Pedestrian Crash Occurrence And Injury Severity In Texas**
Abstract	This study investigates pedestrian-involved crashes across Texas from 2010 through 2019. Crashes were mapped to over 708,738 road segments , along with road design, land use, transit, hospital, rainfall and other location features. Negative binomial model results show how total and fatal pedestrian-crash rates and counts rise with a segment's number of lanes, transit stops, population and job densities, as well as proximity to schools and hospitals, while greater median and shoulder widths provide some protection. Higher speed limits are associated with lower crash frequencies but more fatalities. A heteroskedastic ordered probit (HOP) model for injury severity demonstrates how pedestrian crashes are more likely to be severe and fatal at night (8 PM – 5 AM), without overhead lighting, and when the pedestrians or drivers are intoxicated. Use of light-duty trucks (including SUVs, pickup trucks, CUVs, and vans) also significantly increases the risk of pedestrians being severely injured or killed. While newer vehicle safety features may be argued to lower crash severity, newer crash-involved vehicles in Texas are not found to deliver less pedestrian injury. However, being a younger or female pedestrian, on a straight segment, off the state (and interstate) highway system, in the presence of a traffic control device (stop sign or signal) lowers the likelihood of pedestrian injury, when one does become involved in such a crash.

Authors	Spencer Maddox, Kittelson and Associates, Inc. Colin Usher, Georgia Institute of Technology (Georgia Tech) Kari Watkins (kari.watkins@ce.gatech.edu), Georgia Institute of Technology (Georgia Tech)
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01654
Paper Title	**Automated Video Processing for Pedestrian-Vehicle Conflict Analysis**
Abstract	Pedestrian fatalities have risen in the United States over the past decade. On an individual corridor, however, it is difficult to determine whether crashes and fatalities are statistically significant or random occurrences. When considering mitigation efforts, transportation planners and engineers therefore need to accurately categorize pedestrian exposure and risk. Traditionally, risk and exposure were calculated by performing manual counts. Advancements in automated video processing, where objects are tracked from a recorded video, can categorize conflicts automatically. Using outputs from a developed tracking system, this paper defines a successful methodology to identify conflicts and calculate the post-encroachment time. This methodology can be applied to both intersection and non-intersection locations. Results from four sample sites support previous research that mid-block crossings occur more often when crosswalks are not nearby and the relationship between pedestrians and conflicts are not necessarily linear. Using this conflict identification methodology and automated video processing provides transportation planners and engineers with a better understanding of pedestrian risk at key locations.

Authors	Changxin Sun (782428620@qq.com), Wuhan University of Technology Yi HE, Wuhan University of Technology Chaozhong Wu, Wuhan University of Technology
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01839
Paper Title	**Factors related to road safety of couriers: A comparison of three regions in China**
Abstract	The couriers have become a popular mode for urban cargo transportation in China. Riders' risky behaviors of couriers lead to many accidents. We surveyed population attributes, working conditions, seven types of selected risky driving behaviors, and road accident involvement of 824 participants engaged in couriers from the BTUA, YRDUA ,and the PRDUA. Statistical analysis and regional comparison of data collected identified high-risk population groups and high-risk behaviors by regions, calculated the road accident risk degree (RARD) and the combined workload index (WLX) and discussed in traffic laws and management. A well-fitting path model is set up to explore the relationship between working conditions and road risk. The results show that couriers have a high workload and road accident risk, and BTUA is relatively better in three regions. The young people with intermediate working experience are the high-risk group. Among the seven risk behaviors, distracted driving and aggressive driving are of particular concern that have the high incidence and risk and national and local regulations also lack management of specific risky behaviors (especially in Guangzhou) and punitive measures. Finally, the path analysis model shows that workload promotes the generation of anxiety and anger, and promotes the occurrence of risk behaviors and road accidents to a certain extent. The road safety of couriers can be effectively improved by improving different working conditions according to the path differences in three regions.

Authors	Moinul Hossain (moinul048i@yahoo.com), Islamic University of Technology (IUT) Afia Jahin Prema, Islamic University of Technology Dewan Tanvir Ahammed, Islamic University of Technology Niaz Mahmud, Islamic University of Technology Md Asif Raihan, Bangladesh University of Engineering and Technology Md. Abdullah Al Mamun, Universita degli Studi di Roma La Sapienza
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04058
Paper Title	**Pedestrian Safety Hazard Due to Jaywalking and Cell Phone Induced Distractions: A Synopsis from Highway Intersections in Bangladesh**
Abstract	Pedestrian fatalities account for 22% of all road traffic fatalities around the world. The statistics are even grimmer for the developing countries where jaywalking is predominant. There, along with jaywalking, the use of cell phones while crossing the road is acerbating pedestrian casualties. This delves into thought processing of jaywalkers and pedestrians using cell phones while crossing roads to devise countermeasures for improving pedestrian safety. The study observes pedestrian behavior at 32 intersections on national and regional highways of Bangladesh through video data and subsequently interviews 2,016 pedestrians found jaywalking and/or using cell phones while crossing the road. Data on their socio-economic and demographic characteristics, various risk perceptions, physical obstructions forcing jaywalking, distracting cell phone use, road crossing behavior and their knowledge about basic rules of the road were collected. Next, Bayesian Networks (BBN) were constructed to answer ‘who’, ‘why’ and ‘how’ related questions regarding jaywalkers and pedestrians who use a cell phone while road crossing. The findings suggest that jaywalking is more predominant among males, aged between 26-40 years who have received secondary education despite having decent knowledge regarding basic rules of the road. The most influential factors concerning risky jaywalking and using cell phone while road crossing are ‘Gender’, ‘Jaywalker Activities’, ‘Driving experiences’, ‘Purposes of Journey’, and ‘Frequency of visit that area’. The identified high impact variables associated with jaywalking, and also the triggering factors of cell phone-induced jaywalking are expected to assist decision-makers to develop pragmatic pedestrian safety policies in the context of developing countries.

Authors	Hatem Abou-Senna (habousenna@ucf.edu), University of Central Florida Essam Radwan, University of Central Florida Hassan Tahsin, Cairo University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04213
Paper Title	**Categorical Principal Component Analysis (CATPCA) of Pedestrian Crashes in Central Florida**
Abstract	This research investigates the characteristics and contributing causes of pedestrian crashes that occurred in Central Florida over a 5 year-period at intersections and mid-blocks along roadway segments. The factors affecting pedestrian crashes were classified into five main categories; location characteristics, pedestrian factors, driver/vehicle characteristics, environmental-related factors and crash characteristics. Categorical Principal Components Analysis (CATPCA) was applied to understand the structure of a set of variables and to reduce the dimensionality of the dataset to a predefined number of dimensions and components. The analysis showed that majority of the intersection crashes were during night time with pedestrians under influence and failing to yield to the right of way (ROW). They included mainly left-turn and right-turn crashes. In addition, drivers were also found at fault due to vision issues resulting from absence of lighting at intersections and categorized as failure to yield to the ROW. At midblock locations, major crash types were through moving vehicles hitting pedestrians crossing and walking along the roadway especially during night time conditions. However, majority of the crashes were at locations away from the designated crossings likely due to the long distances between legal locations and pedestrian's failure to utilize them. The findings of this research and examining the factors affecting pedestrians' crash likelihood and injury severity can lead to better crash mitigation strategies, countermeasures and policies that would alleviate this growing problem in Central Florida.

Authors	Jorge Ugan, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai (qingcai@knights.ucf.edu), University of Central Florida Nada Mahmoud, University of Central Florida Ma'en Al-Omari, University of Central Florida Brenda Young, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-03023
Paper Title	**Effects of Various Speed Management Countermeasures on Bicycle Crashes for Urban Roads in Central Florida**
Abstract	In recent years, cycling has become an increasingly popular mode of transportation around the world. In contrast to other popular modes of transportation, cycling is more economic and energy efficient. Many studies that have focused on bicycle safety, were limited in terms of bicycle exposure data This study tries to improve the current safety performance functions for bicycle crashes at urban corridors by utilizing crowdsource data from STRAVA and on-street speed management countermeasures data. Since there is a disproportion in the representation of cyclists from the STRAVA data, adjustments, using a Tobit model, were done to more accurately represent the cyclists based on video detection data. This study aims to (1) identify a method to get more accurate bicycle exposure data, (2) analyze the effect that speed management countermeasures have on bicycle safety, and (3) incorporate other contributing factors to bicycle safety. To achieve these objectives, a Bayesian hierarchical model was used to predict the frequencies of bicycle crashes and adjust STRAVA data at the same time. Traffic, roadway attributes, on-street speed management countermeasures data, and land use data were considered in the model. The results revealed several key components for bicycle safety at urban intersections. The study concluded that crowdsourced data adjusted based on video detection and on-street speed management countermeasures data are significant when analyzing bicycle safety.

Poster Session 1202: Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)

Authors	Jackson Goetz, Western Kentucky University Kirolos Haleem (kirolos60@hotmail.com), Western Kentucky University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-00071
Paper Title	**Investigating Distracted Driving at Roundabouts and Different Road Configurations Using a Driving Simulator**
Abstract	This study investigates the safety impact of distracted driving ("texting while driving") for different roadway configurations (i.e., "intersections, segments, freeways, and roundabouts", "urban, suburban, and rural sections", and "straight and curved road cross-sections") and various lighting conditions (nighttime and daytime) using a driving simulator setting. The novelty of this study is investigating distracted driving at roundabouts. The simulator study took place at Western Kentucky University in Bowling Green, KY. Participants in this study included two main age groups, young adults (between 19 and 25 years) and middle-age groups (between 26 and 64 years). Overall, the standard deviation of speed and lane position of all participants was greater while texting and driving (i.e., when distracted). Both age groups drove significantly different from each other in terms of "lane position keeping" while texting and driving. "Driver speed" was a significant factor impacting "texting while driving" along rural straight and curved road sections. Texting at nighttime on the freeway for middle-age drivers had about 87% higher speed variance than texting at daytime. Texting at nighttime caused the highest speed variance than any daytime operation (either texting or not texting) for both age groups. At roundabouts, middle-age adults had greater speed and lane variances compared to their younger counterparts. Furthermore, there existed a relatively high speed and lane variances for both age groups, raising concerns about texting and driving at roundabouts. Useful recommendations include displaying message signs on the road that alert drivers on the dangerous effect of texting and driving, especially at nighttime.

Authors	Subin Park, Hanyang University, Ansan Cheol Oh (cheolo@hanyang.ac.kr), Hanyang University Shinhye Joo, Korea Transportation Safety Authority Sungmin Hong, Korea Transportation Safety Authority
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-00094
Paper Title	**An Indicator for Evaluating Regional Safety Performance using In-vehicle Hazardous Driving Event Data**
Abstract	The evaluation of traffic safety levels is a fundamental aspect of supporting the establishment of safety policies and technical countermeasures by local governments. Existing safety indices that use actual crash data have limitations for the achievement of more active safety enhancement because long-term data collection is required to obtain sufficient samples. A promising alternative is to use indirect safety measures, which can be further upgraded in the era of big data, in the evaluation of traffic safety. This study proposes a novel safety indicator based on in-vehicle hazardous driving event data that is obtained from on-board devices, called digital tachographs (DTG), in Korea. The DTG-based indicatorex for evaluating traffic safety (DIETS), which is a probabilistic measure for quantifying the safety levels of local governments, was developed based on binary logistic regression (BLR) analyses. Hazardous driving events identified from DTG data were analyzed to derive independent variables in BLR modeling. DIETS is expected to facilitate the effective decision-making of local governments for the development and implementation of safety policies.

Authors	Sijun Shen (sshen@g.clemson.edu), Nationwide Children's Hospital Simon Lin, Research Institute at Nationwide Childrens Hospital Motao Zhu, Research Institute at Nationwide Childrens Hospital
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-00588
Paper Title	**Using Machine Learning Algorithms and Fine Geo-resolution Vehicle Telemetric Data to Predict Crash Spots**
Abstract	Background: The prevalence of mobile sensing platforms allows researchers to evaluate individual driver safety using vehicle telemetric data. However, no study has assessed the feasibility of using aggregated vehicle telemetric data to predict crash spots. Objectives: The objective of this study is to determine if the aggregated fine geo-resolution vehicle telemetric data can be used to predict crash likelihood for roadway segments. Methods: The telemetric data from the GEOTAB company were used. The GEOTAB company recorded the frequency of harsh acceleration, harsh braking, harsh cornering, and the average magnitude of those harsh events for every 150×150 meter2 roadway segments within Columbus, Ohio between January and April 2018. Crash history were obtained from the 2018-2019 Ohio Policy Accident Report. Regularized logistic regression (RLR) with lasso penalty and boosted decision tree (BDT) algorithms were used to develop the predicting models. Results: Aggregated vehicle telemetric data provided effective predictions for crash spots (Area under curve [AUC] ≥ 0.73). Models' predictive performance can be further improved if both vehicle telemetric variables and crash history were included in the models (AUC ≥ 0.77). The BDT models had superior predictive performance than the RLR models, due to its capability of incorporating complex relationships (e.g., non-linearity and all-way interactions) between predicting and predicted variables. Conclusion: Our study demonstrates the utility of geo-resolution vehicle telemetric data to predict crash spots. Aggregated vehicle telemetric data provide valuable information for crash likelihood monitoring and thereby, enable implementation of timely safety interventions by police and city planner.

Authors	Yanli Ma (mayanli@hit.edu.cn), Harbin Institute of Technology Jieyu Zhu, Harbin Institute of Technoloy Ke Chen, Heilongjiang Provincial Highway Survey and Design Institute
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01109
Paper Title	**Left-turn Conflict Identification at Signal Intersections Based on Vehicle Trajectory Reconstruction Via Kalman Filtering**
Abstract	To reduce traffic accidents at signal intersections, it is significant to investigate the conflict identification between left-turning vehicles and straight vehicles in the opposite direction. The trajectory data of vehicles can be used to identify real-time conflicts in intersections. To perform such identification, accurate vehicle localisation should be obtained to clearly recognise the conflicts between left-turning vehicles and straight vehicles in the opposite direction at the signal control intersection. On the basis data collection of coordinate position, velocity, acceleration and yaw Angle of vehicles, Kalman filter algorithm was used to estimate the vehicle trajectory to obtain the vehicle kinematics information via the on-board system. The traffic conflict areas of the left-turning vehicles and straight vehicles in the opposite direction were determined through vehicle trajectory extrapolation, and the left-turn collision at the signal intersection was identified using the post-encroachment time algorithm and vehicle movement information. In addition, Anderson–Darling and modified Kolmogorov–Smirnov tests were performed to verify the goodness of fit of the data. Results show that the vehicle speed and localisation errors of the proposed method decreased by 66.67% and 83.33% compared with the results before filtering, respectively. Moreover, the results of the conflict recognition method based on trajectory reconstruction is consistent for both goodness of fit tests. This study can provide driving decision for drivers of left-turning vehicles and provide technical support for the research and development of left-turn anti-collision systems.

Authors	Margaret Hunter (hunter87@purdue.edu), Purdue University Enrique Saldivar-Carranza, Purdue University Jairaj Desai, Purdue University Jijo Mathew, Purdue University Howell Li, Purdue University Darcy Bullock, Purdue University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01539
Paper Title	**A Proactive Approach to Evaluating Intersection Safety Using Hard-braking Data**
Abstract	Typical safety improvements at signalized intersections are identified and prioritized using crash data over 3-5 years. Enhanced probe data that provides date, time, heading, and location of hard-braking events has recently become available to agencies. In a typical month, over six million hard-braking events are logged in the state of Indiana. This study compared rear-end crash data over a period of 4.5 years at 8 signalized intersections with weekday hard-braking data from July 2019. Using Spearman's rank-order correlation, results indicated a strong correlation between hard-braking events and rear-end crashes occurring more than 400 ft upstream of an intersection. The paper concludes that hard-braking events occurring at a far distance from the stop bar may be a useful tool to screen potential locations of rear-end crashes and follow up with mitigation measures quicker than the 3-5 year cycle used by agencies that rely on crash data. Now that hard-braking data is commercially available in the United States, these techniques scale quite easily to state and national levels for near immediate implementation.

Authors	Panos Prevedouros (pdp@hawaii.edu), University of Hawaii Braxton Chong, University of Hawai'i, Manoa Luana Pereira,, University of Hawai'i, Manoa
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01590
Paper Title	**Analysis of Speed Profiles of Near-Misses from On-Board Cameras in Taxicabs**
Abstract	Partly due to the pre-Covid-19 booming economy and the increasing numbers of distracted 37 motorists and other road users, safety risk (and insurance premiums) increased substantially 38 making liability reduction via monitoring, evaluation and coaching necessary for professional 39 drivers. The CEE Department at the UH, in collaboration with taxi and tour operators in Hawaii 40 have deployed state-of-the-art in-vehicle video monitoring equipment; the UH team assists in the 41 creation of a naturalistic driving database based on accelerometer-triggered "harsh events" that 42 record video clips starting ten seconds before the harsh event and ending ten seconds after the 43 event. Near misses are manually inspected and then coded recorded harsh events with an 44 observable traffic safety risk which could have caused property damage or more serious 45 outcomes. A number of variables are recorded for each near miss event including description of 46 the event, the vehicles and people involved, environmental and roadway factors, and 47 accelerometer/onboard data such as g-force and speed profile. The goal of this research was to 48 analyze the speed profiles by type of incident and level of speed: up to 20 mph, 21 to 35 mph, 49 and over 35 mph and present observable trends and differences in the speed profiles. Nearly 300 50 speed profiles were subjected to a preliminary analysis herein. The accumulation of more cases 51 is necessary for statistically significant inferences.

Authors	Pei Li (peili@knights.ucf.edu), University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01697
Paper Title	**Trajectory Fusion-based Real-Time Crash Likelihood Prediction Using LSTM-CNN with Attention Mechanism**
Abstract	Real-time crash likelihood prediction plays a crucial role in the proactive traffic safety management system. Most of the existing studies obtained traffic data from fixed devices, such as loop detectors, Bluetooth detectors, cameras, etc. However, these devices are not flexible enough to deploy at a large-scale and collect city-wide traffic data. With the help of mobile sensing technologies, vehicle-based data (e.g., GPS trajectory, connected vehicles data) are becoming more popular. Nevertheless, only a few studies investigated the application of this novel data for crash likelihood prediction with limited vehicle types. In addition, crash likelihood prediction using deep learning methods, especially Recurrent Neural Networks (RNNs), has received much attention in recent years. However, temporal attention, a powerful mechanism for learning time-series data, was ignored by all of the studies related to crash likelihood prediction. This paper utilized data fusion techniques to integrate two real-world trajectory datasets with a variety of vehicles. The traffic conditions of urban arterials were described with various speed-related features (e.g. average speed, standard deviation of speed, etc.). To predict the crash likelihood for arterials, this paper designed a deep learning architecture (TA-LSTM-CNN) containing a Long Short-term Memory (LSTM) with temporal attention and a Convolutional Neural Network (CNN). Experimental results indicated that the proposed method could achieve outstanding performance (e.g. high sensitivity and low false alarm rate) for the real-time crash likelihood prediction with the help of trajectory data fusion. Further, model comparison results suggested that the proposed model outperformed other state-of-the-art models in terms of various metrics.

Authors	Parisa Hosseini, Rowan University Mohammad Jalayer (jalayer@rowan.edu), Rowan University Subasish Das, Texas A&M University Huaguo Zhou, Auburn University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-01970
Paper Title	**Identifying Wrong-Way Driving (WWD) Crashes in Police Reports Using Text Mining Techniques**
Abstract	Wrong-way driving (WWD) has been a long-lasting issue for transportation agencies and law enforcement, since it causes pivotal threats to road users. Notwithstanding being rare, crashes occurring due to WWD are more severe than other types of crashes. It is time consuming to identify true WWD crashes from large crash database. It often involves a large man-hours to review hardcopy of crash reports. Otherwise, it may cause overestimation or underestimation of WWD crash frequencies. To fill this gap, the present study aims at identifying WWD crashes from other motor vehicle crashes in police reports. By applying text mining techniques, useful information can be extracted from the crash report narratives. In order to distinguish real WWD crashes from other motor vehicle crashes, machine learning methods were implemented to develop classification algorithms. In this study, four classification algorithms, including Naïve Bayes (NB), Random Forest (RF), Support Vector Machine (SVM), and Neural Network (NN) were implemented to categorize crash reports as WWD and non-WWD crashes. Hardcopies of crash reports were used to evaluate the performance of each classification algorithm. Results indicated that RF outperformed in identifying true WWD crashes in comparison with other algorithms with the highest accuracy of 98%.

Authors	Qinghong Chen (chenqinghong@csu.edu.cn), Central South University Ruifeng Gu, Central South University Helai Huang, Central South University Jaeyoung Lee, Central South Universty Xiaoqi Zhai, Central South University Ye Li, Central South University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02212
Paper Title	**Using Vehicular Trajectory Data to Explore Risky Factors and Unobserved Heterogeneity during Lane-Changing**
Abstract	This study aims to investigate contributing factors to potential collision risks during lane-changing processes from the perspective of vehicle groups and explore the unobserved heterogeneity of individual lane-changing maneuvers. Vehicular trajectory data, extracted from the Federal Highway Administration's Next Generation Simulation dataset, are utilized and 579 lane-changing vehicle groups are examined. Stopping distance indexes are developed to evaluate the potential collision risks of lane-changing vehicle groups. Three binary logit models and three mixed binary logit models are established based on different perception reaction time. Model estimation results show that the mixed binary logit models outperform their counterparts regardless of the perception reaction time type. Several variables significantly affect the risk status of lane-changing vehicle groups, including the mean values of clearance distance and speed differences between the leading vehicle in the current lane and subject vehicle, standard deviations of clearance distance and speed differences between these two vehicles, as well as standard deviations of the speed difference between subject vehicle and the following vehicle in the target lane. Interestingly, the influences of the last three variables differ considerably across the observations. Since one of the explanations is individual heterogeneity, personalized designs for advanced driver assistance system would be an effective measure to reduce the risk.

Authors	Qinghong Chen (chenqinghong@csu.edu.cn), Central South University Helai Huang, Central South University Xiaoqi Zhai, Central South University Ye Li, Central South University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02215
Paper Title	**Analysis of Risky Factors and Unobserved Heterogeneity for Different Lane-Changing Vehicle Patterns**
Abstract	The lane-changing maneuver has critical effects on roadway safety. This study evaluates the risky factors associated with the safety status of lane-changing vehicle groups and investigates the unobserved heterogeneity. Specifically, the instability of different lane-changing vehicle patterns is also investigated. A naturalistic vehicle trajectory dataset HighD was employed and 4,842 lane-changing vehicle groups were obtained. These vehicle groups were divided into 16 patterns according to the vehicle type, and four patterns with relatively large sample sizes were selected. A lane-changing risk index was developed to evaluate the risk level of vehicle groups. Random parameter ordered logit models were established based on the four selected patterns. Likelihood ratio tests were conducted to examine the stability of model estimates across different patterns, which indicated statistically significant instability among most patterns. The model results show that different patterns have different significant variables and the effects of these variables are found to vary across patterns. Generally, the risk level of vehicle groups are highly associated with (1) the longitudinal velocities and accelerations of vehicles; (2) the lateral velocity and acceleration of lane-changing vehicle; and (3) the gap distances between vehicles. And the effects of gap distances are found to vary across vehicle groups. This study suggests that advanced driver assistance system should develop more targeted strategies and provide different services according to vehicle patterns.

Authors	Subasish Das (s-das@tti.tamu.edu), Texas A&M University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02378
Paper Title	**American Generations and Traffic Fatalities: Exploratory Evaluation from Person Level Data**
Abstract	The formulation of generation is based on the criteria that people within a common birth year range will experience the same major events in their lifetime. In crash data analysis, age related factors are commonly based on some age ranges or even sometimes in a simpler way by designating people or drivers as young, mid-age, or elderly. It is mostly due to the suitability of the interventional design. It is anticipated that seven generations are still playing role as driver, non-motorist, or occupant: the Greatest generation, the Silent generation, Baby boomers, Millennials, Generation Z, and Post Z. This study used nine years (2010-2018) of Fatality Analysis Reporting System (FARS) data to provide some insights about traffic fatalities and different generations. This study provides some intuitive exploratory analysis with data visualization tools. As Baby Boomers, Generation X, and Millennials are the top three generations in terms total number of fatalities, odds ratios have been developed to determine the specific traits that are associated with each generation. The findings of this unique analysis will provide more contexts to the generation-based studies.

Authors	Nicolette Formosa (n.formosa@lboro.ac.uk), Loughborough University Mohammed Quddus, Loughborough University Stephen Ison, De Montfort University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02470
Paper Title	**Modelling Vehicle-Based Safety Threat: The Incorporation of New Factors under Uncertainty**
Abstract	Connected and Autonomous Vehicles (CAVs) that rely on Artificial Intelligence to autonomously navigate are expected to deliver a step change in safety. Existing Collision Avoidance Systems (CASs) assess and quantify the threat level surrounding the ego-vehicle. However, they are not able to plan the best response to a fully unexpected dangerous situation while driving. Therefore, it is important that the algorithm has the ability to cope with uncertainties since not all situations are 'car-following'. Previous research has not taken this uncertainty into account, so it is desirable to develop robust systems which are not restricted by the predefined movement patterns of the vehicle. In fact, the readily available CAS estimates the threat level based only on one factor: Time-To-Collision (TTC). This approach is limited since it cannot handle all scenarios and ignores all uncertainties. To overcome these limitations, this paper uses deep learning to develop multiple CASs to identify the optimal factors to estimate the threat level under uncertainty. Comparative analyses were undertaken by incorporating new varying input factors to each system (e.g. surrogate safety measures, vehicle parameters, macroscopic traffic data and hybrid of factors). Experiments based on real-world data highlight which factors are important and validate that adding more factors increases sensitivity of the systems. Results also show that systems considering uncertainty, lower the false alarm rate and extends the systems' application for a wider spectrum of traffic scenarios. This is paramount for CASs as uncertainties are inherent in any real-world deployment of CAVs in a mixed traffic stream.

Authors	Xiaoyan Xu, Tongji University Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Xiangbin Wu, Intel Labs China Yu Lin, Shanghai SH Intelligent Automotive Technology Co., Ltd. Xinyi Hou, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02527
Paper Title	**Examining Causal Factors of Traffic Conflicts at Intersections Using Vehicle Trajectory Data**
Abstract	Conflict severity is the outcome of complex interactions between roadway and environmental characteristics, and vehicle motion. Understanding how and to what extent a vehicle is influenced by roadway and surrounding road users during a conflict can help to analyze the causal mechanisms of collisions, thus providing insights into roadway safety improvement countermeasures. This study utilized the NGSIM Peachtree Street vehicle trajectory dataset to achieve the objective of investigating causal factors of conflicts at intersections by exploring roadway-to-vehicle and vehicle-to-vehicle interactions. In order to remove the outliers and white noise existing in the raw data, vehicle trajectories were reconstructed by discrete wavelet transform and Kalman filtering. The generalized time-to-collision was adopted to detect and measure the severity of conflicts, and 423 conflict events were finally extracted. Path analysis models were then established to explore in exactly which ways the roadway-to-vehicle and vehicle-to-vehicle interactions were related to conflict severity. Various roadway and environmental characteristics such as traffic flow's average speed, percentage of trucks and intersection skew angle were included in the models. The results indicate the roadway and environmental characteristics have both direct and indirect effects on conflict severity; while for the indirect effects, the conflict vehicle's kinematics such as the average and standard deviation of speed play an intermediate role in linking roadway factors and conflict outcome. The framework of this study can be applied to assessing roadway readiness for both human-driven and automated vehicles.

Authors	Jenna Kirsch, Wayne State University Stephen Remias (sremias@wayne.edu), Wayne State University Steven Lavrenz, Wayne State University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-02828
Paper Title	**Improving Safety Analyses by Incorporating the Impacts of Travel Time Reliability**
Abstract	Historically, crash frequency models have not directly incorporated reliability measures for roadway mobility and delay. However, recent developments in crowd-sourced probe vehicle data, which allow for the systematic measurement of travel speeds on arterial and highway segments, are poised to change this. In this study, probe vehicle data is used to investigate the impact of level of travel time reliability (LOTTR) on crashes. Crash and mobility data were collected from 2,945 interstate highway, state trunkline highway, and U.S. highway segments in the State of Michigan. Pavement characteristics, geometric data, and traffic volumes were also obtained. Two negative binomial models were estimated to determine the significance of LOTTR on crash frequency, one with and one without the added variable. The LOTTR variable was found to be statistically significant and the model with LOTTR had a significantly better fit to the data than the model without LOTTR. The results suggest that there is future value in including LOTTR and other reliability metrics in crash frequency models. The findings also suggest that roadway operators who focus on improving LOTTR could observe reduced crashes as well.

Authors	Nipjyoti Bharadwaj, NRC Research Associateship Praveen Edara (EdaraP@missouri.edu), University of Missouri, Columbia Carlos Sun, University of Missouri, Columbia, Ellis Library
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-03149
Paper Title	**Examining Vehicle Kinematics of Rear-End Safety-Critical Events using Naturalistic Driving Data**
Abstract	Car crashes can occur in a variety of ways. A common type of collision involving two vehicles is when one vehicle rear-ends another vehicle. This study describes a methodology to understand the braking judgments in rear-end safety-critical events, i.e., crashes and near-crashes, using naturalistic driving study (NDS) data collected as part of USDOT's Second Strategic Highway Research Program (SHRP 2). A small subset of the rear-end events involving younger drivers (16-19 years old) were used to illustrate the proposed methodology. Kinematic measures such as the inverse time-to-collision (TTC) were used to compare braking performances for crashes and near-crashes. The deceleration of the follower vehicle was modeled using Linear Regression. The independent variables are inverse TTC, deceleration of the lead vehicle, and speed of the follower vehicle. The study also demonstrated that range vs. range rate plots are useful to identify the follower's reaction (i.e., onset of braking) in response to the lead vehicle's deceleration. The average TTC value for the crash and near-crash events at the onset of braking was 0.9 seconds and 1.92 seconds, respectively. All safety-critical events analyzed in this study experienced TTC values lower than 3 seconds. This study also developed representative plots of range versus range rates during braking that clearly delineate the boundaries between a crash and a near-crash. The kinematic differences between a crash and a near crash discerned in this study can be useful for designing collision avoidance and driver assistance systems.

Authors	Zulqarnain Khattak (khattakzh@ornl.gov), Oak Ridge National Laboratory Michael Fontaine, Virginia Transportation Research Council Asad J. Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-03292
Paper Title	**Identification of Safety Critical Events from Vehicle Kinematic Data using Convolutional Neural Networks**
Abstract	This study developed a deep learning approach based on 1D convolutional neural networks (CNN) for detection of safety critical events (SCEs) using large-scale naturalistic driving vehicle kinematics data. The data are unique in the sense that such accurate pre-crash data at high fidelity are not available in traditional crash repositories. This study contributes to the literature by providing a first attempt at predicting responses to SCEs by applying Artificial Intelligence techniques. Specifically, the study develops deep learning-based CNN architectures for identification of SCEs using driving volatility based kinematic thresholds. The key contribution lies in developing a CNN input layout that is acceptable to CNN schemes and represents the motion kinematics such as speed acceleration and volatility measures. Several 1D-CNN architectures were developed using layers numbers of convolutions, layer patterns, and kernels. Shallow and deep architectures were tested, revealing higher accuracy of shallow architectures in detecting SCEs. The optimal number of epochs were identified using an early stopping method while the CNN performance was improved by increasing the number of epochs. The ensemble CNN had the highest predictive accuracy of 95.6%, which was 2.5% higher than the optimal CNN using test data. The ensemble CNN also outperformed classical machine learning models and model performance reported in past studies on detection of SCEs. These results have implications for identification of safety hotspots and providing real-time alerts and warnings in connected and automated vehicle environment.

Authors	Denis Monyo (d.monyo@unf.edu), University of North Florida Henrick Haule, Florida International University Angela Kitali, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-03992
Paper Title	**Are Older Drivers Safe on Interchanges? Analyzing Driving Errors Causing Crashes**
Abstract	Older drivers are prone to driving errors that can lead to crashes. The risk of older drivers making errors increases in locations with complex roadway features and higher traffic conflicts. Interchanges are freeway locations with more driving challenges than other basic segments. Because of the growing population of older drivers, it is vital to understand driving errors that can lead to crashes on interchanges. The knowledge can assist in developing countermeasures that will ensure safety for all road users when navigating through interchanges. The goal of this study was to determine driver, environmental, roadway, and traffic characteristics that influence older drivers' errors resulting in crashes along interchanges. The analysis was based on three years (2016-2018) of crash data from Florida. A two-step approach involving a latent class clustering analysis and the penalized logistic regression was used to investigate factors that influence driving errors made by older drivers on interchanges. This approach accounted for heterogeneity that exists in the crash data and enhanced the identification of contributing factors. The results indicated patterns that are not obvious without a two-step approach, including variables that were not significant in all crashes but specific clusters. These factors included driver gender and interchange type. Results also showed that all other factors, including distracted driving, lighting condition, area type, speed limit, time of day, and horizontal alignment, were significant in all crashes and few specific clusters.

Authors	Qikang Zheng (zhengqikang@seu.edu.cn), Southeast University Pan Liu, Southeast University Chengcheng Xu, Southeast University Yao Xiao, Suzhou Planning & Design Research Institute Co., Ltd.
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04128
Paper Title	**Investigating the Predictability of Crashes on Different Freeway Segments Using Real-time Crash Risk Model**
Abstract	Numerous studies have been conducted to improve the prediction efficiency of crash risks. Nevertheless, the most important crash precursors were neglected. The primary purpose of this study is to identify optimal crash precursors for different segment types, as well as provide a threshold selection method for real-time crash risk models. The mainline was divided into basic sections, weaving areas, merging areas, and diverging areas. Bayesian logistic models were established for each type of segment, and significant factors were distinguished. A threshold selection method was proposed based on cost-benefit theory, and the threshold is determined as the value when the number of proactive safety interventions to prevent a crash is 5000. Models with one, two and three optimal variables were developed, and the prediction performance of the models was evaluated. Comparison results show that the minimum amount of parameters which can achieve the ideal prediction effectiveness is two. In this situation, 25%, 50%, 20% and 20% of the crashes occurring at basic sections, weaving areas, merging areas and diverging areas can be accurately predicted respectively. Downstream average speed was recommended as the best crash precursor variable for all the segment types. Support Vector Machine (SVM) and Random Forest (RF) were utilized to confirm the conclusion. The results of this study can be applied to help reduce crash risk to a relatively economical level in practical applications.

Authors	Xiaoyu Sky Guo, Texas A&M University, College Station Lingtao Wu (wulingtao@gmail.com), Texas A&M Transportation Institute Xiaoqiang Kong, Texas A&M University, College Station Yunlong Zhang, Texas A&M University, College Station
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04183
Paper Title	**Inclusion of Phone Use while Driving Data in Predicting Distraction-affected Crashes**
Abstract	Distracted driving is one of the most significant factors contributing to crashes, and distraction-affected crashes are increasing in recent years. Although researchers have developed safety performance functions (SPFs) for various crash types, SPFs for distraction-affected crashes are rarely reported in the literature. One possible reason is lack of critical distracted behavior information in the commonly used safety data (i.e., roadway inventory, traffic, and crash counts). Recently, drivers' phone use while operating a vehicle (referred as phone use data) are recorded by mobile application companies and become available to safety researchers. The primary objective of this study is to examine if the phone use data can potentially benefit the development of SPFs for distraction-affected crashes. To fulfill the objective, the authors integrated phone use data with roadway inventory, traffic, and crash data in Texas. After that, the Random Forest (RF) algorithm is applied to examine if the frequency of phone use while driving is a significant factor for predicting the number of distraction-affected crashes. Further, this study developed two SPFs for distraction-affected crashes with and without the phone use information, and assessed model fitting and prediction performances of them. RF result reveals that the phone use information is the most important factor contributing to the number of distraction-affected crashes. Performance evaluation indicates that including phone use information in the SPFs consistently improves the model's fitting and prediction abilities.

Authors	Kang Wang, Tongji University Ling Wang (wang_ling@tongji.edu.cn), Tongji University Wanjing Ma, Tongji University Hao Zhong, Tongji University Hongge Zhu, China Highway Engineering Consultants Corporation
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04294
Paper Title	**Real-time Crash Prediction for Expressways Considering Segment Type Heterogeneity**
Abstract	Previous studies have proven that the crash possibility and crash type on different segment types are different. However, there are not enough studies which have conducted microscopic crash mechanism analyses considering different types of segments. To comprehensively identify and analyze the heterogeneity in crash mechanism between four types of segments, i.e., merge, diverge, weaving, and basic segments, this study is proposed. Firstly, the segment type heterogeneity was analyzed from crash characteristics, significant variables, and variables importance aspects. Secondly, a method of variables selection was proposed to solve the "dimension disaster" in modeling. Thirdly, a nested logit model was built to quantitatively analyze the impact of crash contributing factors on the crash risk. The results showed that there exist statistically significant differences between four types of segments in crash characteristics, i.e., crash rate, number of vehicle(s) involved, crash type, and crash severity. Additionally, it was found that the most crash risk for merge and weaving segments is from the segments close to the target segment, but the most crash risk for diverge and basic segments is from vehicles traveling from upstream. Besides, it was found that the weather parameters had a similar effect on the crash risk between four types of segments, but it was different for geometry and traffic parameters, which indicated the heterogeneity of crash mechanisms for different segment types. Moreover, when the number of ramps upstream increases or when the distance between ramps and target segment decreases, the crash risk will increase.

Authors	Chaolun Ma, Texas A&M University System Yongxin Peng, Texas A&M University Lingtao Wu (wulingtao@gmail.com), Texas A&M Transportation Institute Xiaoyu Sky Guo, Texas A&M University, College Station Xiubin Bruce Wang, Texas A&M University System
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	TRBAM-21-04119
Paper Title	**Application of Machine Learning Techniques in Predicting the Occurrence of Distraction-affected Crashes with Phone Use Data**
Abstract	Distraction occurs when a driver's attention is diverted from driving to a secondary task. The number of distraction-affected crashes are increasing in the recent years. Accurately predicting distraction-affected crashes is critical for roadway agencies to reduce distracted driving behaviors and distraction-affected crashes. Recently, emerging phone use data and machine learning techniques are becoming available to safety researchers, and can potentially improve prediction of distraction-affected crashes. Hence, this study first examined if phone use events provide important information for distraction-affected crashes. The authors developed two models with and without phone use events by a machine learning technique (i.e., XGBoost), and compared their performance with a conventional statistical model (i.e., logistic regression model). The measurement demonstrates the superiority of XGBoost over logistic regression with high dimensional dataset. Further, this study implemented SHAP (SHapley Additive exPlanation) to interpret the results and analyze the importance of individual features related to distraction-affected crashes, and tested its ability to improve the prediction accuracy. An XGBoost model is trained and its result achieves sensitivity of 91.59 %, specificity of 85.92% and accuracy of 88.72%, respectively. The results suggest that: (1) phone use information is an important factor associated the occurrences of distraction-affected crashes; (2) distraction-affected crashes are more likely to occur on roadway segments with higher exposure (i.e., length and traffic volume), unevenness of traffic flow condition, or with medium truck volume.

Lectern Session 1295: Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)

Authors	Mohamed El Esawey (m.elesawey@eng.asu.edu.eg), British Columbia Ministry of Transportation and Infrastructure Joy Sengupta, British Columbia Ministry of Transportation and Infrastructure John Babineau, British Columbia Ministry of Transportation and Infrastructure Emmanuel Takyi, British Columbia Ministry of Transportation and Infrastructure Mohamed Essa, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-00013
Paper Title	**Safety Evaluation of Variable Speed Limit System in British Columbia**
Abstract	Adverse weather conditions create a difficult environment for drivers to navigate safely. This study reports the safety impacts associated with the installation of Variable Speed Limit System (VSLS) on provincial rural highways in in British Columbia (BC), Canada. A VSLS is an advanced intelligent transportation system (ITS) scheme that can be employed to increase the safety level of highway facilities by varying the speed limit according to downstream operational condition and/or current weather conditions. The analysis made use of police-attended serious crashes (i.e. fatal + injury) that took place during winter seasons (October to March). Three winter seasons were available as a before-implementation period, and three winter seasons were available as an after-implementation period. The results of a simple-before-and-after were promising where overall reductions of 35.8% and 36.8% in winter serious collision (WSC) frequency and rate, respectively, were found for the evaluation corridors. An Empirical Bayes (EB) before-and-after safety evaluation was also carried out to ensure that the results are reliable. Safety Performance Functions (SPFs) were developed using data collected at similar sites. The EB analysis showed an overall statistically significant reduction of 34.4% in WSC. An economic assessment of the system was undertaken and the results showed that the benefits of implementing a VSLS exceeded the system cost with an overall benefit-cost (B/C) ratio of 4.3 and a NPV of C$34.41 million. The results of this study may motivate transportation

agencies and stakeholders who are interested in pursuing similar systems for mitigating weather-related safety challenges.

Authors	Alaa Torkey, Cairo University Abdulrahman Alrafee, Cairo University Dalia Said (daliasaid@eng.cu.edu.eg), Cairo University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-00742
Paper Title	**Safety Assessment of Existing Roads: A Preliminary Comprehensive Methodology for Restricted Environments for a Safety Improvement Program**
Abstract	Road safety has become a leading topic in recent scientific research. Researchers have studied the effect of different operational and geometric characteristics on road safety such as sight distance, operating speed profiles leading to design consistency evaluation and application of the Highway Safety Manual (HSM) for the development of local safety performance functions. Considering safety improvement projects, a comprehensive study is important to get an overall view of crashes' causals, which would be beneficial in conducting cost-effective safety improvement measures especially in restricted environments where there is a lack of crash data. Surrogate methods are needed then for effective safety assessment. This paper presents a preliminary comprehensive operational analysis using an existing alignment in El Mansoura Governorate in Egypt to appraise the study objective. The analysis begins with sight distance analysis, then a design consistency evaluation and finally using HSM Safety Performance Function for rural two-lane two-way roadways. Two scenarios of remedial measures are suggested; one scenario is based on the comprehensive methodology suggested and the other one focuses on the road element characteristics which is a typical approach if HSM methodology is used. Benefit-cost ratio analysis is used for measuring the economic justification of each scenario. It is suggested to study the possibility of developing safety performance functions having sight distance and design consistency all together as building parameters which could be of great help especially in countries having poor crash data.

Authors	Subasish Das (s-das@tti.tamu.edu), Texas A&M University Xiaoduan Sun, University of Louisiana, Lafayette Bahar Dadashova, Texas A&M Transportation Institute M. Rahman, University of Louisiana, Lafayette Ming Sun, University of Louisiana, Lafayette
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-01764
Paper Title	**Sun Glare and Traffic Crashes: Identifying Patterns of Key Factors**
Abstract	Sun glare is one of the major environmental obstructions that cause traffic crashes. Every year, many traffic crashes in the United States are attributed to sun glare. However, quantitative analysis of the influence of sun glare on traffic crashes has not been widely examined. This study used traffic crash narrative data for seven years (2010-2016) from Louisiana to identify crash reports that provided evidence of drivers indicating sun glare as the primary contributing factor of the crashes. Additional geometry and traffic information was collected to identify the list of key crash-contributing factors. This study used cluster correspondence analysis to perform the data analysis. After performing several iterations, six clusters were identified that provide additional insight regarding sun glare related crashes. The six clusters are associated with mixed (business and residential) localities, intersection related crashes on U.S. roadways, single vehicle crashes on residential two-lane undivided roadways, curve related crashes on Parish roadways in residential localities, interstate related crashes in open county localities, and curve related crashes in open county localities. The findings of the current study can add insights into the ongoing safety analysis on sun glare related crashes.

Authors	Rizky Junirman (rizky-adelwinjunirman@ed.tmu.ac.jp), Shuto Daigaku Tokyo Hiroyuki Oneyama, Tokyo Metropolitan University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-01783
Paper Title	**Effect of Motorcycle Composition to Motorcyclist and Other Motor Vehicle Accident Rate in Mixed Traffic Condition**
Abstract	The disparity in road safety between low- and middle-income countries (LMIC) and high-income countries (HIC) is high. To confront this problem, local road characteristics must be understood. This study attempts to clarify how traffic composition contributes to accident rates in mixed traffic conditions for different road users in Indonesia. The study was conducted within an urban environment in Indonesia; hence, other contributing road elements to support this study are chosen to represent such conditions. Multivariate analysis using negative binomial regression revealed that motorcycle and motor vehicles have a slight difference in contributing factors to their respective accident rate. Furthermore, the motorcycle proportion contributes to accident risk for both motorcycle and motor vehicle. The two-fluid model and road type for undivided roads are not significant for both models. The difference lies in the fact that 1 km radii of through traffic are significant only for motorcycle accident rates. For other variables, they share the same significant variables. The significant variables are motorcycle percentage, network centrality for 10 km radii, access density, signalized intersection type, and road type for divided roads.

Authors	Benjamin Melendez, San Diego State University Anagha Katthe, San Diego State University Arash Jahangiri (AJahangiri@sdsu.edu), San Diego State University Sahar Ghanipoor Machiani, San Diego State University Alidad Ahmadi, Linscott, Law & Greenspan, Engineers Walter Musial, Linscott, Law & Greenspan, Engineers
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-01848
Paper Title	**Safety Impact Evaluation of Narrow AV-Exclusive Lanes on Existing Freeways**
Abstract	A full infrastructure adaptation to the emerging Automated Vehicle (AV) technology is not going to happen soon, especially given that transportation system will be serving both AVs and conventional vehicles for a while. On freeways, co-existence of AV-exclusive lanes and conventional vehicle lanes seems to be a viable solution. It has been suggested that AVs' navigation capabilities could allow for infrastructure standard adjustments such as narrower lanes. Given the difference between the operation of AVs and human-driven vehicles and reliance of AVs on sensors as opposed to human capabilities, the questions are can we provide exclusive and narrower roadways for AVs while maintaining proper safety and what are the safety implications of a narrow AV-exclusive lane on a freeway? To answer these questions, this study conducted three tasks. First, a comprehensive review of existing AV technologies related to lateral control systems was compiled for fifteen different vehicle manufacturers. Then, consumers' complaints from the NHTSA Vehicle Owners' Questionnaires database were investigated to evaluate safety issues that consumers encountered related to lateral vehicle control technology in AVs. Finally, an expert interview was conducted to survey and explore relevant academic researchers', transportation officials', and industry leaders' attitudes and opinions on the topic of AV-exclusive lanes. Conclusions were drawn and a series of recommendations were developed from the results of the study that are usable for practitioners and professional organizations pertaining to AV development.

Authors	Nusayba Megat-Johari, Michigan State University Megat-Usamah Megat-Johari, Michigan State University Peter Savolainen (pete@msu.edu), Michigan State University Timothy Gates, Michigan State University Eva Kassens-Noor, Michigan State University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-02354
Paper Title	**Examining Driver Compliance with a Move-Over/Slow Down Law in Consideration of Vehicle Type and Messages Displayed on Upstream Dynamic Message Signs**
Abstract	Move-over laws are intended to enhance the safety of road agency and law enforcement personnel who are working on or near the roadway. This study examines driver behavior through a series of field studies where these types of vehicles are located on the outside shoulder of a freeway with their lights activated. The study also evaluates the use of upstream dynamic message sign (DMS) to discern whether targeted safety messages have any impact on behavior under this scenario. Upstream and downstream speed and lane position data are collected from vehicles originally traveling in the rightmost lane upstream of the DMS and emergency/service vehicle at two locations in Michigan. Logistic regression models are estimated to assess driver compliance with the law while considering important contextual factors, such as the type of vehicle on the shoulder and the message displayed on the DMS. The results indicate that drivers were more likely to move over or reduce their speeds when a police car was located on the shoulder as compared to a transportation agency pickup truck. In general, the type of message displayed had minimal impact on driver behavior. The one exception showed that drivers were likely to drive at or below the speed limit when targeted move over messages were shown as compared to standard travel time messages. For all message types, both speed and lane compliance were improved if the roadside vehicle was a police car.

Authors	Megat-Usamah Megat-Johari, Michigan State University Nusayba Megat-Johari, Michigan State University Peter Savolainen (pete@msu.edu), Michigan State University Timothy Gates, Michigan State University Eva Kassens-Noor, Michigan State University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-02355
Paper Title	**Examining Trends in Traffic Crashes as They Relate to the Display of Safety Messages on Dynamic Message Signs**
Abstract	Transportation agencies have increasingly been using dynamic message signs (DMS) to communicate safety messages in an effort to both increase awareness of important safety issues and to impact driver behavior. Despite their widespread use, evaluations as to potential impacts on driver behavior, and the resultant impacts on traffic crashes, has been very limited. This study addresses this gap in the extant literature and assesses the relationship between traffic crashes and the frequency with which various types of safety messages are displayed. Safety message data were collected from a total of 202 DMS across the state of Michigan between 2014 and 2018. These data were integrated with traffic volume, roadway geometry, and crash data for segments that were located downstream, as well as at several locations upstream of each DMS. A series of negative binomial models were estimated to examine total, speeding-related, and nighttime crashes based upon historical messaging data while controlling for other site-specific factors. However, the results of this evaluation did not show any meaningful differences in safety performance based on message delivery. While crashes declined marginally when higher frequency messaging was utilized, none of these differences were statistically significant. These findings are in contrast to stated preference surveys, which suggest drivers would be more likely to adapt their behavior to such messaging strategies. Important issues are also highlighted with respect to methodological concerns that arise in the analysis of such data. Field research is warranted to investigate potential impacts on driving behavior at the level of individual drivers.

Authors	Subasish Das (s-das@tti.tamu.edu), Texas A&M University Anandi Dutta, University of Texas, San Antonio
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-02366
Paper Title	**Light Delivery Vehicles Crashes: Identifying Insights using Joint Dimension Reduction and Clustering**
Abstract	In the era of food delivery and grocery delivery startups, traffic crashes associated with light delivery vehicles have increased significantly. Because of the increasing number of these crashes, it is important to investigate light vehicle crashes to gain insights about potential contributing factors. This study collected seven years (2010-2016) of data from traffic crash narrative reports and structured traffic crash data from Louisiana. By using text search options and manual exploration, a database of 1623 light delivery related crashes have been examined by using a comparatively robust clustering method known as cluster correspondence analysis. The findings identified six clusters with specific traits. The key clusters are interstate related crashes due to inattention, fatigue, alcohol impairment, or a young driver on low to mode speed roadways. The findings of the current study can be used by the policy makers to perform data-driven policy development in a way to ensure safety for delivery related travels.

Authors	Darren Torbic (dtorbic@mriglobal.org), MRIGlobal Daniel Cook, HDR Joseph Grotheer, MRIGlobal Richard Porter, VHB Jeff Gooch, VHB Kristin Kersavage, VHB
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-02711
Paper Title	**New Intersection Crash Prediction Models for the Second Edition of the Highway Safety Manual**
Abstract	The objective of this research was to develop new intersection crash prediction models for consideration in the second edition of the Highway Safety Manual (HSM), consistent with existing methods in HSM Part C and comprehensive in their ability to address a wide range of intersection configurations and traffic control types in rural and urban areas. The focus of the research was on developing safety performance functions (SPFs) for intersection configurations and traffic control types not currently addressed in the HSM Part C. SPFs were developed for the following general intersection configurations and traffic control types:Rural and urban all-way stop-controlled intersections Rural three-leg intersections with signal control Intersections on high-speed urban and suburban arterials (i.e., arterials with speed limits greater than or equal to 50 mph) Urban five-leg intersections with signal control Three-leg intersections where the through movements make turning maneuvers at the intersections Crossroad ramp terminals at single-point diamond interchanges Crossroad ramp terminals at tight diamond interchanges Development of severity distribution functions (SDFs) for use in combination with the SPFs to estimate crash severity as a function of geometric design elements and traffic control features was explored; but due to challenges and inconsistencies in developing and interpreting the SDFs, it was recommended for the second edition of the HSM that crash severity for the new intersection configurations and traffic control types be addressed in a manner consistent with existing methods in Chapters 10, 11, and 12 of the first edition of the HSM, without use of SDFs.

Authors	Abhinav Bhattacharyya (ab8230@nyu.edu), New York University Bekir Bartin, Ozyegin Universitesi Kaan Ozbay, New York University Chuan Xu, Southwest Jiaotong University Hani Nassif, Rutgers University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-02992
Paper Title	**Calibration and Development of Safety Performance Functions for Rural Two-Lane Two Way Roadways: A New Jersey Case Study**
Abstract	Calibrating the safety performance functions (SPF) in the Highway Safety Manual (HSM) and developing jurisdiction-specific SPFs both require significant time, effort and resources, and detailed data from different sources. It is therefore crucial to identify all the readily available data sources and automatically gather much of the data required by the HSM. However, datasets maintained by the state transportation agencies are rarely comprehensive enough to meet all data requirements, often including errors and inconsistencies. This paper presents a detailed discussion of data needs and availability, data processing methods and approaches to gather the required data for calibration and development of SPFs using rural two-way two-lane rural roadway segments and intersections in New Jersey (NJ) as a case study. It is shown that generating a usable dataset from various different data sources is a rigorous task of data compiling, cleaning and processing, and requires a significant computer programming effort. While presenting the results of the SPF calibration and development process, this paper points to the importance of crash location information and its impact on analyses results. In addition, through past literature and best practices, this paper also discusses the practicality of the current manual data extraction practices, and argues that novel data extraction methods, such as the clustering approach used in this study, should be adopted to minimize labor-intensive and cost-prohibitive manual data collection processes and increase data accuracy. The choice between calibration and development of jurisdiction-specific SPFs is also discussed.

Authors	Mohammadreza Koloushani (mk18h@fsu.edu), Florida A&M University-Florida State University College of Engineering Mahyar Ghorbanzadeh, Florida A&M University-Florida State University College of Engineering Eren Ozguven, Florida A&M University-Florida State University College of Engineering Alireza Ermagun, Mississippi State University Mehmet Ulak, University of Twente
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03025
Paper Title	**How did COVID-19 affect crash patterns in Florida? A GIS-based Spatiotemporal Investigation in Four Counties**
Abstract	As a result of the COVID-19 pandemic, stay-at-home orders were issued in many states in the U.S. including the State of Florida. Due this order, many businesses have been closed or have started working virtually, and many other activities were cancelled. There is, consequently, a significant decrease in the number of trips, which might impact the pattern of crash density differently in counties with distinct characteristics. This study intends to investigate the impact of the COVID-19 on the spatiotemporal patterns of crash density in four demographically different counties in Florida: Escambia, Hillsborough, Leon, and Liberty. We propose a GIS-based method to examine whether the differences of crash density during the COVID-19 impacted dates are significantly and spatially significant than previous time periods. The statistical significance test results show that the mean crash density during the COVID-19 is statistically different from others. The Kernel Density Estimation (KDE)-based spatial analysis indicates that the crash density patterns vary from county to county based on demographic characteristics. The time series analyses also show that the curfew in the metropolitan area, namely the Hillsborough county, results in a higher number of crashes whereas we follow a more stable decreasing effect in other mid-size counties. The GIS-based results obtained from this study can help understand how changes in travel policies may affect traffic safety and inform policy-makers on safety outcomes of shifts in mobility patterns that are expected in the near future.

Authors	Tanmoy Bhowmik (tanmoy78@Knights.ucf.edu), University of Central Florida Shamsunnahar Yasmin, Queensland University of Technology Naveen Eluru, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03184
Paper Title	**Accommodating for Systematic and Unobserved Heterogeneity in Panel Data: Application to Macro-Level Crash Modeling**
Abstract	The current research contributes to the burgeoning literature on multivariate models by proposing a hybrid model framework that (a) incorporates unobserved heterogeneity in a parsimonious framework and (b) allows for additional flexibility to accommodate for observed/systematic heterogeneity. Specifically, we estimate a Latent Segmentation Panel Multivariate Negative Binomial (LPMNB) to study the zonal level crash counts across different crash types. Further, we undertake a comparison exercise of the proposed hybrid LPMNB model with a Panel Mixed Negative Binomial model (PMNB) that accommodates for all unobserved heterogeneity via a simulation setting. The analysis is conducted using the zonal level crash records by different crash types from Central Florida region for the year 2016 considering a comprehensive set of exogenous variables. Based on the statistical data fit, we find that the segmented model (LPMNB) is a preferred choice as long as the framework is estimated in a closed form system. The comparison exercise is further augmented by computing several goodness of fit measures and the results offered by the LPMNB model highlight the value of the proposed model.

Authors	Raul Avelar (r-avelar@tamu.edu), Texas A&M Transportation Institute Karen Dixon, Texas A&M University Boniphace Kutela, Texas A&M Transportation Institute Samuel Klump, HDR Wemple Elizabeth, HDR Richard Storm, HDR
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03234
Paper Title	**Developing an Index-based Methodology to Assess the Quality of SPF Calibration. A Multivariate Approach**
Abstract	The calibration of Safety Performance Functions (SPFs) is a mechanism included in the Highway Safety Manual (HSM) for practitioners to adjust SPFs in the HSM for use in their respective jurisdictions. Critically, the quality of the calibration procedure must be assessed prior to using the calibrated SPFs. Multiple resources to aid practitioners in calibrating SPFs have been developed in the years following the publication of the HSM first edition. Similarly, the literature suggests multiple ways to assess the goodness of fit (GOF) of a calibrated SPF to a dataset from a given jurisdiction. This paper uses the calibration of multiple intersection SPFs to a large Mississippi safety database to examine the relations between GOF metrics. The goal is to develop a sensible single index that leverages the joint information from multiple GOF metrics. A factor analysis applied to the calibration results revealed three underlying factors that explain 76 percent of the variance of the GOF metrics. From the factor analysis results, the authors developed an index and performed a sensitivity analysis. The key metrics explaining index variation were found to be, in descending order: the deviation of the cumulative residual (CURE) plot from the 95 percent confidence area, the mean absolute deviation, the modified R-squared, and the value of the calibration factor. This paper also presents comparisons between the index and alternative scoring strategies, as well as an effort to verify the results using synthetic data. The developed index is recommended to assess the quality of the calibrated intersection SPFs.

Authors	John Kodi (jkodi001@fiu.edu), Florida International University Angela Kitali, Florida International University MD Sultan Ali, Florida International University Priyanka Alluri, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03255
Paper Title	**Estimating Safety Effects of Adaptive Signal Control Technology Using the Full Bayesian Approach**
Abstract	Adaptive Signal Control Technology (ASCT) is a traffic management strategy that optimizes signal timing based on real-time traffic demand. Although the primary intent of ASCT is to improve the operational performance of signalized intersections, the technology may also have substantial safety benefits. This study explored the potential safety benefits of the ASCT strategy deployed at signalized intersections in Florida. An observational before-after full Bayes (FB) approach with a comparison-group was adopted to develop crash modification factors (CMFs) for total crashes, rear-end crashes, and specific crash severity levels (fatal plus injury (FI), and property damage only (PDO) crashes). The analysis was based on 20 intersections equipped with ASCT and their corresponding 40 comparison intersections without ASCT. The ASCT deployment was found to significantly reduce total crashes by 8.5% (CMF = 0.915), rear-end crashes by 8.5% (CMF = 0.915), and PDO crashes by 8.1% (CMF = 0.919). The 8.7% reduction in FI crashes (CMF = 0.913) was not significant at a 90% Bayesian credible interval. These findings provide researchers and practitioners with an effective means to quantify the safety benefits of the ASCT strategy and conduct economic appraisals of ASCT deployments.

Authors	Qing Chang (qzc0010@tigermail.auburn.edu), Auburn University Md Atiquzzaman, Auburn University Huaguo Zhou, Auburn University Yukun Song, Auburn University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03488
Paper Title	**A Before-and-After Evaluation of Traditional Traffic Control Devices for Preventing Wrong-Way Driving at Freeway Off-Ramps**
Abstract	This paper presents a before-and-after study of the effectiveness of traditional traffic control devices (TCDs) on preventing Wrong-Way Driving (WWD) at two partial cloverleaf (parclo) off-ramp terminals in Alabama. These two locations were selected because (1) they were identified as the high-risk locations for WWD; and (2) the traditional TCDs have been improved to mitigate the WWD activities. WWD incident data was collected from more than 800 hours of video surveillance before-and-after the countermeasures implementations at each location. At I-65 Exit 284 Southbound (SB) off-ramp terminal, the pavement marking was improved, including (1) repainted double yellow line and newly painted left-turn skip strips, and (2) yield line for off-ramp right-turn lane and stop bar for the left-turn lane at the end of the exit ramp. At I-65 Exit 208 SB off-ramp terminal, a raised-curb channelizing island was implemented as the first stage of improvement. At the second stage, the additional signages were installed on the channelizing island, and the double yellow line on the crossroad was repainted. For I-65 Exit 284 SB ramp, the improvements reduced 60% of the total and approximately 75% of nighttime WWD incidents. For I-65 Exit 208 SB ramp, the channelizing island alone implemented at the first stage resulted in an approximately 80% increase in WWD incidents, however the number decreased by approximately 50% after the improvements at the second stage.

Authors	Justice Appiah (Justice.Appiah@VDOT.Virginia.gov), Virginia Transportation Research Council Mo Zhao, Virginia Transportation Research Council Bhaven Naik, Ohio University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03763
Paper Title	**Road Geometry and Pavement Surface Condition Impacts on Roadway Departure Crashes**
Abstract	Roadway departure (RD) crashes are one of the major causes of fatalities on rural roads in Virginia. Thus, research to develop and enhance understanding of potential influencing factors continues to be of interest in mitigating these crashes. SCRIM, a truck-based multifunctional roadway monitoring device that can simultaneously and continuously collect roadway surface condition and geometry data while being driven in the speed range of 15–53 mph, has been widely used in European countries for nationwide road surveys. The Virginia Department of Transportation (VDOT) started to conduct SCRIM surveys in 2018. These SCRIM surveys comprise a new source of data for pavement skid resistance, texture, and roadway alignment—all features that are not routinely collected or archived as part of current practice, but have potential to influence RD crashes. This study explored SCRIM data collected on 86 miles of rural highways in Virginia for relationships between pavement condition, road geometry, and RD crash frequency. The analysis was supplemented with additional information including archived pavement management and crash records that were obtained from VDOT sources. Standard statistical methods were used to investigate the relationship between RD crash frequency and likely influencing variables identified in the composite dataset. It was found that this relatively new data source holds promise for further insights into factors influencing RD crashes. In particular, the study found statistically significant association between RD crash frequency and geometric characteristics such as cross slope and curvature. A significant association was also found between crash frequency and pavement skid resistance.

Authors	Roodson Pierre (pierreroodson@yahoo.com), Florida A&M University Doreen Kobelo, Florida A&M University Ntagwanko Kisabanzira, University of North Florida John Kodi, Florida International University Angela Kitali, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03793
Paper Title	**Investigating Changes in Florida Traffic Crash Trends Due to COVID-19 Pandemic**
Abstract	The novel COVID-19 pandemic has caused dramatic changes in almost everybody's life in the world. Transportation safety is one of the sectors that experienced dramatic changes due to due to stay-at-home orders that were issued across the United States and in other countries, to combat the widespread of the pandemic. Variations in traffic pattern, travel behavior, and human behavior leads to significant changes in traffic safety. This study investigated the impacts of the COVID-19 pandemic on traffic crashes in Florida's freeway (I-10, I-75, and I-95). Traffic crashes for the months of March and April for the years 2018 through 2020 along the selected corridors were analyzed to explore the impacts of the novel pandemic in crash safety. The analysis showed that since the first confirmed case in Florida, there was a decreasing trend in the total traffic crash frequency in the selected study corridor. Compared to the similar period in 2018 and 2019, the overall traffic crashes dropped significantly by up to 45.3% following the restrictions imposed to slow down the spread of the virus. Also, a decrease in the rear-end crashes and an increase in the run-off-road were observed. This study helps to understand the early impacts of the pandemic and may be useful in operational and strategic planning for future pandemics.

Authors	Eugene Antwi Boasiako (ean246@uky.edu), University of Kentucky Mei Chen, Kentucky Transportation Center Xu Zhang, Kentucky Transportation Cabinet Benjamin Blandford, Kentucky Transportation Center
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03898
Paper Title	**Investigating the Relationship between Vehicle on Shoulder and Crash: Correlation or Causation**
Abstract	Technological advancements have afforded road users the ability to contribute to traffic data. These road user generated data, termed crowdsourced traffic data, aid traffic managers to monitor roadway conditions and coordinate more effective incident management. Moreover, integrating crowdsourced traffic data with conventional traffic data provides additional information for traffic safety analysis. In this study, we focus our analysis on vehicles on the shoulder, using Waze vehicle-on-shoulder alerts, and their impact on safety of limited access highways in Kentucky. The analysis showed that about 36% of crashes had vehicle on shoulder present in their vicinity, defined as 0.25 miles upstream and downstream of a crash site and 30 minutes before crash occurrence. While congestion was associated with about 25% of crashes, 11.7% of crashes were attributable to both congestion and vehicles on the shoulder. As such, a statistically significant association was found between vehicles-on-shoulder, congestion and crashes. Based on crash narrative review, 1.8% of all crashes directly involved vehicles on shoulder and 23% of the crashes cited congestion as a contributor. However, there is little indication in the crash narratives on how vehicles on shoulder contributed to crashes, beyond their direct involvement, or how they contributed to congestion which may led to crashes. Though a small fraction of crashes were attributed to vehicles on shoulder, these crashes tended to be more severe on average than all interstate crashes. Data used in this study, and the analytical methods proposed, offer much-needed insights into the challenges posed by vehicles on roadway shoulders.

Authors	Adika Iqbal (amammad@g.clemson.edu), Clemson University Wayne Sarasua, Clemson University Afshin Famili, Clemson University Jennifer Ogle, Clemson University William Davis, Citadel Military College Devesh Kumar, Clemson University Saurabh Basnet, Clemson University Emmanuel Adjei, Clemson University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-04402
Paper Title	**Assessing the Predictability of Short Segment Crash Analysis in the State of South Carolina**
Abstract	The main objective of this research is to evaluate the predictability of a short segment peak search method with lengths of less than 0.1 miles for the statewide screening of midblock crash locations. Three different approaches (Based on HSM SPFs) are used to evaluate the short segment method. These approaches include state-specific SPFs, Driveway SPFs (using only AADT), and driveway SPFs with adjusted CMFs. Frequency-based identification of short segments stratified by six different roadway types (R2U, R4D, U2U, U4D, U3T, and U5T) has been compared with three SPF based screening methods to determine segments with the highest excess predicted average crash frequency. For short segment sites with highest crash frequencies (3 for U3T, U4D, and U2U; 4 for U5T and 2 for R4D and R2U), the comparison showed similar results (Top 90% agreement). Thus, should insufficient data be available to conclude SPFs, a frequency-based approach will likely identify the top sites. While this method works relatively well with top sites, the reliability of this method will wane with lower-ranked sites.

Authors	Raunak Mishra, University of North Carolina, Charlotte Srinivas Pulugurtha (sspulugurtha@uncc.edu), University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	TRBAM-21-03723
Paper Title	**Evaluating the Safety Effectiveness of Restricted Crossing U-turn (RCUT) Intersections**
Abstract	The focus of this paper is on evaluating the safety effectiveness of restricted crossing U-turn (RCUT) intersections. Both unsignalized and signalized RCUT intersections were evaluated using the Empirical Bayes (EB) before-after evaluation method. The forty-two RCUT intersections considered in this research were converted from a two-way stop-controlled (TWSC) intersection or signalized intersection in the rural and suburban areas. The results show a 73.27% reduction in the total number of crashes and a 79.42% reduction in the number of fatal and injury crashes at unsignalized stop-controlled RCUTs in the rural area. In the suburban areas, a 64.86% reduction in the total number of crashes and a 73.39% reduction in the number of fatal and injury crashes was observed. Further, a 10.15% and a 31.08% reduction in the total number of crashes, and an 84.26% and 31.13% reduction in the number of fatal and injury crashes was observed at signalized RCUTs in the rural and suburban areas, respectively. Overall, the unsignalized RCUTs in the rural areas with a larger sample size were found to be more safer than was observed by researchers in the past. These findings are useful to researchers and practitioners for making informed decisions and implementing RCUTs from a safety perspective.

Poster Session 1304: Transportation Safety Management Systems from Start to Finish

Authors	Morgan Chatmon (morgan.n.chatmon@gmail.com), Tennessee State University Beatriue Cherop, Tennessee State University Deo Chimba, Tennessee State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-00273
Paper Title	**The Impact of COVID-19 on Traffic Crash trends in Tennessee**
Abstract	The first Coronavirus case detected in Wuhan city, Hubei province in China towards the end of 2019. In order to decrease the rate of transmission of COVID-19, the United States passed an order requiring people to work from home, closure of schools and non-essential businesses and barring mass gatherings. The move reduced number of people travelling, and altered travel patterns. The trend of traffic crashes before and during the COVID-19 pandemic is presented in this paper. The analysis of 4-year crash trends covering the months of March, April and May for 2017, 2018, 2019 (averaged as pre- COVID-19) and 2020 (during COVID-19) is presented. The decline in crashes was due to the limited movement and travel which decreased road traffic by more than 38%. Non parametric test was used to compare the mean of crashes before and during COVID-19, the results showed that the mean of crashes during COVID-19 was significantly lower than pre- COVID-19 for the same range of months. The geometric and traffic factors used to analyze the traffic crashes included the number of lanes, AADT, speed limit, land use, population density, median income and weather. Negative Binomial regression was used to model the impact of these factors on crashes. It was found that for each unit increase in the factors, traffic crashes increased with the increase being less for the COVID-19 period. The restrictions put in place to minimize the spread of COVID-19 decreased number of traffic crashes and generally increased road safety.

Authors	Qinglin Hu (qhu10@ua.edu), University of Alabama Xiaobing Li, University of Alabama Jun Liu, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-00299
Paper Title	**A Low-Cost Approach to Identify Hazard Curvature for Local Road Networks Using Open-Source Data**
Abstract	Vehicle crashes are a leading cause of death in the United States. Among those crashes, curvature in local roadway was identified as one of the most significant factors correlated with fatal crashes. Given the large number of local roads and their relatively lower traffic compared with interstates or freeways, most local roads may not receive priorities in the first phase of highway upgrades. However, critical locations, e.g., sharp curves (vertical and/or horizontal), in the network that may be a deadly threat for both new advanced autonomous vehicles and conventional vehicles. In addition, Identifying local roadway curvatures exists various uncertainty by most authorities, such as high budget and lack of data. To fill this gap, this study offers a low-cost approach to constructing three-Dimensional geometric profiles for local roads in a relatively large study area using open-source data. With the profiles, critical road segments, including extreme horizontal and vertical curves and their combinations, can be identified. Our study redefined the local road segments into 20 sub-categories based on the calculated vertical grades and curve radius that were incorporated into a zero-inflated native binomial model. Model results showed that grades or curves were associated with decreased crash frequency compared with straight and flat roads. However, segments with larger horizontal curve radius and low grades were found to associate with increased crash frequency. More implications are discussed in the paper.

Authors	Shraddha Sagar (shraddha.sagar@greshamsmith.com), Gresham Smith and Partners Nick Stamatiadis, Kentucky Transportation Center Arnold Stromberg, University of Kentucky
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-00658
Paper Title	**Effect of Socioeconomic and Demographic Factors on Crash Occurrence**
Abstract	Road traffic crashes are a leading cause of death in the United States. In Kentucky, per capita crash rates and crash-related fatalities have outpaced the national average for over a decade. Researchers have argued that the region's unique socioeconomic conditions provide a compelling explanation for these trends. This study examined the relationship between highway safety and socioeconomic characteristics using crash data from Kentucky. This research sought to identify at-risk drivers based on the socioeconomic and demographic attributes of their residence zip codes. Using the quasi-induced exposure approach, binary logistic regression was used to predict the probability of be the at-fault driver in a single- and two-unit crashes based on socioeconomic characteristics of their residence zip code. Statistical analysis found that variables such as income, education level, poverty level, employment, age, gender, rurality, and number of traffic-related convictions of a driver's zip code influence the likelihood of their being at fault in a crash, while educational attainment is observed to have an impact only on single-unit crash occurrence. Finally, it is concluded that younger and older drivers residing in zip codes with low socioeconomic conditions have a higher likelihood of causing a crash for both single- and two-unit crashes. This finding can be used to identify zip codes or groups of drivers with higher likelihood to be involved in crashes and develop targeted and efficient safety programs.

Authors	Yuan Zhu (yz614@nyu.edu), New York University Sami Demiroluk, AgileAssets, Inc. Kaan Ozbay, New York University Kun Xie, Old Dominion University Hong Yang, Old Dominion University Di Sha, New York University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-00981
Paper Title	**SAVE-T: Safety Analysis Visualization and Evaluation Tool**
Abstract	Traffic crashes are one of the biggest issues which constitute a threat to lives the motorists and disrupt operations of the transportation system. To reduce the number of crashes and alleviate their impacts, it is necessary to scrutinize the factors contributing to the risk of traffic crashes. Lately, visual analytics tools become very popular for data exploration and obtaining insights from the data. In this paper, a new web-based data visualization tool called Safety Analysis Visualization and Evaluation Tool (SAVE-T) was introduced. This tool enables users to interactively create queries and visually explore the results. By utilizing an on-line crash database, it offers various innovative functionalities for analysis and visualization of the crash data such as custom query development module, and a subway-like map for easily visualizing the accident on the roadway segments. This tool provides an effective and efficient way to transportation agencies and professionals for traffic safety analyses and visualizations.

Authors	Rebeka Yocum, Pennsylvania State University, University Park Vikash Gayah (gayah@engr.psu.edu), Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-01517
Paper Title	**Identifying relationships between socioeconomic indicators and crash frequency in Pennsylvania**
Abstract	Current crash prediction models utilize roadway and traffic data as independent variables to describe crash frequency on individual roadway segments. Recent work has moved toward predicting crashes within some region as a function of roadway and traffic data, as well as non-traditional variables, such as alcohol, gasoline prices, and socioeconomic measures. This paper aims to introduce measures of wealth into the crash modeling conversation by determining the effect of wealth on total, fatal and injury, and pedestrian crash frequencies in Pennsylvania counties. The analysis presented in this paper will serve as a case study with intentions to promote the development of more robust, wealth-inclusive crash prediction models in the future. The study reveals that population of unemployed individuals, percentage of the population on cash public assistance or receiving SNAP benefits, and the percentage of households without a vehicle are each positively related to the observed frequency of total, fatal + injury and pedestrian crashes in each county. This result not only supports previous work, but expands on that work by considering multiple crash types, and multiple wealth related variables. The existence of a relationship between crash frequency and wealth related variables opens the door to further exploration of including wealth in traditional crash prediction methods. This paper discusses this relationship and offers recommendations for future work.

Authors	Amy Romeo-Garcia (arome109@fiu.edu), Florida International University John Kodi, Florida International University Angela Kitali, Florida International University Priyanka Alluri, Florida International University Albert Gan, Florida International University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-01852
Paper Title	**Impacts of COVID-19 Pandemic on Traffic Crashes in Florida**
Abstract	The novel COVID-19 pandemic outbreak has brought significant impacts on all aspects of peoples' lives in the entire world. While this pandemic is still unfolding, it has already had unprecedented health, social, and economic consequences. The virus being easily transmittable from person-to-person, social distancing through stay-at-home orders is considered as effective in containing the rapid spread of the disease. For example, in Florida the stay-at-home orders came into effect on April 01, 2020. These strategies have resulted in drastic changes in the traffic pattern and travel behavior which in turn has led to significant changes in traffic safety. This study investigated the impacts of the COVID-19 pandemic on traffic crashes. Traffic crashes for March and April (2018-2020) in Florida were analyzed to identify if there was a significant change in traffic crashes following the outbreak of the pandemic and statewide directives to prohibit person-to-person interaction. Compared to similar days in 2018 and 2019, the overall statewide traffic crashes dropped significantly by 10% and 45% in the first and last two weeks of March 2020 respectively, and by 58% in April 2020. A similar significant decrease was observed in the fatal and injury crashes although as a percentage of all crashes they increased in 2020 compared to 2018 and 2019. Also, a decrease in the rear-end crashes and an increase in the run-off-road and non-motorist crashes were observed. This study helps to understand the early impacts of the pandemic and may be useful in operational and strategic planning for future pandemics.

Authors	Ruchika Agarwala (ruchikaagarwal03@gmail.com), Indian Institute of Technology, Bombay Vinod Vasudevan, University of Alaska, Anchorage
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-02224
Paper Title	**Relating Household Consumption Expenditures to Road Traffic Fatalities: A Rural-Urban Study**
Abstract	Traffic fatality risk is higher in rural areas than in urban areas. In developing countries, vehicle ownership and investments in public transportation typically increase with economic growth. These two factors together increase the vehicular population, which in turn impacts traffic safety. However, the impacts of personal and non-personal modes of travel on traffic safety in rural versus urban areas in developing countries is still unexplored. This paper fills this gap in the literature by presenting a study focused on the relationship of various factors—including household consumption expenditure data—with traffic fatality in rural and urban areas. An exhaustive panel data modelling approach is adopted. One important finding of this study is that evidence exists of a contrasting relationship between economy and traffic fatality in rural and urban areas. Increases in most expenditure variables, such as fuel, non-personal modes of travel, and two-wheeler expenditures, are found to be associated with an increase in traffic fatality in rural areas.

Authors	Zhicheng Dai, Tongji University Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Wenbin Luo, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-02415
Paper Title	**Macro Safety Analysis for Non-motorized Vehicles Based on Roadway and Safety Education Improvement Countermeasures**
Abstract	Non-motorized vehicles such as bicycles and e-bikes have gained great popularity in recent decades because of their high mobility and economy. Because these road users have a higher risk of injury in a crash, macro safety analyses have been conducted according to crash location. However, this strategy could be inefficient when comprehensive improvements such as traffic safety education programs are considered, due to differences between crash locations and the locations of the crash-involved road users' residences. To improve implementation of such countermeasures, this study proposes a new analysis strategy of separately aggregating crashes for roadway engineering improvement and road users for education improvement. Roadway, socioeconomic and land use characteristics from 213 Shanghai sub-districts were collected as independent variables. The dependent variables of crashes and road users were divided into four subjects by crash severity level: fatal and injury (FI) and property damage only (PDO). A multivariate Poisson lognormal conditional autoregressive (CAR) model was developed to examine the relationships between regional characteristics and traffic safety, and potential safety improvement (PSI) was calculated for each sub-district based on model results. Hot-zone identification showed significant differences in distribution of sub-districts with urgent need for roadway versus education improvement. False positive and false negative indexes were developed to identify the differences quantitatively. Results indicated that nearly half the identified hot zones were inconsistent in unnecessarily prioritizing either engineering or education improvement. The findings of this paper are of great practical significance to better utilize resources for non-motorized vehicle traffic safety improvement.

Authors	Cody Hodgson, University of Idaho Kevin Chang (kchang@uidaho.edu), University of Idaho
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-02436
Paper Title	**Using Drone Technology to Collect School Transportation Data**
Abstract	Travel tally surveys are administered by elementary, middle, and high (K-12) schools to collect data that measure how students arrive and leave school each day. This data can be used to determine both transportation safety and mobility needs. Collecting this data is usually accomplished by asking teachers to collect a tally in their classrooms; the data are then compiled to determine a representative result for each school. This process requires advanced planning from school administrators and teachers to ensure that information gathering is coordinated and relies on the personal input of each student. Since the age of elementary school students may be as little as six or seven years old, this approach may not always be reliable.In this study, a new method using a quadcopter drone was examined. For comparison purposes, participatory student tally surveys and drone videos were collected on the same day at three different elementary school sites, and the results and effectiveness of each counting method were compared and analyzed. The study concluded that the survey and drone results did not always yield similar results for all modes, so an explanation as to why these deviations occurred and what it means for researchers and practitioners is discussed. Given that drone technology continues to evolve, the lessons learned from this study can be applied toward future school transportation and other mobility studies

Authors	Amin Mohamadi Hezaveh (amohamad@vols.utk.edu), University of Tennessee, Knoxville Christopher Cherry, University of Tennessee, Knoxville Candace Brakewood, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-02442
Paper Title	**Traveler-Involved Traffic Crashes As A Negative Externality Of Tourism Industry**
Abstract	Although it is well established that travelers have a higher risk of injury in traffic crashes compared to non-travelers, less is known about the magnitude of traffic crashes involving travelers and the negative externality of travelers' crashes (NETC) imposed on non-travelers. In this note, we rely on the U.S. Travel Association's definition of a traveler to conduct an empirical analysis focusing on the state of Tennessee; we define travelers as those who travel more than 50 miles from home or have a home-address outside of Tennessee state. We find that 19.2% (127,031 out of 694,276 from 2014-2016) of traffic crashes in Tennessee involve a traveler. The injury cost of non-traveler crashes due to a crash with a traveler (i.e., monetized value of NETC) exceeds $7.6 billion, or 12.3% of tourist expenditures between 2014-2016. Analyzing the net impact of travel (tourist expenditures minus NETC) at county level reveals that the NETC exceeds tourist expenditures in 19 of 97 counties (or 20%) in Tennessee. The results of this analysis reveal that an overlooked negative externality of tourism is traffic crashes involving travelers, which warrants further study and potentially policy remediation.

Authors	Numan Ahmad (nahmad1@vols.utk.edu), University of Tennessee Ramin Arvin, University of Tennessee, Knoxville Asad J. Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-02508
Paper Title	**Exploring Pathways from Driving Errors and Violations to Crashes: The Role of Speed Volatility**
Abstract	Transportation safety can be enhanced by applying safe systems approach to harness new forms of large-scale data. To enhance safety, this study explores how pre-crash data can be used to categorize various driving errors and violations and explore their contribution to speed volatility and crash outcomes. A rigorous path-analytic framework is applied analyzing subsample of Naturalistic Driving Study (NDS) data (N = 9,239). NDS data not only includes realworld information on pre-crash driving behavior and vehicle kinematics but also data on baselines, near-crashes, and crashes which can help quantify crash risk. We first classify human factors into six driving errors and violations using our previously developed systematic taxonomy of errors. Results indicate that human factors still prevail, contributing to 92.43% crashes. Next, tobit regression and ordered probit regression are used to model speed volatility and event outcomes. Results indicate that compared to no error, all six types of driving errors and violations are positively associated with both speed volatility and crash risk. While speed volatility shows significant association with crash risk indicating that all six types of driving errors and violations not only increase crash risk directly but also through speed volatility. For instance, recognition errors associate with 16% higher crash risk while indirect effect of recognition error through speed volatility was found to be about 3%, with total effects of 19%. From practical implication standpoint, implementing technology-based strategies such as cruise control, collision warning system, and dilemma-zone mitigation system can correct or lessen potentially dangerous driving errors and violations.

Authors	Md Hasibur Rahman (mhrahman@knights.ucf.edu), University of Central Florida Mohamed Abdel-Aty, University of Central Florida Mohamed H. Zaki, University of Central Florida Zubayer Islam, University of Central Florida Zubayer Islam, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-02905
Paper Title	**EVALUATION OF THE IMPACT OF COMMUNICATION SYSTEM ON TRAFFIC SAFETY UNDER CONNECTED AND AUTOMATED VEHICLES ENVIRONMENT**
Abstract	The operation of connected and automated vehicles (CAVs) depends on effective communication between vehicles and other roadway infrastructure. However, the impact of the communication network on road safety under the CAV environment is not thoroughly explored. Hence, the focus of this study is to evaluate the performance of various communication parameters and traffic conditions and their impacts on traffic safety in the CAV environment. This research considered Dedicated Short-Range Communications (DSRC) for vehicle ad-hoc network (VANET) and intelligent driver model (IDM) for driving behavior of CAV. For the safety evaluation, the crash risk was estimated based on the time-to-collision (TTC) value. A binary logistic regression model was developed for the safety assessment of different communication parameters and traffic conditions based on traffic conflicts. The simulation study was carried out on one of the major expressways (SR408) in Orlando, Florida. The results of the performance of different communication parameters indicated that queue size and transmission power have a significant effect on traffic safety. With the increase of queue size, crash risk was lower for a smaller number of packet drops. Higher transmission power creates more interference, which culminates in a higher number of traffic conflicts. From the transportation aspect, the study considered lane closure and different percentages of traffic flow scenarios. The results showed that lane closure increased the crash risk due to the higher number of communication collisions between packets. The crash risk was also higher with the increase in traffic flow

Authors	Matthew Hui, University of California, Berkeley Jonathan Kupfer (jonathankupfer.14@gmail.com), University of California, Berkeley Offer Grembek, University of California, Berkeley
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03043
Paper Title	**Traffic Safety During the COVID-19 Pandemic: A Study of How Incident-Based Traffic Safety Metrics Changed Over Time on State Highways in the San Francisco Bay Area and Los Angeles Regions**
Abstract	This research examined the traffic safety impacts of the COVID-19 pandemic and shelter in place on California state highways from February to May 2020 in the San Francisco Bay Area (SFBA) and the Los Angeles (LA) regions. This paper used police dispatch data and highway loop data to observe the vehicle miles traveled (VMT), number of incidents, and incident risk daily and during the peak hours. VMT data were used to establish four unique time periods; 2019 data were used for comparison. Our analysis found that the relative reduction in incident risk (incidents per VMT) was less than the relative reduction in the number of incidents. We found that the reductions in VMT, number of incidents, and incident risk were not uniform across time of day between the morning peak period, evening peak period, and the daily average. We also found notable differences in trends between the two regions. These findings help us better understand how traffic safety metrics are changing in response to the COVID-19 pandemic and illuminate questions for further research.

Authors	Fahmida Rahman (fra228@uky.edu), Kentucky Transportation Cabinet Xu Zhang, Kentucky Transportation Cabinet Mei Chen, Kentucky Transportation Center
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03068
Paper Title	**Effect of Speed on Crash Prediction Model of Rural Two-Lane Highways**
Abstract	Speed plays an important role in traffic safety. Previous works investigated speed's effect on the crashes of rural two-lane highways using estimated speed due to inadequate speed data. It implies a need to understand the effect using measured speed on these roads. This study filled this gap by utilizing ubiquitous probe speed data. Zero Inflated Negative Binomial model was adopted for accounting the excess zeros in crash dataset. Four speed measures, including average speed, the 85 th percentile speed, difference in average speed and speed limit, and difference in 85 th percentile speed and speed limit, were evaluated. The average speed-based model was found to outperform other speed-based models as well as the traditional model. Later, to evaluate whether speed as a categorizer improves the overall model performance, separate prediction models were developed by dividing the dataset based on three-speed ranges: low, medium, and high speeds. Noticeably, speed becomes more significant for the crashes from low to high speed and is an obvious factor for the high-speed category. Compared to the traditional model, inclusion of speed reduced prediction error by 5% for the high-speed roads. Furthermore, for the medium-speed roads, using AADT as another categorizer resulted in further improvement over the model with speed categorizer only. Finally, the models developed for all three-speed ranges showed the lowest error in comparison to the no categorizer model. Since speed and AADT categorizer models enhance prediction accuracy, such an approach is recommended for developing crash prediction models for rural two-lane highways whenever possible.

Authors	Subasish Das (s-das@tti.tamu.edu), Texas A&M University Anandi Dutta, University of Texas, San Antonio Ioannis Tsapakis, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03150
Paper Title	**Motorcycle Crash Causation Study: Exploratory Topic Models from Crash Narrative Reports**
Abstract	The Motorcycle Crash Causation Study (MCCS) is a matched case-control study that contains a very wide list of crash contributing factors associated with motorcycle crash occurrences. It contains information such as motorcycle information, rider information, motorcycle information, and associated trip information. This study also provides crash narrative information that presents in-depth narrative discussion of the crash causation. Due to the plethora of information, it is critical to investigate MCCS related data. Some studies examined the structured information in MCCS datasets. There is no in-depth study that has examined the unstructured textual contents in the MCCS data. This study aims to mitigate this research gap by applying different natural language processing (NLP) tools (e.g., text mining, topic modeling). Fatal and non-fatal crash narratives are clustered separately to gain injury level specific insights. The findings of this study will contribute to the on-going studies on MCCS to better understand the crash causation mechanism associated with motorcycle crashes.

Authors	Nada Mahmoud, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai (qingcai@knights.ucf.edu), University of Central Florida Brenda Young, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03294
Paper Title	**Factors Contributing to Operating Speed on Different Context Classifications of Arterial Segments in Central Florida**
Abstract	Operating speed is fundamental in many fields of transportation engineering including traffic safety, transportation planning, and geometric design. Hence, many studies explored the impact of different exogenous variables on the operating speed represented by the 85th percentile speed. This study contributes to the literature by evaluating and identifying the factors influencing operating speed considering context classification. The study focused on three contect classifications: C3R-Suburban Residential, C3C-Suburban Commercial, and C4-Urban General. Further, it identifies the potential speed calming measures that influence the operating speed for specific context classification categories. Hence, a Tobit model was proposed and developed using big data including traffic roadway characteristics, land use attributes, and socio-demographic information. Three years INRIX speed data were obtained for around 1800 roadway segments and to calculate the 85th percentile speed. The study propsed an approach to adjust the 85th percentile speed from INRIX data since traffic flow on arterials could be disrupted by signalized intersections. Afterwards, empirical analysis was conducted by developing three Tobit models: Generic, C3C/C3R, and C4 models using the adjusted 85th percentile speed. In conclusion, for the three developed models, several variables (e.g., inside shoulder type, inside shoulder width, speed limit, and number of signalized intersections per mile) were found to have significant influence on the 85th percentile speed. The analysis also indicated the potential speed management countermeasures that have significant impact on the 85th percentile speed.

Authors	FAHMID HOSSAIN (fahmid.hossain@utah.edu), University of Utah Juan Medina, University of Utah
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03366
Paper Title	**VERIFICATION OF USRAP RISK ASSESSMENTS FOR RUN-OFF AND HEAD-ON CRASHES USING FIELD DATA**
Abstract	The United States Road Assessment Program (usRAP) provides a systemic approach to estimate the risk of severe injury and fatal crashes along roadway segments based on expected safety performance of roadway and roadside characteristics, together with a general estimation of traffic volume. Detailed crash data is not needed for safety assessments, providing advantages over more traditional crash-driven approaches. However, experiences with usRAP are limited in the U.S., and to date, the program has a growing but limited number of participating states. Verification of the adequacy of usRAP assessments is therefore of significant value, not only to identify strengths and limitations of the methodology within the U.S. context, but also to potentially expand the set of tools available to agencies. This paper presents a verification of usRAP risk assessments for run-off road and head-on crashes using over 7,000 miles of coded segments and five years of crash data collected in Utah. Comparisons between risk estimations from usRAP and actual crash rates provided insights on expected and observed effects of roadside objects and their distances from the traveled lanes, type of median present, as well as horizontal curves. A spatial correlation test also confirmed the agreement between usRAP risk assessments and crash data, providing additional promising indications of the suitability of this systemic methodology for safety applications.

Authors	Yingying Pei, Tongji University Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Mingjie Feng, Tongji University Zhixing Zhu, Traffic Police Headquarters of Jiangsu Province Fang Liu, Traffic Police Department of Suzhou City Zhongyang Qie, Traffic Police Department of Suzhou City Paul P. Jovanis, Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03435
Paper Title	**Macro-Level Safety Analysis of Crashes and Violations: Influencing Factors and Crash Hotspots**
Abstract	Regional traffic safety has been a public concern for many metropolitan areas, and it is urgent to turn this situation around by using an appropriate traffic safety analysis and crash hotspot identification method. Existing studies mainly focus on the effects of engineering-related indicators on regional crashes and violations, neglecting the traffic police enforcement-related factors. Meanwhile, the relationship between crashes and violations is insufficiently recognized. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, and collected socio-economic indicators, road features, land use intensity, facility data, and police enforcement information as independent variables. A Bayesian bivariate negative binomial spatial conditional autoregressive (BNB-CAR) model was developed to capture the association between crashes and violations, as well as their contributing factors. Results showed that (1) there existed a significantly correlated effect between crashes and violations; (2) engineering-related indicators had similar effects on crashes and violations, while some police enforcement-related factors were dual-effective. Based on the model results, this study used the potential for safety improvement (PSI) method to identify the hazardous areas of the 115 towns in Suzhou. It was observed that (1) the spatial distribution of crashes indicated the spatial correlations among the towns; (2) the fringe areas suffered higher crash risks than the downtown areas. Several engineering and enforcement countermeasures were provided for urban planning departments and traffic police to enhance their work effectiveness. Additionally, decision makers and administrators will benefit from this study to improve daily traffic safety management.

Authors	Branislav Dimitrijevic, New Jersey Institute of Technology Sina Darban Khales, New Jersey Institute of Technology Roksana Asadi (ra653@njit.edu), New Jersey Institute of Technology Joyoung Lee, New Jersey Institute of Technology Kitae Kim, New Jersey Institute of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-03591
Paper Title	**Segment-Level Crash Risk Analysis for New Jersey Highways Using Advanced Data Modeling**
Abstract	Highway crashes are the most significant challenge to the goal of providing a safe and efficient highway transportation system. They result in significant societal toll reflected in numerous fatalities, personal injuries, property damage, and traffic congestion. To that end, much attention has been given to developing models to study and predict crash occurrence. More recently advancements have been made in developing proactive crash risk models, aiming to assess crash risks in the short term, and inform traffic management strategies to prevent and mitigate the negative effects of crashes. This study developed and tested several models for segment-level crash risk considering the data available to most transportation agencies in real-time on a regional network scale. The data included roadway geometry characteristics, traffic flow characteristics, and weather condition data. The models included Bayesian Logistics Regression (BLR), Decision Tree (DT), Random Forest (RF), Gradient Boosting Machine (GBM), K-Nearest Neighbor (KNN), and Gaussian Naïve Bayes (GNB). The models were trained and tested using a dataset containing records of 10,155 crashes that occurred on two interstate highways in New Jersey over two years. It was found that for the given dataset the models provided limited predictive value. Keywords: Crash analysis, crash risk forecasting, machine learning

Authors	Asad J. Khattak, University of Tennessee Numan Ahmad (nahmad1@vols.utk.edu), University of Tennessee Behram Wali, University of Tennessee
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-04104
Paper Title	**Heterogeneity in Naturalistic Driving Errors, Violations, and Crash Risk in Diverse Environmental Context**
Abstract	Driving errors and violations are identified as contributing factors in most crash events. Different types of driving errors and violations may vary across diverse roadway environments. Due to unique nature of several types of driving errors and violations, crash risk associated with each type of these driving errors and violations can be different. To empirically explore errors and violations in diverse built environments, this study harnesses unique and highly detailed pre-crash sensor data collected in SHRP2 Naturalistic Driving Study (NDS), containing 673 crashes, 1,331 near-crashes and 7,589 baselines (no-event). First, we apply our previously proposed systematic taxonomy of driving errors and violations to bring all types of human crash-contributing factors into systematic framework, and then compute crash risk associated with different driving errors and roadway environment. Based on percentage of crashes per percentage of baselines in a specific locality, interstates and rural and semi-rural settings may pose lower risks. Contrarily, urban, business/industrial, and school locations seem to have higher percentage of crashes per percentage of baselines indicating higher crash risk. Human errors and violations contributed to 93% of crashes. Recognition and decision errors occurred more frequently (each contributing to ~39% of crashes) in business or industrial land use environments (but not in dense urban localities). Distribution of driving errors and violations across different roadway environments can aid in implementation of place-based countermeasures with implications for connected and automated vehicle development, e.g., by understanding complex and unusual (fringe case) situations for safety, testing of connected and automated vehicles can be enhanced.

Authors	Shefa Arabia Shioma, University of Toledo Ahmad Ilderim Tokey (ahmadtokey@gmail.com), University of Toledo Muhammad Salaha Uddin, University of Toledo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-21-04448
Paper Title	**Assessing the Effectiveness of Built Environment-based Safety Measures by Urban and Rural Area for Reducing the Non-motorist Crashes**
Abstract	Built environment (BE)-based safety measures are usually implemented for reducing the non-motorist crashes in urban and rural area. However, their usefulness differing the urban and rural area were not widely explored in literature. Therefore, this study was explored the effectiveness of built environment-based safety measures in urban and rural settings. The study used four years' (2015-2018) non-motorist (pedestrian and bi-cyclist) crash data of Florida and examined the effect of built-environment based safety measures such as sidewalk, distance from the road, bike lane, barrier, land use mix. In this study urban and rural area were classified by applying the multivariate clustering method. The study used the negative binomial and geographically weighted Poisson regression (GWPR) for understanding the effects of BE factors assuming their spatial heterogeneity. The study finds that building the sidewalk only, and existence of intersection expose the people to crash incidents in urban areas while traffic volume works for increasing non-motorist crashes in the rural areas. The analysis also reveals that combinedly sidewalk and barrier can reduce the risks of non-motorist crashes. Signalized intersection also reduces the effect of high traffic volume on the frequency of crashes. Higher percentage of commercial Land uses (LU) in high mixed LU are helpful for ensuring the safety of pedestrian and cyclists. This study findings will be supporting for implementing the BE based safety measures considering their combined effectiveness as well as the urban and rural characteristics of the area.

Poster Session 1311: Case Studies in Performance Based Analysis of Geometric Design

Authors	Ida van Schalkwyk, Washington State Department of Transportation
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1311
Session Title	Case Studies in Performance Based Analysis of Geometric Design
Paper Number	P21-20305
Paper Title	**The Societal Crash Value of Existing and Potential Rumble Strip Installations on WA two lane rural state highways**
Abstract	In 2019/2020 WSDOT staff completed an analysis of the two lane rural state highway system to determine what the societal crash benefits of existing and potential new installations of centerline and/or shoulder rumble strips would be. This analysis and the use of this analysis as a method to determine a break-even cost for rumble strips are valuable given that the installation costs of rumble strips can vary significantly from project to project: from as low as $5,000 to as high as $45,000 per mile. This is because of the great extent to which WSDOT has had to leverage chip seals in order to maintain asphalt pavement. The HSM predictive analysis of the two lane rural state highway system used the AASHTO Highway Safety Manual Chapter 10 predictive method for segments. This analysis incorporates roadway cross section, alignment (vertical grade and horizontal curvature), and the historic crash experience for the specific crash types and severities targeted with rumble strip installation. The analysis produces an estimate of how the particular segment is performing compared to similar locations on the system. The analysis segments can be aggregated for individual projects or as part of other projects. The results of this analysis is now deployed on the WSDOT Pavement Management System where regions and HQ staff can access the results along with line diagrams of geometrics, pavement characteristics, traffic characteristics and other key project information. This analysis provides the foundation for not only a systemwide perspective on project selection but also paves the way for other statewide analysis that can support scoping, design, and project development across the state.

Authors	Huaguo Zhou, Auburn University Qing Chang, Auburn University Yukun Song, Auburn University
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1311
Session Title	Case Studies in Performance Based Analysis of Geometric Design
Paper Number	P21-21214
Paper Title	**Impact of Geometric Design Elements on Deterring Wrong-Way Driving at Interchange Terminal**
Abstract	Wrong-Way driving (WWD) incident is a dangerous act caused by driver driving on the opposite direction of the traffic flow inadvertently or deliberately. Especially on the limited access highways, due to the high speeds and limited reaction time, the WWD incidents are more likely to cause fatalities or serious injuries. Due to the majority of the WWD crash happened on the freeway are originated from the exit-ramp terminals, the objective of this study is to quantify the impact of geometric design elements regarding WWD incidents at interchange terminal based on case studies in Alabama, Illinois, Texas, Michigan, etc. To achieve the purpose, this study first summarized the geometric design features that may prevent or contribute to WWD from various literatures such as AASHTO Green book, Guidelines from the Department of Illinois (IDOT), etc., including type of interchanges, intersection balance, control radius, intersection angles, channelizing island, types of medians, visibility of on-ramp (elevation), median type and width on two-way ramps. The researchers also summarized past studies investigating the effects of geometric design elements including control radius and type of median on the crossroad, reduced width of exit ramp, and intersection balance. The case studies in Illinois ranked different interchange types on WWD crashes based on an estimated weighted WW entries per one hundred interchange terminals (1). The design manual provided by Washington State Department of Transportation (WSDOT) indicated that the control radius with larger radii may encourage a wrong way right turn onto the exit ramp, the angular corner or tight radii make this movement difficult, as a result, it is necessary to avoid the control radius tangent to the edge when considering this element (2, 3). More importantly, a wider off-ramp opening may increase the likelihood of the WWD since driver may have hard time to figure out the right way. That is the reason why the implementation of the channelizing island is encouraged by past studies (4, 5). However, the recent case

study conducted in Florida found that the channelized island at the end of the off ramp may confuse coming drivers (6). Another before-and-after case study in Alabama was conducted at one partial cloverleaf interchange terminal, where a raised-curb channelizing island was implemented to narrowing the off-ramp opening. The study found that the placement of a channelizing island on the throat of the off ramp creates confusion for the left turning vehicles on the crossroad, which eventually increased the WWD incident. A study conducted by North Texas Tollway Authority (NTTA) found the existence of a side street close to an exit ramp will confuse drivers while entering the ramp (7). Similarly, the Michigan department of transportation (MDOT) identified 161 interchanges with adjacent and parallel ramps extending to the crossroad that may potentially cause WWD (8). Additionally, an inadequate sight distance not only blocks driver's view of ramp terminals, but also fails to help drivers distinguish between entrance and exit ramps. Previous studies revealed that an intersection balance of 51% to 60% ensures a good view for the left-turning drivers from the crossroad to the two-way ramp (2).

Poster Session 1327: Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)

Authors	Ross McCarthy (rjmccar1@vt.edu), Virginia Polytechnic Institute and State University Gerardo Flintsch, Virginia Polytechnic Institute and State University Edgar de Leon Izeppi, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-00051
Paper Title	**Benefit-Cost Approach for Using Continuous Friction Measurements to Choose a Pavement Surface Treatment**
Abstract	Motor vehicle crashes continue to be a leading cause of death in the United States, which makes them the primary driving force behind the development of highway safety programs that aim to reduce related fatal and serious injuries. A key component of these safety programs is that they are driven by safety data, which must be collected and analyzed in order to identify and choose sites and countermeasures that reduce crash risk in a cost-effective manner. Skid resistance is an example of a parameter that can be routinely monitored with testing equipment and used as a measure of safety. The relationship between crash risk and skid resistance is well grounded in decades of literature and serves as the foundation for establishing investigatory levels of skid resistance. Investigatory levels are used in pavement friction management programs found in countries such as Australia, New Zealand, and the United Kingdom to identify low-friction sites with a high potential for skidding crashes. Low-friction sites are investigated to determine the need for treatment. For the investigation, friction measurements are included in regression models, such as safety performance functions (SPFs), and used along with the Empirical Bayes (EB) method in a benefit-cost analysis to predict the potential benefits of improving friction with surface treatment at low-friction sites. In this paper, it is shown that a pilot application of this methodology on a small network can predict crash reductions and assist in choosing friction improvement treatment.

Authors	Muhammad Khattak, Universiteit Gent Hans De Backer, Universiteit Gent Pieter De Winne, Universiteit Gent Tom Brijs, Universiteit Hasselt Ali Pirdavani (ali.pirdavani@uhasselt.be), Hasselt University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-00755
Paper Title	**Investigating the Impact of Road Cross-Section Elements on Crash Occurrence in Urban Areas**
Abstract	Appropriate roadway cross-section design is critical due to its impact on safety, capacity, and function of the facility. While it is generally straightforward to assess this impact on capacity and function, it is not always easy for safety evaluation. Literature shows contradictory observations concerning the complex relationship between roadway cross-section elements and crashes, particularly in urban areas. Another important issue is the presence of on-street parking and their safety implications in urban areas.

	In the current study, safety performance functions were developed to investigate the impact of roadway cross-section elements and on-street parking on crash occurrence using negative binomial distribution framework. A database consisting of six-year crash records, traffic data, and road geometry of urban roads of Antwerp, Belgium was created for modeling. This paper reports how cross-section elements, on-street parking, and exposure contribute to crash occurrence in urban areas and discusses whether the results could be used to improve safety performance of road segments. The results indicated that the effects of number of lanes, segment length, and traffic volume on crash occurrence were significant while that for lane width was not. Parking variable (parking arrangement) was significantly related to "injury", and "injury & fatal" crashes. Roads with higher number of lanes experience more crashes than roads with fewer lanes. Roads with parking were more prone to injury & fatal crashes than no parking settings. To conclude, these findings showed that road cross-section elements and parking settings play an important role in crash occurrence on road segments in urban areas.

Authors	Moataz Bellah Ben Khedher, University of Science and Technology of Lille Dukgeun Yun (dkyun@kict.re.kr), Korea Institute of Civil Engineering and Building Technology (KICT)
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-00971
Paper Title	**A Comparative Approach of Crash Frequency Modelling in Two Lane Rural Roads**
Abstract	Road accidents are now one of the leading causes of death in the world. Investigating the underlying factors that contribute to increased risk of these accidents is an essential procedure to take effective countermeasures. In this study, we take a particular interest in two lane rural roads in South Korea. Six count data regression models were developed and evaluated for the goodness of fit. Traditionally, the evaluation is performed using information criterion such as Akaike Information Criterion. In this research, assessment of different models performances was carried using additional methods that include machine learning techniques, i.e. data splitting, and graphical tools, i.e. rootgrams . Based on the results of every evaluation technique, negative binomial hurdle model clearly outperformed all other regression models. Therefore, three variables were identified to have a significant impact on crash occurrence in two lane rural roads. These features are safety barrier, shoulder width and Annual Average Daily Traffic.

Authors	Shubham Patil, Sardar Vallabhbhai National Institute of Technology Narayana Raju, Sardar Vallabhbhai National Institute of Technology Shriniwas Arkatkar (sarkatkar@gmail.com), Sardar Vallabhbhai National Institute of Technology Said Easa, Ryerson University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-01259
Paper Title	**Modeling Vehicle Collision Instincts Over Road Midblock Using Deep Learning**
Abstract	The study aimed to understand the vehicle safety of heterogeneous (mixed) and homogenous traffic flow over road midblock. In addressing the limitations of existing safety frameworks, the paper proposes a new safety framework that includes the collision instincts caused by the surrounding vehicles using the conventional time-to-collision (TTC) measure. An automated trajectory data tool is developed using advanced image processing concepts to generate trajectory data over the study sections. In the proposed framework, the lateral movement of vehicles is accurately modeled using deep learning. Further, the proposed framework is tested using the developed trajectory datasets. The results show that, in mixed traffic, the collision points occur over the entire study section. In the case of homogeneous traffic, the collision instincts are clustered toward the median lanes. With advanced technologies, trajectory data can be implemented in real-time within the proposed safety framework. The application of the proposed methodology can flag critical areas over the road network for better treatment to improve road safety.

Authors	Nishant Pawar, Indian Institute of Technology, Bombay Nagendra Velaga (n.r.velaga@iitb.ac.in), Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-01268
Paper Title	**A Proactive Safety Approach to Assess Overtaking Behavior and Crash Risk of Drivers under Time Pressure Situations**
Abstract	The aim of the current study is to assess the driving behavior, overtaking and crash probabilities of drivers during a car-following situation. Three different time pressure conditions (i.e., No Time Pressure (NTP), Low Time Pressure (LTP), and High Time Pressure (HTP)) were considered to analyze driving behavior during car-following and overtaking as well as crash probabilities. Minimum Time-to-Line Crossing (TLC) and Coefficient of Variation in Speed (CVS) were considered to examine driving behavior while following the lead vehicle. Further, minimum TLC and CVS were considered as explanatory variables to explore their influence on overtaking and crash probabilities. Minimum TLC was modelled using parametric survival analysis. CVS, overtaking and crash probabilities were modelled using Generalized Linear Mixed Models. The results showed that minimum Time-to-Line crossing reduced by 36.7% and 63.8% in LTP and HTP driving conditions, respectively. The Coefficient of Variation in Speed increased by 3.437% in HTP (no significant effect in LTP). The drivers using a car for work purpose and non-professional drivers showed aggressive driving behavior with low minimum Time-to-Line Crossing and Coefficient of Variation in Speed. The increase in overtaking probability (with time pressure) exposed drivers to greater collision risks which increased the likelihood of crashes. In general, male drivers showed more risky driving decisions than female drivers under time pressure conditions. However, it was observed that female drivers were more prone to crashes than male drivers. Overall, the results suggest that drivers take more risk to complete the driving task under time pressure conditions.

Authors	Zhihua Zhang, University of Tennessee, Knoxville Yuandong Liu, Oak Ridge National Laboratory Lee Han, University of Tennessee Phillip Freeze, Tennessee Department of Transportation
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-01324
Paper Title	**Secondary Crash Identification Using Crowdsourced Waze User Reports**
Abstract	Secondary crashes are considered to be crashes that occur as a result of the noncurrent congestion originating from primary crashes, which always has a greater impact on safety and traffic than a single crash. A better understanding of secondary crashes would benefit traffic incident management, and this requires accurate identification of secondary crashes. In this study, we explored using crowdsourced Waze user reports to identify secondary crashes. A network-based clustering algorithm was proposed to extract the primary crash cluster, including all user reports originating from the primary crash, and any crash that occurred within the cluster would be the secondary crash. This method worked as a filter to select accurate primary-secondary relationships, thus identifying the exact secondary crashes. Then, we performed a case study for crashes occurring from June to December 2019 on a 30-mile stretch of I-40 in Knoxville. A static threshold method (crash duration and 10 miles), was used to pre-select the potential primary-secondary crash pairs. We pre-selected 75 out of 708 crashes as potential secondary crashes. Based on the pre-selected primary-secondary crash pairs, 17 secondary crashes were obtained with our method. We compared the results of our method with one of the commonly used methods, the speed contour plot method. Though our method captured fewer secondary crashes, it did identify several secondary crashes that could not be observed with the speed contour plot method. The results showed the applicability of our method and the potential of crowdsourced Waze user reports.

Authors	Rajesh Paleti (rpaleti@psu.edu), Pennsylvania State University Asif Mahmud, Pennsylvania State University Vikash Gayah, Pennsylvania State University Abdul Pinjari, Indian Institute of Science
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-01431
Paper Title	**When and Where does the Next Crash Occur? A Discretized Duration Based Modeling Approach**
Abstract	This paper develops real-time crash prediction modeling system that seeks to predict the time until the next crash is expected along a roadway facility. The proposed model incorporates both the parsimonious parametric probability structure of hazard duration models and the flexibility of discrete choice models for incorporating time-varying covariates and unobserved heterogeneity. Another useful feature of the proposed model is that it does not require case-control or sampling of time-intervals that are ubiquitous in existing real-time crash prediction models. The model was applied to estimate inter-crash durations along I-405 in California. The statistical fit measures on 80% estimation sample as well as validation metrics and policy analysis on 20% test sample demonstrate the practical applicability of the proposed modeling system.

Authors	Mankirat Singh, California State Polytechnic University, Pomona Wen Cheng (wcheng@cpp.edu), California State Polytechnic University, Pomona Yihua Li, Central South University of Forestry and Technology Dean Samuelson, California Department of Transportation (CALTRANS) Edward Clay, California State Polytechnic University, Pomona
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-01915
Paper Title	**Exploration of Various Spatio-temporal Interactions in Crash Frequency Models**
Abstract	Extensive research efforts have been put forth to improve the prediction of crash frequencies by employing the spatio-temporal models. Despite the large number of studies exploring various spatial and temporal effects, there is still a lack of conclusive findings related with the performance of spatio-temporal interactions. The current study bridges the gap by performing a comprehensive comparison of different spatio-temporal interactions with distinct temporal treatments in crash frequency models. Fifteen spatio-temporal models were developed which can be clustered from different perspectives: (1) three groups of models based on temporal treatments containing linear time trend, autoregressive-1 (AR1), and random walk-1 (RW1); (2) models with and without spatio-temporal interaction terms; (3) four different types of interactions including both structured and unstructured spatial or temporal random effects. To estimate the model parameters, the present study employed a fast Bayesian inference approach, or, Integrated Nested Laplace Approximation (INLA). The predictive accuracy of alternative models was assessed by employing various evaluation criteria which include deviance information criterion (DIC), log pseudo marginal likelihoods (LPML), and Probability Integral Transform (PIT). The results illustrated that the models with spatiotemporal interaction perform better than the models without spatiotemporal interactions. The dynamic temporal effects, RW1 and AR1, were found to perform almost the same, with both being superior to the non-dynamic parametric linear trend. With respect to the average performance among all interactions, the interaction of both unstructured spatial and temporal effects was found to outperform others.

Authors	Yang-Jun Joo, Seoul National University Ho-Chul Park, Myongji University Seung-Young Kho, Korea National University of Transportation Dong-Kyu Kim (dongkyukim@snu.ac.kr), Seoul National University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-02229
Paper Title	**Reliability-based Assessment of Potential Risk for Lane Changing Maneuvers**
Abstract	Despite the urgent need for continuous risk assessments during autonomous driving, achieving reliable assessment results is still challenging due to the unpredictable behaviors of adjacent human drivers and the resultant complexity. Such complexity especially increases during lane changes, because several vehicles need to interact with other vehicles. This paper proposes a new framework to analyze lane changing risk on freeways considering the forecastability in adjacent vehicles. Virtual lane change scenarios are constructed based on historical maneuvers in adjacent vehicles, and the risk of potential lane change is evaluated through the safety evaluation result of the scenario. Adjacent vehicles' future maneuvers are predicted using a multivariate Bayesian structural time series (MBSTS) model, and the forecastability is estimated as the standard error of the predicted values. The failure probability of those lane changing scenarios is obtained through the first-order reliability method (FORM) assuming that failure occurred when any time to collisions (TTC) value for adjacent vehicles was less than a threshold during the lane change. This study compares six scenarios with different levels of uncertainty to show the effect of uncertainty in the level of risk. The proposed framework differentiates itself from existing methods by estimating higher risk in more significant uncertainties in adjacent vehicles. It is expected that the outcome of this study will be valuable in developing reliable lane change strategies in autonomous driving.

Authors	Jeremiah Roland (fpf852@mocs.utc.edu), University of Tennessee, Chattanooga Peter Way, University of Tennessee, Chattanooga Mina Sartipi, University of Tennessee, Chattanooga Osama Osman, University of Tennessee, Chattanooga
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-02286
Paper Title	**Spatio-Temporal Accident Prediction: Effects of Negative Sampling on Understanding Network-Level Accident Occurrence**
Abstract	In projects centered around rare event case data, the challenge of data comprehension is greatly increased due to insufficient data for deriving insight and analysis. This is particularly the case with traffic accident occurrence, where positive events (accidents) are rare with, in most cases, no data set existing for negative events (non accidents). One method to increase available data is negative sampling. In this work, four negative sampling techniques are presented with varying ratios of negative to positive data. These types of techniques are based on spatial, temporal, and a mixture of the two types of data, with the data ratios acting as class balancing tools. The best performing model found was with a negative sampling technique that shifted temporal information and had an even 50/50 data split, with an F-1 score of 93.68. These results are promising for ITS applications to inform of potential accident locations in an entire area for proactive measures to be put in place.

Authors	Cheuk Ki Man (c.k.man@lboro.ac.uk), Loughborough University Mohammed Quddus, Loughborough University Athanasios Theofilatos, Loughborough University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-02446
Paper Title	**Utilizing Transfer Learning for Temporal and Spatial Transferability of Real-Time Crash Prediction Models**
Abstract	Real-time crash prediction is a heavily studied area given its potential in proactive traffic safety management. A plethora of statistical and machine learning models have been developed to predict crashes in real-time. However, limited studies have been conducted to assess and improve the transferability of models. This paper attempts to address this gap by combining Generative Adversarial Network (GAN) and transfer learning, in order to examine the transferability of real-time crash prediction model under an extremely imbalanced data setting. Initially, a baseline model was developed using Deep Neural Network with crash and macroscopic traffic data collected from M1 Motorway in United Kingdom in 2017. The dataset utilized in the baseline model is naturally imbalanced with 257 crash cases and 16,359,163 non-crash cases. To overcome data imbalance issue, GAN was utilized to generate synthetic crash data. Non-crash data were randomly undersampled due to computational limitations. Weights obtained from the trained model were then fitted to five other datasets obtained from M1 (2018), M4 (2017 & 2018 separately) and M6 Motorway (2017 & 2018 separately) using transfer learning. Transferability results were compared with direct transfer through testing from the baseline model. This study revealed that direct transfer is not feasible. However, models become transferable temporally, spatially and spatio-temporally under transfer learning. The predictability of the transferred models is satisfactory with high AUCs ranging between 0.76 to 0.87 relative to existing studies. The best transferred model can predict nearly 80% crashes with 20% false alarm rate by tuning thresholds.

Authors	Hari-Krishnan Melempat-Kalapurayil, University of Texas, San Antonio Amit Kumar (amit.kumar@utsa.edu), University of Texas, San Antonio
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-02607
Paper Title	**County-Level Crash Data Exploration Using Principal Component Analysis Based Agglomerative Hierarchical Clustering**
Abstract	This study aims to conduct a county-level data exploration to identify the county groups or clusters in relation to socio-demographics, road infrastructure, traffic and crash features using clustering algorithm from the stream of unsupervised machine learning. Hierarchical clustering algorithm was adopted in this study to group the 254 counties in Texas, USA into identical groups with reference to the socio-demographics, road, and crash features. Such analysis can assist decision-makers in delivering efficient and effective resources allocation and policy analysis for priority regions. Three separate analyses are performed for crashes related to motor vehicles, pedestrians, and pedal cyclist. The study also presents an analysis framework that attempts to address the issue of low sample size high dimension to capture maximum variation in the data by utilizing the concepts from principal component analysis (PCA). Primary results from the clustering analysis shows two distinct groups of counties which shows high variation with respect to the crash features. The cluster tree results from this study indicate small variations in cluster members for motor vehicle crashes and pedestrian crashes whereas large variations for pedal cyclist crashes.

Authors	Md Abu Sayed (sayed@uwm.edu), University of Wisconsin, Milwaukee Xiao Qin, University of Wisconsin, Milwaukee Rohit J Kate, University of Wisconsin, Milwaukee D M Anisuzzaman, University of Wisconsin, Milwaukee Zeyun Yu, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-02668
Paper Title	**Identifying Underreported Work Zone Crash Using Machine Learning Techniques – A Comparative Study**
Abstract	The manifold data format of traffic crash report and the scared use of advance machine learning technologies in crash classifications are the reasons for many work zone(WZ) crashes remain unreported in crash statistics. This study aimed to automate the process of finding these underreported work zone crashes from police reported crash narratives. Seven state-of-the art of machine learning techniques; (1) multinomial naive bayes(MNB), (2) logistic regression(LGR), (3) Support Vector Machine(SVM), (4) Random Forest(RF), (5) K-nearest neighbor(K-NN), (6) Gated recurrent Unit(GRU) and (7) NoisyOR, were applied to recover underreported WZ crashes from reported non work zone(NWZ) crash narratives. As an experimental study, three-years crash narratives were collected from Wisconsin DOT, of which 70% were noises (false positive or false negative) and most of the words in narratives were irreverent to work zone. Our investigation using a test sample of top-scorer narratives of seven models showed that GRU and NoisyOR outperformed the rest of the classifiers in detecting underreported WZ crashes. Moreover, GRU and NoisyOR were successful finding WZ related words to use them for classifications, whereas the second-best performers; LGR and SVM, were mostly affected by irreverent words. Further investigation using a large test sample size for GRU and NoisyOR revealed that GRU detected a few more underreported WZ crashes than NoisyOR. However, the detection rate changes a bit abruptly for GRU whereas it changes uniformly for NoisyOR. Both models can be used to automatically detect underreported WZ crashes from crash narratives without human intervention.

Authors	Haipeng Cui (cuihp2013@163.com), National University of Singapore Kun Xie, Old Dominion University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-02807
Paper Title	**A Full Bayesian Space-time Random Effect Approach for Hexagon-based Crash Frequency Modeling**
Abstract	Although spatial and temporal correlations of crash observations have been well addressed in recent studies, the interactions between them are rarely studied in the safety literature. To accommodate the complex spatiotemporal data structures, Markov Chain Monte Carlo (MCMC) method is generally used, resulting in high computational expense for model estimation. This paper proposes a Bayesian spatiotemporal interaction (BSTI) approach for crash frequency modeling with an integrated nested Laplace approximation (INLA) method to greatly expedite the estimation process. Manhattan is selected as the study area. Hexagons are used as the basic geographic units to capture crash, transportation, land use, and demo-economic data. A series of Bayesian spatiotemporal models are developed and compared. Results show that the BSTI model with type II interaction outperforms the other models by showing the ability to capture both spatial and temporal correlations as well as spatiotemporal interactions. It is also found that the unobserved heterogeneity is mostly attributed to the spatial effects instead of temporal effects. The findings show the necessity of addressing the spatiotemporal interactions in crash frequency modeling.

Authors	Osama Osman (osama-osman@utc.edu), University of Tennessee, Chattanooga Mustafa Hajij, Santa Clara University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-03024
Paper Title	**Crash Prediction for Advanced Driver Assistance Systems: Development and Comparative Analysis of Advanced Deep Learning Techniques**
Abstract	Motor vehicle crashes have claimed the lives of 38,800 lives and caused 4.4 million injuries in 2019 alone. Studies have shown that 94% of these crashes are because of driver errors. Such a huge contribution of driver errors to crashes points out that efforts to improving safety should be directed towards both vehicles and drivers through advanced driver assistance systems (ADAS) and vehicular technologies. This study investigates the potential realtime data collected through vehicular technologies on driver behavior offer to predict crashes as a first line of defense to avoid them. Three deep learning models were developed including multilayer perceptron neural networks (MLP-NN), long-short-term memory networks (LSTMN), and convolutional neural networks (CNN) using vehicle kinematics time series data extracted from the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS) dataset. The study builds on the hypothesis that crashes are preceded by turbulences that take place over time (turbulence horizon). If these turbulences are detected in a timely manner they can help predict and avoid crashes. Several values were tested for the turbulence horizon and the prediction horizon (how long before the crash impact it can be predicted) to identify the optimal values. The results showed that the CNN model can predict all crashes with a 100% accuracy and zero false alarms 3 seconds before the crash impact time, when a 6-second turbulence horizon is used. This outstanding performance presents the developed model as a promising tool for implementation in ADAS.

Authors	Md Tanvir Ashraf, West Virginia University Kakan Dey (kakan.dey@mail.wvu.edu), West Virginia University Sabya Mishra, University of Memphis
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-03336
Paper Title	**Extracting Rules from AV involved Crashes by applying Decision Tree and Association Rule Methods**
Abstract	Autonomous Vehicles (AVs) can dramatically reduce the number of traffic crashes and associated fatalities by eliminating the avoidable human-errors related crash contributing factors. Many companies have been conducting pilot tests on public roads in several states in the US and other countries to fast-track AV mass deployment. AV pilot operations on California public roads caused 251 AV involved crashes (as of February 2020). These AV involved crashes provide a unique opportunity to investigate AV crash risks in the mixed traffic environment. This study collected the AV crash reports from the California DMV and applied the Decision Tree (DT), and Association Rule methods to extract the pre-crash rules of AV involved crashes. Extracted rules revealed that the most frequent AV involved crash type was rear-ended crash and predominantly occurred at intersections when AVs were stopped and engaged in the autonomous mode. AV and Non-AV manufacturers, and transportation agencies can use the findings of this study to minimize AV related crashes. AV companies could install a distinct signal/display to inform the operational status of the AV (i.e., autonomous or non-autonomous mode) to human drivers around the AVs. Moreover, the Automatic Emergency Braking (AEB) system in non-AV could avoid a significant number of rear-end crashes as often rear-end crashes occurred due to the failure of non-AV's timely slow down behind AVs. Transportation agencies can consider separating the AVs from the non-AVs by assigning "AV only lanes" to eliminate the excessive rear-end crashes due to the mistakes of human-drivers in non-AVs.

Authors	Sina Asgharpour (s.asgharpour2016@student.sharif.edu), Sharif University of Technology Mohammadjavad Javadinasr, University of Illinois, Chicago Zeinab Bayati, Sharif University of Technology Amir Samimi, Sharif University of Technology
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-03372
Paper Title	**Missing Data Problem Treatment in Crash Data: A Genetic Algorithm-based Clustered Weighting Method**
Abstract	Addressing the missing data problem, as one of the most commonplace challenges in the crash data studies, is of vital importance. The detrimental effects induced by a missing-containing dataset on the subsequent analyses seem inevitable. In this sense, missing data treatment techniques endeavor to compensate for the bias engendered by missing-ness. Considering that the missing-ness potentially causes variables' distribution to undergo drastic deviations from their unbiased state, in this study, we proposed a new weighting method in an optimization model framework to minimize the overall deviation from the unbiased state of the dataset, with respect to a predefined set of essential variables (i.e., the control variables). In this regard, we devised a heuristic algorithm based on Genetic Algorithm, as well as a boosting process, called clustering, to circumvent the calculation burden. Moreover, we used Iran's nation-wide yearly crash data to appraise the performance of the proposed algorithm. According to the results, the overall deviation, in case of having 10 control variables, decreases from 10% (associated with the Complete Deletion) to approximately 0.9% (i.e., 92% improvement). Besides, the statistical significance tests in the before/after stages demonstrate the high performance of the method in reducing the deviation. Another finding reveals the inverse relationship between the performance of the algorithm and the number of the control variables with the reduction of the performance index from 92 to roughly -40, subsequent to a decrease in the number of the control variables from 10 to 1.

Authors	Angela Kitali (akita002@fiu.edu), Florida International University Priyanka Alluri, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-03548
Paper Title	**Influence of Incident Spatiotemporal Estimation Method in Secondary Crash Identification**
Abstract	Accurate estimation of the primary incident spatiotemporal impact area is essential and imperative for successfully mitigating secondary crashes. This study presents a data-driven approach to automatically determine the spatiotemporal impact areas of primary incidents and hence detect secondary crashes that occurred within the affected area. The proposed approach considered how the queue caused by the primary incident grows and dissipates along each roadway segment upstream of the incident. The effectiveness of the proposed approach was compared with the approach that assumed that the impact of the incident along all the impacted segments is the same, referred to as the base approach . A majority of secondary crashes occurred under congested traffic conditions. Incidents with a major impact on traffic were the primary contributors to secondary crashes. The comparison of the secondary crashes detected by the improved and the base approach indicated that the base approach identified 54% more secondary crashes than the improved approach . These additional crashes were found to occur mostly under less traffic congestion such as during off-peak hours, on weekends, and when the primary incident had only a minor impact on traffic. Although the improved approach identified fewer secondary crashes, it is more precise because it considers segment-based traffic conditions. The proposed method more accurately identifies secondary crashes since it better reflects the changes in traffic characteristics caused by the primary incident.

Authors	Seyedmirsajad Mokhtarimousavi (smokh005@fiu.edu), Florida International University Jason Anderson, Portland State University Mohammed Hadi, Florida International University Atorod Azizinamini, Florida International University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-03739
Paper Title	**Hybrid Artificial Intelligence Models for Work Zone Crash Frequency Analysis at Bridge Locations**
Abstract	Crash characteristics differ from location to location, as well as over time, along with varying features of participants at fault, environmental and geometrical conditions. Although the impact of work zone presence on crash frequency has been investigated in previous studies, the risk factors associated with work zone crash frequency at bridge locations are not fully understood. With this in mind, this study utilizes a Negative Binomial (NB) regression and a Support Vector Regression (SVR) models trained by Artificial Bee Colony (ABC) optimization algorithm for modeling work zone crash frequency. Incorporating three years of crash records from 2015-2017, road inventory data, bridge geometric and location specification, into a data-driven analysis, work zone crash frequency were investigated on a number of 60 bridge locations in Miami-Dade County. A sensitivity analysis was also conducted considering the black-box characteristic of the SVR and compared to the effects of variables indented through the NB modeling framework. The prediction performance of the developed models was evaluated by three commonly-used criteria including the coefficient of determination (R 2), the Mean Absolute Deviation (MAD), the Mean Square Error (MSE), and the Root Mean Square Error (RMSE). The results demonstrated that the proposed SVR models predict work zone crash data more effectively and accurately than traditional NB models. In addition, bridge median type, law enforcement, horizontal curve, bridge surface width indicators were among the most important factors that affects the number of work zone related crashes on bridges.

Authors	Seyedmirsajad Mokhtarimousavi (smokh005@fiu.edu), Florida International University Mohammed Hadi, Florida International University Eazaz Sadeghvaziri, California State University, Fresno Atorod Azizinamini, Florida International University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-03834
Paper Title	**Evolutionary Training Approaches for Machine Learning Models for Analyzing Classification Imbalanced Crash Datasets**
Abstract	Machine learning techniques have gained attention by safety researchers for use in predicting the attributes of crashes on transportation facilities. Crash events typically occur in rare instances which results in imbalanced datasets. Thus, the utilization of such techniques to predict crash outcomes require selecting the appropriate modeling techniques to cope with imbalanced dataset. Supervised algorithms consist of two major phases: training and testing. Learning from data to predict the outcome of interest on unseen data makes training procedure the most difficult challenge in the context of machine learning, in which finding the optimal set of parameters can highly affect the prediction performance of the model. In this study, three widely-used machine learning algorithms, Support Vector Machine (SVM), Artificial Neural Network (ANN), and K-Nearest Neighbour (KNN) are utilized for the classification of work zone crash severity. Three evolutionary optimization algorithms, including the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Artificial Bee Colony (ABC) are used for training the developed models to enhance the performance of the models. The prediction performance enhancements are evaluated against the base models without using the optimization algorithms. The results indicated that while the best prediction performance was obtained when using the GA optimization combined with the SVM, utilizing PSO and GA to train and optimize the parameters of the ANN and KNN significantly improved their performances especially in dealing with imbalanced data.

Authors	Seyedehsan Dadvar, CYFOR Technologies LLC Mohamed Ahmed (mahmed@uwyo.edu), University of Wyoming
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-04068
Paper Title	**California Autonomous Vehicle Crashes: Explanatory Data Analysis and Classification Tree**
Abstract	Autonomous Vehicle (AV) is an evolving technology with many capabilities and limitations. The main safety attribute of AVs is eliminating human drivers from the driving process with the promise to decrease road crashes drastically. AV field tests are being conducted in several states in the US and in other parts of the world. California Department of Motor Vehicle (DMV) has mandated all AV crashes and disengagement incidents being publicly reported by permit holders since 2014. Several different studies had used the CA DMV data to investigate different aspects of AVs especially road safety attributes. In this study, 234 CA DMV AV-related crashes (2017-2020) were examined. Explanatory Data Analyses indicated that rear-end and side-swipe were the main collision types and based on geographic distribution of crashes, the majority of them happened in a relatively small area in San Francisco bay area usually surrounding the permit holder headquarters. The classification tree using Chi-square Automatic Interaction Detector (CHAID) method was developed for AV-related crashes based on driving mode and AV movement, company (permit holder), road surface, other vehicle movement, intersection / control type, and crash time was identified as a significant contributing factor. Results, limitations, and potential future work were discussed in the context of the AVs and roadway safety.

Authors	Angela Kitali (akita002@fiu.edu), Florida International University Emmanuel Kidando, Cleveland State University Md Asif Raihan, Bangladesh University of Engineering and Technology Boniphace Kutela, Texas A&M Transportation Institute Priyanka Alluri, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-04403
Paper Title	**Exploring A Need to Model Two- and Multiple-vehicle Crashes Separately**
Abstract	Single-vehicle crashes have been shown to differ from two-plus vehicle crashes. Several studies have discussed the issues with modeling single- and two-plus vehicle crashes together. However, none of the empirical studies have attempted to study two-vehicle (2V), and multiple-vehicle (MV), i.e., three-plus, crash groups to understand their correlation and influencing factors. This study first investigates whether there is a need to develop separate safety performance functions for 2V and MV crashes, in addition to single-vehicle crashes. Then, the correlation and influencing factors of 2V and MV are evaluated. Three regression models – a correlated bivariate negative binomial regression (BNR) model, an uncorrelated bivariate negative binomial regression (NR) models, and a univariate negative binomial regression (UNR) model, are fitted and compared. The analysis is based on the 2011-2015 crash data that occurred on I-4 in Florida. Findings indicate that the BNR model significantly outperformed the NR and the UNR models. The model results suggest that disaggregating these crashes while allowing correlation between the groups for the latent effects in the model best describes the data. Traffic volume, posted speed limit, and median type were found significant in contributing to the occurrence of both 2V and MV crashes. Additional contributing factors included the presence of interchange influence area for 2V crashes and the presence of a vertical curve and the presence of a horizontal curve for MV crashes. Study findings could assist transportation officials implement specific safety countermeasures for road segments that are identified as hotspots for 2V and MV crashes.

Authors	Xiaoyan Shen, Chang'an University Shanshan Wei (weishan1995@foxmail.com), Chang'an University Yuqing Feng, Chang'an University Fan Zhang, Chang'an University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-00754
Paper Title	**Risk Analysis of Road Transport Accidents of Hazardous Materials by Machine Learning**
Abstract	The safe movement of hazardous materials is receiving increasing attention because various sudden and devastating hazardous material accidents have resulted in substantial injury to humans, damage to property and environmental pollution. The aim of this paper is to explore a suitable method for analyzing road transport accidents involving hazardous materials and to study the main risk factors for accidents of different severities (property damage only (PDO), injury (INJ) and fatality (FAT)). Initially, we assessed three classification algorithms, i.e., decision tree C5.0 (C5.0), support vector machine (SVM) and multilayer perceptron (MLP), using a hazardous material transportation accident dataset. The results reveal that the predictions of C5.0 algorithms are superior to those of SVM and MLP. Hence, C5.0 algorithm was applied to extract the probable risk factors and associations between these factors and 3 different severities of hazardous material transportation accidents. The results showed that direct accident form (DAF), indirect accident form (IAF), and road section (RS) all have significant effects on accidents involving only property damage.Direct accident form (DAF), indirect accident form (IAF), road type (RT), road segment (RS) and time (TIME) all have a substantial effect on injury accidents. Direct accident form (DAF), indirect accident form (IAF), hazardous material type (HMT) and road surface condition (SC) are important factors in the occurrence of fatal accidents. The above results provide a theoretical basis for discussing safety problems in hazardous materials transport activities and offer valuable suggestions for measures to reduce the severity of accidents.

Authors	Karla Diaz-Corro (kjdiazco@uark.edu), University of Arkansas, Fayetteville Leyla Coronel Moreno, University of Arkansas, Fayetteville Suman Mitra, University of Arkansas, Fayetteville Sarah Hernandez, University of Arkansas, Fayetteville
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	Poster Session 1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	TRBAM-21-01773
Paper Title	**Assessment of Crash Occurrence Using Historical Crash Data and A Random Effect Negative Binomial Model: A Case Study for a Rural State**
Abstract	The objective of this work is to identify factors that influence crash occurrence within a Traffic Analysis Zone (TAZ) by accounting for serial and spatial correlation in longitudinal crash data. This is accomplished by applying a Random Effect Negative Binomial model (RENB). Unlike commonly used count models such as Poisson and Negative Binomial (NB), RENB accounts for heterogeneity and serial correlation in crash occurrence. A RENB was applied to 15 years (180 months) of crash data in Arkansas, a relatively rural state, with 1,817 TAZs. RENB estimated impacts were measured using the Incidence Rate Ratio (IRR). The significant causal factors found to contribute to increases in observed crashes include, in order of IRR-estimated magnitude: (i) average precipitation (a one unit increase in average precipitation results in a 134% increase in total monthly crashes for a TAZ), (ii) average wind speed (16%), (iii) urban designation (7%), (iv) traffic volume (2%), and (v) total roadway mileage (1% for each functional class). Snow depth and days of sunshine were found to decrease the number of accidents by 15% and 2%, respectively. Employment and total population had no impact on crash occurrence. Goodness-of-fit comparisons show that RENB provides the best fit among Poisson and NB formulations. Model diagnostics confirm the presence of over-dispersion and serial correlation indicating the necessity of RENB model estimation. The main contribution of this work is the identification of crash causal factors at the TAZ level for longitudinal data, which supports data-driven performance measurement requirements of recent federal legislation.

Poster Session 1356: Safety, and Traffic Management Developments for Low Volume Road Applications

Authors	Afia Yeboah, Louisiana Transportation Research Center (LTRC) Julius Codjoe (Julius.Codjoe@la.gov), Louisiana Department of Transportation and Development Raju Thapa, Louisiana Department of Transportation and Development
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	Poster Session 1356
Session Title	Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	TRBAM-21-00969
Paper Title	**Estimation of ADT for Low Volume Roadways in Rural Areas of Louisiana**
Abstract	Traffic volume is an important parameter agencies use as a decisive factor especially at the time of design, maintenance, and operation. Thus, its correct estimation is very essential. There are already few established proprietary products available on the market that can predict traffic volumes. In addition, research studies use several mathematical models to predict traffic volume. Relatively fewer studies have been conducted on predicting traffic volume on low volume roadways. To bridge the gap on the prediction of low and high-volume roadways, this study seeks to establish an inexpensive way of estimating daily traffic volumes on low volume roadways located in rural areas of Louisiana. A total of 192 locations with low traffic volume of less than 500 vehicles per day were selected within the state of Louisiana. Census tract data was used to extract demographic and socioeconomic information for each location. A linear regression model was developed to predict traffic on these low volume roadways. Few data for testing were used to check accuracy of the prediction model. The result shows the prediction model performed very well with an R squared value of 0.97. Functional class of roadway, number of lanes, median household income, income density and household density were significant predictors in the model. Validation of the model, using the test data, shows MAPE and %RMSE of 41.45% and 57.08% respectively. The findings from the model concluded that linear regression can be used to predict traffic volume on low volume roadways, using census tract data as input data.

Authors	Ioannis Tsapakis (i-tsapakis@tti.tamu.edu), Texas A&M Transportation Institute Subasish Das, Texas A&M University Paul Anderson, Texas A&M Transportation Institute Steven Jessberger, Federal Highway Administration William Holik, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	Poster Session 1356
Session Title	Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	TRBAM-21-02832
Paper Title	**Improving Stratification Procedures and Accuracy of Annual Average Daily Traffic (AADT) Estimates for Non-Federal Aid-System (NFAS) Roads**
Abstract	The 2016 safety Final Rule requires States to have access to annual average daily traffic (AADT) for all public paved roads, including non-Federal aid-system (NFAS) roads. The latter account approximately for 75 percent of the total roadway mileage in the country making it difficult for agencies to collect traffic data on these roads. Many agencies use stratified sampling procedures to develop default AADT estimates for uncounted segments; however, there is limited guidance and information about how to stratify the network effectively. The goal of this paper is to enhance transportation agencies' ability to improve existing stratification schemes, design new schemes, and ultimately develop more accurate AADT estimates for NFAS roads. The paper presents the results from five pilot studies that validated and compared the performance of current, updated, and new (traditional and decision-tree-based) schemes using readily available data. According to the results the median absolute percent error of existing AADT estimates, developed by state agencies, ranged between 71 and 120 percent. Updating these schemes using recent counts resulted in an AADT accuracy improvement of 25 percent. The best performing schemes were developed using decision trees that improved the AADT accuracy of existing schemes by 41 percent. Overall, having more strata and very homogenous strata is better than having fewer strata and more samples within each stratum. The analysis revealed that a key to selecting an effective scheme is to

determine a critical point, beyond which creating more strata improves the AADT accuracy marginally but increases the required sample size exponentially.

Authors	Michael Williams (bikepedx@gmail.com), Michael Williams Company Marcial Lamera, California Polytechnic State University Aleksandar Bauranov, Harvard University Anurag Pande, California Polytechnic State University, San Luis Obispo Carole Voulgaris, Harvard University
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	Poster Session 1356
Session Title	Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	TRBAM-21-03146
Paper Title	**Safety Performance of Edge Lane Roads**
Abstract	This paper provides an observational analysis of the safety effects of Edge Lane Road (ELR) (also known as advisory bike lanes or advisory shoulders) installations in the United States. This analysis employs the following study designs: (a) yoked comparison where each ELR installation was matched with at least two comparable 2-lane roads to serve as comparison sites, and (b) an Empirical Bayes (EB) before/after analysis for ELR sites where requisite data on AADT and other relevant characteristics were available. Crash data was collected and compiled into four different groups: ELR before implementation, ELR after implementation, comparison site before the implementation of the corresponding ELR, and comparison site after implementation of the corresponding ELR. Analysis of crash trends in the "before" period showed that most ELR sites had crash trends similar to their comparison sites. A yoked comparison showed that nine of the thirteen ELRs nominally had crash counts that were either the same or lower than the counts expected based on the data from the comparison sites. However, at eight of nine sites, the differences were not statistically significant. After this inconclusive preliminary evaluation, an EB estimation of change in safety before and after the ELR installation at nine sites was performed. EB analysis showed eight of nine ELR sites demonstrated a reduction in crashes.

Authors	Meghna Chakraborty, Michigan State University Timothy Gates (gatestim@egr.msu.edu), Michigan State University
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	Poster Session 1356
Session Title	Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	TRBAM-21-03405
Paper Title	**Relationship between Horizontal Curve Density and Safety Performance on Rural Two-Lane Road Segments by Road Jurisdiction and Surface Type**
Abstract	This study involved the assessment of the safety impacts associated with horizontal curve density (in terms of number of curves per mile) on rural two-lane state and county road segments in Michigan. Non-animal road segment crashes from 2011 to 2015 were analyzed along with roadway geometry data for greater than 5,556 miles of state highways, 5,890 miles of paved county segments and 2,007 miles of unpaved roads from across Michigan. Several mixed-effects negative binomial regression models with a county- and site-specific random effects combined were generated. The model results indicated a consistent positive association between the density of horizontal curves with design speeds below 55 mph (radius less than 0.191 miles) and crashes across all classes of rural two-lane road segments. Specifically, although the mere presence of a horizontal curve along the segment increases crash occurrence across each of the rural roadway classes analyzed here, the crash occurrence is further increased when the frequency of horizontal curves exceeds 1 per mile for state highways and paved county roads. These results provide further contribution to previous research on the safety effects of horizontal curvature on rural roadways, by suggesting that more frequent changes in horizontal alignment (as indicated by an increasing frequency of curves per mile) increases crash occurrence. This study also further contributes to the limited body of knowledge regarding safety performance on rural secondary roadway segments, including roads under county jurisdictions and unpaved roads.

Authors	Samaa Agina (agina@ualberta.ca), University of Alberta Amr Shalkamy, University of Alberta Maged Gouda, University of Alberta Karim El-Basyouny, University of Alberta
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	Poster Session 1356
Session Title	Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	TRBAM-21-03543
Paper Title	**Automated Assessment of Passing Sight Distance on Rural Highways using Mobile LiDAR Data**
Abstract	Providing adequate Available Sight Distance (ASD) that meets the minimum design requirements is a crucial step to ensure safe and efficient highway operation. The majority of previous studies on sight distance evaluation focused on stopping sight distance with little attention given to Passing Sight Distance (PSD) which, if not sufficient, could lead to severe collisions. This paper introduces an automated method for PSD assessment on two-lane highways using mobile Light Detection And Ranging (LiDAR) data. The proposed method was tested on 16-km of LiDAR data of highways located in Alberta, Canada. The procedure involved extracting centerline lane marking, defining passing-allowed and passing-prohibited regions, computing the ASD, and comparing the existing centerline marking pattern (i.e. passing and no-passing zones) to the sight distance available for passing. Regions that meet the design guide requirements, substandard zones, and non-optimal design regions were all defined. A review of historical PSD-related collisions revealed that 30% of crashes occurred along regions at which passing is currently allowed although the ASD is less than the minimum PSD requirements. A reallocation of PSD zones was conducted based on the ASD and existing lane marking pattern which resulted in increasing the total length of passing zones by up to 20% providing more, but safer, passing opportunities. The proposed framework represents a tool by which transportation agencies could assess PSD, review and upgrade the design of existing highways, and investigate the consequences of PSD limitations to ensure compliance with design standards during highways service life.

Lectern Session 1408: Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce

From traffic incidents to regional weather events, the resilience of the transportation network falls in large part, upon the shoulders of emergency responders. Recent workforce shortages brought to bear by the COVID-19 pandemic and calls to defund the police have highlighted the vulnerability of responder agencies. This panel discussion features leaders from Police, Fire, EMS and towing services. Speakers will discuss their unique perspective on workforce related issues from recruitment and retention to safety and mental health. Particular focus will be given to the implications of a diminished, diseased, and defunded responder workforce on transportation systems safety and operations.

Authors	Michael Brown, Alexandria Police Department
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Subcommittee on Emergency Responders () Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Standing Committee on Systems, Enterprise, and Cyber Resilience (AMR40)
Session Number	Poster Session 1327
Session Title	Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce
Paper Number	P21-21302
Paper Title	**COVID-19 Impacts on Alexandria, Virginia Emergency Management**
Abstract	NA

Authors	Candice McDonald, Emergency Responder Safety Institute
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Subcommittee on Emergency Responders () Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Standing Committee on Systems, Enterprise, and Cyber Resilience (AMR40)
Session Number	Poster Session 1327
Session Title	Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce
Paper Number	P21-21303
Paper Title	**Success Up Life**
Abstract	NA

Authors	Gaynell Rochester, Towing and Recovery Association of American
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Subcommittee on Emergency Responders () Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Standing Committee on Systems, Enterprise, and Cyber Resilience (AMR40)
Session Number	Poster Session 1327
Session Title	Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce
Paper Number	P21-21304
Paper Title	**Rochester Imarc Handling of COVID-19**
Abstract	NA

Authors	Robert Lawrence
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Subcommittee on Emergency Responders () Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Standing Committee on Systems, Enterprise, and Cyber Resilience (AMR40)
Session Number	Poster Session 1327
Session Title	Diminished, Diseased, and Defunded: Critical Issues in the Emergency Responder Workforce
Paper Number	P21-21305
Paper Title	**Our Heros in Ambulance and Emergency Management Services**
Abstract	NA

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.

The subcommittee identified **nine papers** related to network screening. Some papers in this category provide a case study of an application in a specific context. Other studies discuss methods with suggestions on the possibility of using these methods for network screening. This year, few papers proposed using surrogate measures with or without crash data for network screening.

From the **methodological** perspective, the following methods have been used:

- Use of different crash-severity level SPFs (total crashes, fatal and severe crashes, and a combination of fatal, severe and visible injury crashes) along with potential for safety improvement (PSI) based on the Empirical Bayes (EB) approach (Vayalamkuzhi et al.; paper 21-04188).
- Detailed analysis of crash reports in the context of systemic safety improvements (Tsyganov and Read; paper 21-01428).
- Improved incremental benefit-cost ratio method (Tsapakis et al.; paper 21-01698).
- Bayesian bivariate negative binomial spatial conditional autoregressive (BNB-CAR) (Pei et al.; paper 21-03435).
- Empirical Bayes method (Al-Kaisy and Huda; paper 21-01505).
- Connected video cameras and a cloud-based computing analytics platform for large-scale video processing traffic exposure metrics, frequency of speeding events, and conflict rates (Samara et al.; paper 21-03654).
- Boosted decision tree (BDT) and regularized logistic regression (RLR) with lasso penalty for analyzing aggregated fine geo-resolution vehicle telemetric data (frequency of harsh acceleration, harsh braking, harsh cornering) (Shen et al.; paper 21-00588).
- Safe Route Mapping (SRM) model that integrates crash-based estimates with conflict risks (Jiang et al.; paper 21-01009).
- Negative sampling based on spatial, temporal, and a mixture of the two types of data, with the data ratios acting as class balancing tools (Roland et al.; paper 21-02286).

From the **application** perspective, the following applications have been discussed:

- Intersections in Virginia targeting angle crashes (Tsyganov and Read; paper 21-01428).
- Regional macro-level analysis using data from Suzhou, a Chinese city (Pei et al.; paper 21-03435).
- Low volume roads in Oregon (Al-Kaisy and Huda; paper 21-01505).
- City of Bellevue (Samara et al.; paper 21-03654).
- Segments in City of Columbus (Shen et al.; paper 21-00588).

Below, for each of the nine papers, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Praveen Vayalamkuzhi, University of California, Berkeley Aditya Medury, Indian Institute of Technology, Kanpur Lin Yang, University of California, Berkeley Offer Grembek, University of California, Berkeley Venky Shankar, Texas Tech University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-04188
Paper Title	Impact of Injury-Based Safety Performance Functions on Network Screening
Abstract	Safety Performance Functions (SPF) are proven to be the best resource for evaluating highway safety. However, agencies have a difficult time selecting the type of SPF from among the various options to use in analysis—whether all crashes will be included or determining the impact of Property Damage Only (PDO) crashes in the safety analysis. Injury severities considered for network screening have important implications for how limited agency resources are used. This operational reality that dominates many agencies can inhibit their ability to systematically choose the appropriate SPF type for prediction and implementation. This paper describes the application and outcome of different crash-severity level SPFs to address such concerns through a set of SPFs—total crashes, fatal and severe crashes, and a combination of fatal, severe and visible injury crashes. Potential for Safety Improvement (PSI) based on the Empirical Bayes (EB) approach was then used for network screening to select the top one percent of hotspots within each facility type by injury severity level. The findings indicate differences in site characteristics across hotspots identified using different crash types, with total crashes favoring sites in heavier traffic urban areas. There is a greater need to understand the type of sites that yield high property damage only (PDO) crashes within network screening—for example, there is mixed evidence about the over-representation of PDO crashes among secondary crashes on highways. The analysis also revealed the differences in site demographic type and Annual Average Daily Traffic (AADT) across hotspots identified by different crash combinations.

Authors	Alexei Tsyganov (Alexei.Tsyganov@VDOT.Virginia.gov), Virginia Department of Transportation Stephen Read, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01428
Paper Title	Emphasis Areas and Risk Factors for Angle Collisions in Virginia
Abstract	Recently the FHWA Office of Safety developed sets of low-cost countermeasures for systemic intersections safety improvements. The suggested basic treatments are low in unit cost and collectively effective in terms of reducing future crash potential. For the effective implementation of the FHWA recommendations, the Virginia Department of Transportation (VDOT) Highway Safety Improvement Program (HSIP) initiated a study targeting analysis of angle collisions, identification of emphasis areas for improvements and associated risk/human factors. The conducted descriptive crash analysis considered multiple factors, such as day, time, highway functional class, traffic control system, travel conditions, crash severity, driver age, driver pre-crash improper action and maneuver, as well as influences of intoxication, distraction, inattention, and vision obstruction. The analysis identifies the emphasis areas for angle collisions related safety improvements and quantify their significance in terms of contribution to the overall statewide highway crashes and severity. The detailed analysis of the 2,122 police crash reports together with the review of crash sites, allowed identification and classification of various pre-crash events, as well as driver risk/human factors, and quantification of their significance. Based on the study results, a procedure for crash tree analysis was developed with the identified risk factors. The study results provide more detailed information for the selection of the most applicable and effective safety improvement strategies and measures targeting angle collisions.

Authors	Ioannis Tsapakis (i-tsapakis@tti.tamu.edu), Texas A&M Transportation Institute sushant sharma, Texas A&M Transportation Institute William Holik, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01698
Paper Title	Alternatives in Prioritizing Safety Improvement Projects
Abstract	The Highway Safety Improvement Program (HSIP) aims to reduce the number and severity of fatalities and serious injury crashes by implementing safety improvement projects. The Traffic Operations Division (TRF) of the Texas Department of Transportation (TxDOT) currently administers TxDOT's HSIP. TRF requests HSIP projects from TxDOT districts every year. All proposed projects are subjected to a benefit-cost ratio (BCR), called Safety Improvement Index (SII). After projects are submitted to the program, the TRF prioritizes them based on the SII. Although the structure and main components of TxDOT's HSIP comply with relevant requirements, a review of modern safety assessment methods and tools revealed that there are several areas for improvement, including economic analysis and prioritization of HSIP projects. The objectives of this study are to a) compare TxDOT's BCR-based project prioritization approach against an improved incremental benefit-cost ratio (IBCR) method, recommended by the Highway Safety Manual (HSM), and b) minimize the amount of time and resources required to prioritize HSIP projects. To address the first objective, the researchers applied both methods using data from the 2016 TxDOT HSIP and compared the results. The comparison showed that the projects selected using the IBCR method were more cost-effective than the projects funded by the BCR method. Further, the IBCR method awarded high-cost projects where more crashes had been observed. To address the second objective, the authors developed a prioritization tool that automatically ranks candidate projects using the IBCR method. The average runtime to prioritize 1,000 projects is less than 0.5 seconds.

Authors	Yingying Pei, Tongji University Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Mingjie Feng, Tongji University Zhixing Zhu, Traffic Police Headquarters of Jiangsu Province Fang Liu, Traffic Police Department of Suzhou City Zhongyang Qie, Traffic Police Department of Suzhou City Paul P. Jovanis, Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03435
Paper Title	Macro-Level Safety Analysis of Crashes and Violations: Influencing Factors and Crash Hotspots
Abstract	Regional traffic safety has been a public concern for many metropolitan areas, and it is urgent to turn this situation around by using an appropriate traffic safety analysis and crash hotspot identification method. Existing studies mainly focus on the effects of engineering-related indicators on regional crashes and violations, neglecting the traffic police enforcement-related factors. Meanwhile, the relationship between crashes and violations is insufficiently recognized. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, and collected socio-economic indicators, road features, land use intensity, facility data, and police enforcement information as independent variables. A Bayesian bivariate negative binomial spatial conditional autoregressive (BNB-CAR) model was developed to capture the association between crashes and violations, as well as their contributing factors. Results showed that (1) there existed a significantly correlated effect between crashes and violations; (2) engineering-related indicators had similar effects on crashes and violations, while some police enforcement-related factors were dual-effective. Based on the model results, this study used the potential for safety improvement (PSI) method to identify the hazardous areas of the 115 towns in Suzhou. It was observed that (1) the spatial distribution of crashes indicated the spatial correlations among the towns; (2) the fringe areas suffered higher crash risks than the downtown areas. Several engineering and enforcement countermeasures were provided for urban planning departments and traffic police to enhance their work effectiveness. Additionally, decision makers and administrators will benefit from this study to improve daily traffic safety management.

Authors	Ahmed Al-Kaisy (alkaisy@montana.edu), Montana State University Kazi Huda, Montana State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01505
Paper Title	Network Screening on Low-Volume Roads: A New Proposed Method
Abstract	This paper presents a proposed new method for network screening on rural low-volume roads. These roads constitute an important and integral part of the rural roadway network by providing access to remote rural areas including farms and ranches. The majority of low-volume roads belong to the lowest functional class (local rural roads) and many were built decades ago, and therefore their geometric features are often considered “substandard” by today’s design practices. The conventional hot spot newtwork screening techniques may not be appropriate for low-volume roads due to the sporadic nature of crashes occurring on these roads. Other approaches for network screening (e.g. Highway Safety Manual preditive methodology, EB method, etc.) require extensive roadway and traffic data that are often unavailable at local agencies for lack of resources, and/or impractical to use for lack of technical expertise. This research attempts to address these obstacles in low-volume roads network screening with the purpose of identifying candidate sites for safety treatments. The research used an extensive low-volume road sample from the state of Oregon and the Empirical Bayes expected number of crashes in developing the proposed models for network screening. The proposed models do not require exact measurement of roadway geometric features as all geometric variables were classified into categories that are easy to compile by local agencies. Further, the method could be used with and without traffic data without much compromising the effectiveness of the network screening process.

Authors	Lana Samara, Transoft Solutions Inc. Paul St-Aubin, Transoft Solutions Inc. Franz Loewenherz, City of Bellevue Noah Budnick, Together For Safer Roads Luis Miranda-Moreno (luis.miranda-moreno@mcgill.ca), McGill University
Sponsoring Committee	Standing Committee on Intelligent Transportation Systems (ACP15)
Session Number	1110
Session Title	Intelligent Transportation Systems 2021, Part 1
Paper Number	21-03654
Paper Title	Video-based Network-wide Surrogate Safety Analysis to Support a Proactive Network Screening Using Connected Cameras: Case Study in the City of Bellevue (WA) United States
Abstract	Surrogate road safety approaches, as part of road improvement programs, have gained traction in recent years. Thanks to emerging technologies such as computer-vision and cloud-computing, surrogate methods allow for proactive scanning and detection of safety issues and address them before collisions and injuries occur. The objective of this paper is to propose an automated and continuous monitoring approach for road network screening using connected video cameras and a cloud-based computing analytics platform for large-scale video processing. Using the wide network of traffic cameras from cities, the proposed approach aims to leverage video footage to extract critical data road network screening (ranking and selection of dangerous locations). Using the City of Bellevue as an application environment, different safety metrics are automatically generated in the platform such as traffic exposure metrics, frequency of speeding events, and conflict rates. Using Bellevue's camera network, the proposed approach is demonstrated using a sample of 40 cameras and intersections. The results and platform provide a proactive tool that can constantly look for dangerous locations and risk contributing factors. This paper provides the details of the proposed approach and the results of its implementation. Directions for future work are also discussed.

Authors	Sijun Shen (sshen@g.clemson.edu), Nationwide Children's Hospital Simon Lin, Research Institute at Nationwide Childrens Hospital Motao Zhu, Research Institute at Nationwide Childrens Hospital
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-00588
Paper Title	Using Machine Learning Algorithms and Fine Geo-resolution Vehicle Telemetric Data to Predict Crash Spots
Abstract	Background: The prevalence of mobile sensing platforms allows researchers to evaluate individual driver safety using vehicle telemetric data. However, no study has assessed the feasibility of using aggregated vehicle telemetric data to predict crash spots. Objectives: The objective of this study is to determine if the aggregated fine geo-resolution vehicle telemetric data can be used to predict crash likelihood for roadway segments. Methods: The telemetric data from the GEOTAB company were used. The GEOTAB company recorded the frequency of harsh acceleration, harsh braking, harsh cornering, and the average magnitude of those harsh events for every 150×150 meter2 roadway segments within Columbus, Ohio between January and April 2018. Crash history were obtained from the 2018-2019 Ohio Policy Accident Report. Regularized logistic regression (RLR) with lasso penalty and boosted decision tree (BDT) algorithms were used to develop the predicting models. Results: Aggregated vehicle telemetric data provided effective predictions for crash spots (Area under curve [AUC] $\geqslant$ 0.73). Models' predictive performance can be further improved if both vehicle telemetric variables and crash history were included in the models (AUC $\geqslant$ 0.77). The BDT models had superior predictive performance than the RLR models, due to its capability of incorporating complex relationships (e.g., non-linearity and all-way interactions) between predicting and predicted variables. Conclusion: Our study demonstrates the utility of geo-resolution vehicle telemetric data to predict crash spots. Aggregated vehicle telemetric data provide valuable information for crash likelihood monitoring and thereby, enable implementation of timely safety interventions by police and city planner.

Authors	Shan Jiang (sj576@scarletmail.rutgers.edu), Rutgers University Mohsen Jafari, Rutgers University Mohammad Jalayer, Rowan University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01009
Paper Title	Safe Route Mapping of Roadways Using Multiple Sourced Data
Abstract	The use of systematic techniques with historical crash data and qualitative measures has long been a common practice to identify the problematic road features and develop countermeasures to mitigate the crash risk in crash-prone locations. This paper proposes a novel approach, Safe Route Mapping (SRM) model that integrates crash-based estimates with conflict risks computed from driver-based data to score the safety of roadways. An advanced Safety Performance Function (SPF) estimates the number of crashes, and a driver-based model calculates dynamic conflict risk measures from driver and traffic data. In real-life implementations of the proposed methodology, the driver-based data and traffic data can be collected from vehicles or infrastructure-based data sources, including smartphones. We demonstrated the methodology using real historical crash data and simulated driver-based data obtained from VISSIM and SSAM. We show safety risk heat maps for the example roadway and illustrate how these maps change with driver types and traffic volumes. The proposed methodology fills the existing gaps in the use of near real-time dynamic data to designate safe corridors, dispatch law enforcement, and plan safety projects. Drivers can also use the road heat maps for situational awareness and trip planning.

Authors	Jeremiah Roland (fpf852@mocs.utc.edu), University of Tennessee, Chattanooga Peter Way, University of Tennessee, Chattanooga Mina Sartipi, University of Tennessee, Chattanooga Osama Osman, University of Tennessee, Chattanooga
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-02286
Paper Title	Spatio-Temporal Accident Prediction: Effects of Negative Sampling on Understanding Network-Level Accident Occurrence
Abstract	In projects centered around rare event case data, the challenge of data comprehension is greatly increased due to insufficient data for deriving insight and analysis. This is particularly the case with traffic accident occurrence, where positive events (accidents) are rare with, in most cases, no data set existing for negative events (non accidents). One method to increase available data is negative sampling. In this work, four negative sampling techniques are presented with varying ratios of negative to positive data. These types of techniques are based on spatial, temporal, and a mixture of the two types of data, with the data ratios acting as class balancing tools. The best performing model found was with a negative sampling technique that shifted temporal information and had an even 50/50 data split, with an F-1 score of 93.68. These results are promising for ITS applications to inform of potential accident locations in an entire area for proactive measures to be put in place.

4 Safety Performance Functions

Mohamed Abdel-Aty, Jinghui Yuan, and Heesub Rim
University of Central Florida (UCF)

Studies related to safety performance functions (SPFs) aim to predict the number or frequency of crashes and analyze the factors contributing to crash occurrence. The subcommittee identified forty-three papers that are related to SPFs. The papers are classified by type of roadway facilities, type of crashes, scope, data source, and methodology.

Research related to SPFs can be classified according to the **roadway facility type**. Most of the papers analyzed the safety performance of intersections (21-00313, 21-00113, 21-00179, 21-02711, 21-03234, 21-03255, 21-03672, 21-01696, and 21-03625) and rural roadways (21-00190, 21-00742, 21-02844, 21-03916, 21-20074, 21-03068, and 21-00971). In addition, two papers (21-01202 and 21-03284) developed SPFs for freeway segments, paper 21-01783 studied motorcycle-related SPF for the urban roadway, and paper 21-20074 developed SPFs for urban-suburban collector roadways. Furthermore, there are several papers that focused on more specific roadway facilities such as tunnels (21-02300), interchanges (21-00026), trails (21-01569), median (21-00190), acceleration and deceleration lane (21-01202), and work zone (21-03739).

In addition, several papers developed **zonal level SPFs** through macro-level analysis based on different analysis units, including census blocks (21-03625), administrative units (21-01968), traffic analysis zones (21-01987), counties (21-01517), and sub-districts (21-02415).

SPFs regarding **different crash types and severities** have also been widely conducted. In paper 21-04403, SPFs were developed by separating single-vehicle crashes, two-vehicle crashes, and multiple-vehicle crashes. Paper 21-04188 developed a set of SPFs for different crash severities and conducted network screening to select the top 1% hotspots by crash severities based on the Potential for Safety Improvement (PSI). They found that the identified hotspots are significantly different between different crash severities.

SPFs for **pedestrian and cyclist crashes** were developed in several papers. Papers 21-02609, 21-03625, and 21-00955 developed SPFs for pedestrian crashes while considering the effect of land use, roadway design, and demographic characteristics. It was found that the proportion of the elderly population influenced the crash frequency (21-03625). In paper 21-02609, the activity-based exposure measures such as the number of walking trips were utilized to predict pedestrian-motor crash frequency. As the number of cyclists and E-bikes have been increasing in recent years, several studies developed SPFs for bicycle and E-bike crashes (21-01968, 21-01987, and 21-03023). Paper 21-01968 developed SPFs for E-bike crashes and found that the size of analysis units has a significant influence on the model performance. In

paper 21-01987, the infrastructure for bicycles, land use, and socio-demographic data were utilized to consider regional effects for bicycle crashes. To address the limitations of collecting bicycle exposure data, paper 21-03023 utilized the crowdsourced data adjusted with video detection as the exposure variable.

Transferability and local calibration are popular topics for research of SPFs. Several papers insisted on the importance of local calibration and presented SPFs for the specific circumstance. The major factors and the degree to which each factor influences the crash frequency is analyzed differently depending on the region (21-02992, 21-03672, and 21-04402). Paper 21-00313 developed context-specific SPFs for signalized intersections, and paper 21-00113 presented different SPFs for different intersection configurations. Paper 21-02844 developed Ohio-specific SPFs for rural two-lane highways based on HSIS data. The proper regional level of SPFs varies depending on the hierarchy of roads and geometry (21-20074). Paper 21-03597 developed SPFs for low-volume roadways and tested the performance of the model.

Moreover, some studies introduced **distinct data sources** into the development of SPFs. To address regional perspectives, two papers (21-01517 and 21-02415) utilized socio-economic and demographic data to predict crash frequency. Paper 21-03068 emphasized the importance of speed data on SPFs and utilized four speed-related measures collected from probe vehicle data, including average speed, the 85th percentile speed, difference in average speed and speed limit, and difference of 85th percentile speed and speed limit. Paper 21-03284 developed SPFs for freeways by incorporating microscopic traffic detector data. They found that the average speed is significant with a negative coefficient, and the standard deviation of speed was found to be positively associated with the crash frequency. In paper 21-00755, on-street parking was considered to develop the SPF, and paper 21-03435 utilized traffic violation data.

Finally, it is notable for introducing **much effort has been exerted to select appropriate methodology or develop a new method for the specific circumstance**. Paper 21-03284 developed short-term SPF using high-resolution data to capture temporal variation that might be missed when using highly aggregated data. To take into account regional characteristics, 21-04448 used a geographically weighted Poisson regression and negative binomial model, and 21-03435 introduced the Bayesian bivariate negative binomial spatial conditional autoregressive model. To evaluate the performance of the proposed model, 21-00971 utilized machine learning techniques and graphical tools, and paper 21-03234 developed a calibration method for SPF. For low-volume cases, 21-00742 introduced a comprehensive framework for safety, considering sight distance and roadway design consistency with SPF, and 21-03829 used zero-favored negative binomial and negative binomial-Lindley model.

Below, for each of the forty-three papers involving safety performance functions, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract. Papers are ordered according to their ID number.

Authors	Ghalia Gamaleldin, University of Central Florida Haitham Al-Deek (Haitham.Al-Deek@ucf.edu), University of Central Florida Adrian Sandt, University of Central Florida John McCombs, University of Central Florida Alan El-Urfali, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Regional Transportation Systems Management and Operations (ACP10)
Session Number	1059
Session Title	Regional Transportation Systems Management and Operations 2021
Paper Number	21-00113
Paper Title	A Regional Perspective of Safety Performance Functions and Their Application to Florida Intersections in Suburban Residential and Urban General Context Classification Categories
Abstract	Safety Performance Functions (SPFs) are essential tools to help agencies predict crashes and understand influential factors. The Florida Department of Transportation (FDOT) has implemented a context classification system which classifies intersections into eight context categories rather than the three classifications used in the Highway Safety Manual (HSM). Using this system, regional SPFs could be developed for 32 intersection types (unsignalized and signalized 3-leg and 4-leg for each category) rather than the 10 HSM intersection types. In this paper, eight individual intersection group SPFs were developed for the C3R-Suburban Residential and C4-Urban General categories and compared with full SPFs for these categories. These comparisons illustrate the unique and regional insights that agencies can gain by developing these individual SPFs. Poisson, negative binomial, zero-inflated, and boosted regression tree models were developed for each studied group as appropriate, with the best model selected for each group based on model interpretability and five performance measures. Additionally, a linear regression model was built to predict minor roadway traffic volumes for intersections which were missing these volumes. The full C3R and C4 SPFs contained four and six significant variables, respectively, while the individual intersection group SPFs in these categories contained six and nine variables. Factors such as major median, intersection angle, and FDOT District 7 regional variable were absent from the full SPFs. By developing individual intersection group SPFs with regional factors, agencies can better understand the factors and regional differences which affect crashes in their jurisdictions and identify effective treatments.

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Jun Liu, University of Alabama Chenxuan Yang, University of Alabama Timothy Barnett, University of Alabama
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-00190
Paper Title	Context-based Crash Modification Factors for Medians on Rural Four-Lane Roadways: A Bayesian Approach
Abstract	Rural four-lane roadways provide important transportation accessibility and mobility to populations in rural areas. Practitioners are often challenged to determine cross-section types when both benefits and costs need to be considered. The Crash Modification Factors (CMFs) are often developed to evaluate safety effectiveness of alternative designs. However, safety effectiveness could vary significantly across contexts. Thus, the study aims to estimate CMFs for alternative cross-sections of rural four-lane roadways under different contexts characterized by traffic volume, truck percentage, and access point density. Using Georgia state-wide crash data, this study developed Safety Performance Functions (SPFs) to predict crash frequencies for different contexts. Considering linearity and independence assumptions of traditional negative binomial SPFs, this study adopts the Bayesian generalized negative binomial (BGNB) modeling approach to relax those assumptions and only follows the Bayes rule to form SPFs for CMF estimation. This study focuses on four typical cross-sections including 1) non-traversable medians; 2) two-way-left-turn lanes; 3) 4-ft flush medians; and 4) undivided roadways with double-yellow lines (the base cross-section). The results show that CMFs vary significantly across different contexts. Compared with base cross-section design, safety benefits of other three designs can be either positive or negative under different traffic or road conditions. For example, 4-ft flush medians are found to have positive safety benefits (CMF < 1) under lower average daily traffic volumes (e.g., <=6,000); but negative benefits (CMF >1) under greater average daily traffic volumes (e.g., >=15,000). The findings offer practitioners insights that cross-section designs may need to be varied for different contexts.
Authors	John McCombs, University of Central Florida Haitham Al-Deek (Haitham.Al-Deek@ucf.edu), University of Central Florida Adrian Sandt, University of Central Florida

	Ghalia Gamaleldin, University of Central Florida Alan El-Urfali, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Regional Transportation Systems Management and Operations (ACP10)
Session Number	1059
Session Title	Regional Transportation Systems Management and Operations 2021
Paper Number	21-00313
Paper Title	A Regional Perspective on Safety Performance Function Development and Implementation: National Survey of Current Regional Practices and Evaluation of Crash Predictions for Rural Florida Intersections
Abstract	The Highway Safety Manual (HSM) provides guidance for agencies on developing safety performance functions (SPFs) to predict traffic crashes. However, some states develop their own SPF methodologies due to data differences and a need for additional roadway categories. The Florida Department of Transportation has developed a context classification system that groups intersections into eight categories, allowing for the development of regional context-specific SPFs. To best utilize this system, departments of transportation (DOTs) across the United States were surveyed about their current SPF development practices and context classification. Many states (64% of the 42 respondents) use HSM SPFs or SPFs calibrated to their jurisdiction. Although 62% of states had not heard of context classification, 67% of states expressed interest in it. One reason some states were not interested in using context classification was insufficient evidence of its benefits compared to the current HSM methodology. To showcase the increased accuracy of SPFs developed using this system, HSM SPFs [baseline, baseline with crash modification factors (CMFs), and calibrated with CMFs] for rural two-lane, two-way roads were compared with a context-specific SPF for C2T-Rural Town signalized four-leg intersections. These comparisons found that the HSM SPF with CMFs overpredicted crashes for Florida intersections (calibration factor of 0.87). The context-specific SPF contained additional variables (including a regional variable) not included in the baseline HSM SPF and performed statistically better than all three HSM SPFs. By implementing a similar context classification system, agencies could develop more accurate SPFs and identify regional differences, improving safety throughout their jurisdictions.

Authors	Alaa Torkey, Cairo University Abdulrahman Alrafee, Cairo University Dalia Said (daliasaid@eng.cu.edu.eg), Cairo University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-00742
Paper Title	Safety Assessment of Existing Roads: A Preliminary Comprehensive Methodology for Restricted Environments for a Safety Improvement Program
Abstract	Road safety has become a leading topic in recent scientific research. Researchers have studied the effect of different operational and geometric characteristics on road safety such as sight distance, operating speed profiles leading to design consistency evaluation and application of the Highway Safety Manual (HSM) for the development of local safety performance functions. Considering safety improvement projects, a comprehensive study is important to get an overall view of crashes' causals, which would be beneficial in conducting cost-effective safety improvement measures especially in restricted environments where there is a lack of crash data. Surrogate methods are needed then for effective safety assessment. This paper presents a preliminary comprehensive operational analysis using an existing alignment in El Mansoura Governorate in Egypt to appraise the study objective. The analysis begins with sight distance analysis, then a design consistency evaluation and finally using HSM Safety Performance Function for rural two-lane two-way roadways. Two scenarios of remedial measures are suggested; one scenario is based on the comprehensive methodology suggested and the other one focuses on the road element characteristics which is a typical approach if HSM methodology is used. Benefit-cost ratio analysis is used for measuring the economic justification of each scenario. It is suggested to study the possibility of developing safety performance functions having sight distance and design consistency all together as building parameters which could be of great help especially in countries having poor crash data.

Authors	Rizky Junirman (rizky-adelwinjunirman@ed.tmu.ac.jp), Shuto Daigaku Tokyo Hiroyuki Oneyama, Tokyo Metropolitan University

Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-01783
Paper Title	Effect of Motorcycle Composition to Motorcyclist and Other Motor Vehicle Accident Rate in Mixed Traffic Condition
Abstract	The disparity in road safety between low- and middle-income countries (LMIC) and high-income countries (HIC) is high. To confront this problem, local road characteristics must be understood. This study attempts to clarify how traffic composition contributes to accident rates in mixed traffic conditions for different road users in Indonesia. The study was conducted within an urban environment in Indonesia; hence, other contributing road elements to support this study are chosen to represent such conditions. Multivariate analysis using negative binomial regression revealed that motorcycle and motor vehicles have a slight difference in contributing factors to their respective accident rate. Furthermore, the motorcycle proportion contributes to accident risk for both motorcycle and motor vehicle. The two-fluid model and road type for undivided roads are not significant for both models. The difference lies in the fact that 1 km radii of through traffic are significant only for motorcycle accident rates. For other variables, they share the same significant variables. The significant variables are motorcycle percentage, network centrality for 10 km radii, access density, signalized intersection type, and road type for divided roads.

Authors	Soyoung Jung (jung2@dyu.ac.kr), Dongyang University Xiao Qin, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-02300
Paper Title	Evaluation of the Factors Affecting Injury Involved Crashes in Freeway Tunnels
Abstract	Freeway tunnels in South Korea have suffered from frequent injury involved crashes. Recently, the Korea Ministry of Land, Infrastructure and Transport recently provided several strategies for traffic safety management in tunnels. This study intended to quantitatively evaluate the recent government strategies and employed random forest based binomial logit regression with a comparative variance inflation factor based regression. As a result, the following risk factors were found to be significantly associated with injury involved crashes in freeway tunnels: head-on/angle/rear-end collision, tunnel exit, tunnel width, curve radius, adverse weather, heavy vehicle, fatigued and distracted drivers. By confirming each government strategy specifications based on the identified risk factors, this study quantitatively supports decision-making to modify the government strategies. For future research, the current study suggests comparing random forest and its variation of tree growth algorithm with more tunnel crash data and driver surveys.

Authors	Darren Torbic (dtorbic@mriglobal.org), MRIGlobal Daniel Cook, HDR Joseph Grotheer, MRIGlobal Richard Porter, VHB Jeff Gooch, VHB Kristin Kersavage, VHB
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-02711
Paper Title	New Intersection Crash Prediction Models for the Second Edition of the Highway Safety Manual
Abstract	The objective of this research was to develop new intersection crash prediction models for consideration in the second edition of the Highway Safety Manual (HSM), consistent with existing methods in HSM Part C and comprehensive in their ability to address a wide range of intersection configurations and traffic control types in rural and urban areas. The focus of the research was on developing safety performance functions (SPFs) for intersection configurations and traffic control types not currently addressed in the HSM Part C. SPFs were developed for the following general intersection configurations and traffic control types:Rural and urban all-way stop-controlled intersections Rural three-leg intersections with signal control Intersections on high-speed urban and suburban arterials (i.e., arterials with speed limits greater than or equal to 50 mph) Urban five-leg intersections with signal control Three-leg intersections where the through movements make turning maneuvers at the intersections Crossroad ramp terminals at single-point diamond interchanges Crossroad ramp terminals at tight diamond interchanges Development of severity distribution functions (SDFs) for use in combination with the SPFs to estimate crash severity as a function of geometric design elements and traffic control features was explored; but due to challenges and inconsistencies in developing and interpreting the SDFs, it was recommended for the second edition of the HSM that crash severity for the new intersection configurations and traffic control types be addressed in a manner consistent with existing methods in Chapters 10, 11, and 12 of the first edition of the HSM, without use of SDFs.

Authors	Abdulrahman Faden (Akfaden@iau.edu.sa), University of Dayton Deogratias Eustace, University of Dayton
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-02844
Paper Title	Development Of Safety Performance Functions For Two-Lane Rural Highways In The State Of Ohio
Abstract	The Highway Safety Manual (HSM), which is the guidance document for state departments of transportation (DOTs), was published in 2010, and one of its sections, called Part C of HSM, it involves the development of crash prediction models. However, HSM's default prediction models are not suitable for all states or jurisdictions because each state and jurisdiction have different characteristics, such as terrain, driver behaviors, weather conditions, etc. Hence, the principal objective of this study is to develop a prediction method for producing Ohio-specific SPF models to use for rural two-lane highways in the state of Ohio. Highway geometric data for almost 40,067 segments that have 21,666.03 miles and 79,481 total crashes that occurred for 4 consecutive years (2012-2015) were obtained from the Highway Safety Information System (HSIS) to create these new models using negative binomial regression and the pruned forward selection method by adding the interaction terms via JMP Pro software. The most critical variables used for analyzing and creating the best models for the state of Ohio are average annual daily traffic (AADT), segment length, lane width, shoulder width, posted speed limit, presence of curves and grades, which were proven to be statistically significant in developing SPFs. Besides, the standard goodness-of-fit parameters were chosen to evaluate the regression models was AIC. Two models were created for rural two-lane road segments in the state of Ohio, which can be used to predict all crash types and fatal and injury crashes.

Authors	Abhinav Bhattacharyya (ab8230@nyu.edu), New York University Bekir Bartin, Ozyegin Universitesi Kaan Ozbay, New York University Chuan Xu, Southwest Jiaotong University Hani Nassif, Rutgers University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-02992
Paper Title	Calibration and Development of Safety Performance Functions for Rural Two-Lane Two Way Roadways: A New Jersey Case Study
Abstract	Calibrating the safety performance functions (SPF) in the Highway Safety Manual (HSM) and developing jurisdiction-specific SPFs both require significant time, effort and resources, and detailed data from different sources. It is therefore crucial to identify all the readily available data sources and automatically gather much of the data required by the HSM. However, datasets maintained by the state transportation agencies are rarely comprehensive enough to meet all data requirements, often including errors and inconsistencies. This paper presents a detailed discussion of data needs and availability, data processing methods and approaches to gather the required data for calibration and development of SPFs using rural two-way two-lane rural roadway segments and intersections in New Jersey (NJ) as a case study. It is shown that generating a usable dataset from various different data sources is a rigorous task of data compiling, cleaning and processing, and requires a significant computer programming effort. While presenting the results of the SPF calibration and development process, this paper points to the importance of crash location information and its impact on analyses results. In addition, through past literature and best practices, this paper also discusses the practicality of the current manual data extraction practices, and argues that novel data extraction methods, such as the clustering approach used in this study, should be adopted to minimize labor-intensive and cost-prohibitive manual data collection processes and increase data accuracy. The choice between calibration and development of jurisdiction-specific SPFs is also discussed.

Authors	Tanmoy Bhowmik (tanmoy78@Knights.ucf.edu), University of Central Florida Shamsunnahar Yasmin, Queensland University of Technology Naveen Eluru, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-03184
Paper Title	Accommodating for Systematic and Unobserved Heterogeneity in Panel Data: Application to Macro-Level Crash Modeling
Abstract	The current research contributes to the burgeoning literature on multivariate models by proposing a hybrid model framework that (a) incorporates unobserved heterogeneity in a parsimonious framework and (b) allows for additional flexibility to accommodate for observed/systematic heterogeneity. Specifically, we estimate a Latent Segmentation Panel Multivariate Negative Binomial (LPMNB) to study the zonal level crash counts across different crash types. Further, we undertake a comparison exercise of the proposed hybrid LPMNB model with a Panel Mixed Negative Binomial model (PMNB) that accommodates for all unobserved heterogeneity via a simulation setting. The analysis is conducted using the zonal level crash records by different crash types from Central Florida region for the year 2016 considering a comprehensive set of exogenous variables. Based on the statistical data fit, we find that the segmented model (LPMNB) is a preferred choice as long as the framework is estimated in a closed form system. The comparison exercise is further augmented by computing several goodness of fit measures and the results offered by the LPMNB model highlight the value of the proposed model.

Authors	Raul Avelar (r-avelar@tamu.edu), Texas A&M Transportation Institute Karen Dixon, Texas A&M University Boniphace Kutela, Texas A&M Transportation Institute Samuel Klump, HDR Wemple Elizabeth, HDR Richard Storm, HDR
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-03234
Paper Title	Developing an Index-based Methodology to Assess the Quality of SPF Calibration. A Multivariate Approach
Abstract	The calibration of Safety Performance Functions (SPFs) is a mechanism included in the Highway Safety Manual (HSM) for practitioners to adjust SPFs in the HSM for use in their respective jurisdictions. Critically, the quality of the calibration procedure must be assessed prior to using the calibrated SPFs. Multiple resources to aid practitioners in calibrating SPFs have been developed in the years following the publication of the HSM first edition. Similarly, the literature suggests multiple ways to assess the goodness of fit (GOF) of a calibrated SPF to a dataset from a given jurisdiction. This paper uses the calibration of multiple intersection SPFs to a large Mississippi safety database to examine the relations between GOF metrics. The goal is to develop a sensible single index that leverages the joint information from multiple GOF metrics. A factor analysis applied to the calibration results revealed three underlying factors that explain 76 percent of the variance of the GOF metrics. From the factor analysis results, the authors developed an index and performed a sensitivity analysis. The key metrics explaining index variation were found to be, in descending order: the deviation of the cumulative residual (CURE) plot from the 95 percent confidence area, the mean absolute deviation, the modified R-squared, and the value of the calibration factor. This paper also presents comparisons between the index and alternative scoring strategies, as well as an effort to verify the results using synthetic data. The developed index is recommended to assess the quality of the calibrated intersection SPFs.

Authors	John Kodi (jkodi001@fiu.edu), Florida International University Angela Kitali, Florida International University MD Sultan Ali, Florida International University Priyanka Alluri, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-03255
Paper Title	Estimating Safety Effects of Adaptive Signal Control Technology Using the Full Bayesian Approach
Abstract	Adaptive Signal Control Technology (ASCT) is a traffic management strategy that optimizes signal timing based on real-time traffic demand. Although the primary intent of ASCT is to improve the operational performance of signalized intersections, the technology may also have substantial safety benefits. This study explored the potential safety benefits of the ASCT strategy deployed at signalized intersections in Florida. An observational before-after full Bayes (FB) approach with a comparison-group was adopted to develop crash modification factors (CMFs) for total crashes, rear-end crashes, and specific crash severity levels (fatal plus injury (FI), and property damage only (PDO) crashes). The analysis was based on 20 intersections equipped with ASCT and their corresponding 40 comparison intersections without ASCT. The ASCT deployment was found to significantly reduce total crashes by 8.5% (CMF = 0.915), rear-end crashes by 8.5% (CMF = 0.915), and PDO crashes by 8.1% (CMF = 0.919). The 8.7% reduction in FI crashes (CMF = 0.913) was not significant at a 90% Bayesian credible interval. These findings provide researchers and practitioners with an effective means to quantify the safety benefits of the ASCT strategy and conduct economic appraisals of ASCT deployments.

Authors	Jinghui Yuan (jinghuiyuan@Knights.ucf.edu), University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jingwan Fu, University of Central Florida Yina Wu, University of Central Florida Lishengsa Yue, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-03284
Paper Title	Developing Short-Term Safety Performance Functions for Freeways at Different Aggregation Levels by Using Multi-State Microscopic Traffic Detector Data
Abstract	Safety Performance Functions (SPFs) have been widely used by researchers and practitioners to conduct roadway safety evaluation. Traditional SPFs are usually developed by using annual average daily traffic (AADT) along with geometric characteristics. However, the high level of aggregation may lead to a failure of capturing the temporal variation in traffic volume, speed, weather, crashes, and other factors. In this study, short-term SPFs at different aggregation levels were developed based on microscopic traffic detector data from California, Florida, and Virginia. Five aggregation levels were considered: (1) annual average weekday hourly traffic (AAWDHT), (2) annual average weekend hourly traffic (AAWEHT), (3) annual average weekday peak/off-peak traffic (AAWDPT), (4) annual average day of the week traffic (AADOWT), and (5) annual average daily traffic (AADT). Model estimation results showed that the segment length and volume are significant across all the aggregation levels. Average speed is significant with a negative coefficient, and the standard deviation of speed was found to be positively associated with the crash frequency. It is noteworthy that the HOV operation status was found to have a positive effect on crash frequency across all the aggregation levels. The model comparison results in prediction performance showed that the AADOWT and AAWDPT models consistently performed slightly better than the other models, which implies that the differences between the day of the week and peak/off-peak periods should be considered in the development of crash prediction models.

Authors	Zihe Zhang, University of Alabama Xiaobing Li, University of Alabama Jun Liu (jliu@eng.ua.edu), University of Alabama Xing Fu, University of Alabama Chenxuan Yang, University of Alabama Steven Jones, University of Alabama
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-03672
Paper Title	Localized Safety Performance Functions for Rural 3-Leg Stop-Controlled Intersections in Alabama
Abstract	Safety Performance Functions (SPFs) are often used to predict the expected crash frequency for a proposed highway facility (intersection or road segment). Highway Safety Manual (HSM) provides a set of SPFs for practitioners to use and also recommends the development of jurisdiction-specific SPFs using local safety data. Because only limited variables are available in the data, SPF models need to handle the potential unobserved heterogeneity in data. Random-parameter models are often applied to develop SPFs; but the model outcomes are still to represent the regionwide relationships between crash frequency and factors. Given the interactions between traffic safety and the environment (social, culture as well as geography), the unobserved heterogeneity is likely related to the space. This study employs a spatial modeling approach, namely Geographically Weighted Negative Binomial Regression (GWNBR), to incorporate the spatial heterogeneity into SPF model specification. In contrast with models that provide regionwide SPFs (e.g., a state), the GWNBR model can generate an SPF for local areas (part of the region), called Localized SPFs (or L-SPFs). This study uses the 2014 to 2018 geo-referenced crash data from Alabama to develop L-SPFs for rural 3-leg stop-controlled intersections. The results show the L-SPFs estimated by the GWNBR model vary substantially across Alabama. For example, the coefficients for traffic volume (AADT) range from 0.121 to 0.919 across different parts of the state. Practitioners and decision-makers could use the L-SPFs to predict crash frequency in their local area, so the countermeasures and funds could be better allocated to reflect the local situations.

Authors	Samantha Islam (sislam@southalabama.edu), University of South Alabama Richard Dzinyela, University of South Alabama Grace Toledo, University of South Alabama
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-03916
Paper Title	Development of Safety Performance Functions for Low Volume Rural Local Roads in Alabama
Abstract	The objective of this study was to develop safety performance functions (SPF's) for rural local roads in Alabama with low traffic volume (AADT<2000 vehicles per day) for three types of facilities: two-lane undivided roadway segments (LR2U), three-leg stop controlled intersections (3ST), and four-leg stop controlled intersections (4ST). The dataset used for the development of SPF's was compiled from several sources and included data related to traffic crashes, volumes, roadway classification, geometry, cross-sectional features and roadway characteristics from all 67 counties throughout the state from 2012 to 2014. The total length of roadway segments that was used for SPF development was 1,036 miles and corresponding number of crashes were found to be 1,929 crashes. Similarly, the compiled dataset included 622 three-leg intersections (3ST) with 825 crashes and 325 four-leg intersection (4ST) with 539 crashes. Separate SPFs were developed for roadway segments and stop-controlled intersections for total (KABCO), fatal plus injury (KABC), and property damage only (PDO) crashes for the AADT ranges of 0-2000, 0-399, 400-1599, and 1600-2000 vehicles per day. Overall, it was found that the SPFs fit the data well. However, due to small number of sample sizes for three- and four-legged intersections, variables other than AADT's for major and minor roads were not found to have significant impacts on crash frequencies. At the end of this paper, simple step-by-step examples have been provided for the users to familiarize them with the network screening process using these SPFs.

Authors	Praveen Vayalamkuzhi, University of California, Berkeley Aditya Medury, Indian Institute of Technology, Kanpur Lin Yang, University of California, Berkeley Offer Grembek, University of California, Berkeley Venky Shankar, Texas Tech University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-04188
Paper Title	Impact of Injury-Based Safety Performance Functions on Network Screening
Abstract	Safety Performance Functions (SPF) are proven to be the best resource for evaluating highway safety. However, agencies have a difficult time selecting the type of SPF from among the various options to use in analysis—whether all crashes will be included, or determining the impact of Property Damage Only (PDO) crashes in the safety analysis. Injury severities considered for network screening have important implications for how limited agency resources are used. This operational reality that dominates many agencies can inhibit their ability to systematically choose the appropriate SPF type for prediction and implementation. This paper describes the application and outcome of different crash-severity level SPFs to address such concerns through a set of SPFs—total crashes, fatal and severe crashes, and a combination of fatal, severe and visible injury crashes. Potential for Safety Improvement (PSI) based on the Empirical Bayes (EB) approach was then used for network screening to select the top one percent of hotspots within each facility type by injury severity level. The findings indicate differences in site characteristics across hotspots identified using different crash types, with total crashes favoring sites in heavier traffic urban areas. There is a greater need to understand the type of sites that yield high property damage only (PDO) crashes within network screening—for example, there is mixed evidence about the over-representation of PDO crashes among secondary crashes on highways. The analysis also revealed the differences in site demographic type and Annual Average Daily Traffic (AADT) across hotspots identified by different crash combinations.

Authors	Adika Iqbal (amammad@g.clemson.edu), Clemson University Wayne Sarasua, Clemson University Afshin Famili, Clemson University Jennifer Ogle, Clemson University William Davis, Citadel Military College Devesh Kumar, Clemson University Saurabh Basnet, Clemson University Emmanuel Adjei, Clemson University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs
Paper Number	21-04402
Paper Title	Assessing the Predictability of Short Segment Crash Analysis in the State of South Carolina
Abstract	The main objective of this research is to evaluate the predictability of a short segment peak search method with lengths of less than 0.1 miles for the statewide screening of midblock crash locations. Three different approaches (Based on HSM SPFs) are used to evaluate the short segment method. These approaches include state-specific SPFs, Driveway SPFs (using only AADT), and driveway SPFs with adjusted CMFs. Frequency-based identification of short segments stratified by six different roadway types (R2U, R4D, U2U, U4D, U3T, and U5T) has been compared with three SPF based screening methods to determine segments with the highest excess predicted average crash frequency. For short segment sites with highest crash frequencies (3 for U3T, U4D, and U2U; 4 for U5T and 2 for R4D and R2U), the comparison showed similar results (Top 90% agreement). Thus, should insufficient data be available to conclude SPFs, a frequency-based approach will likely identify the top sites. While this method works relatively well with top sites, the reliability of this method will wane with lower-ranked sites.

Authors	Jason Hershock, Pennsylvania Department of Transportation
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35)
Session Number	1307
Session Title	Top 16 High Value Research Projects
Paper Number	21-20074
Paper Title	Regionalized Urban/Suburban Collector Road Safety Performance Functions (SPFs)
Abstract	The AASHTO Highway Safety Manual (HSM) provides transportation professionals with quantitative tools that can be used to assess the safety performance of planned or existing highways. One set of tools currently available in the HSM are safety performance functions (SPFs), which relate the expected crash frequency of a roadway segment or intersection to anticipated traffic volumes, geometric characteristics, and other roadway and roadside features. This study focused on the development of SPFs for urban-suburban collector roadway segments. SPFs were developed for urban and suburban collector highway intersections and segments. Based on the regionalization process, engineering district-level SPFs with county-level adjustments were recommended for two-lane undivided roadway segments. Statewide SPFs were recommended for three-leg all-way stop controlled, four-leg minor-street stop-controlled, four-leg all-way stop-controlled and four leg signalized intersections. Statewide SPFs with district-level adjustments were recommended for three-leg minor-street stop controlled intersections. Implementation The new SPFs for collector roads and intersections were added to PennDOT's network screening and will be utilized with the 2019 crash data. PennDOT is also updating our Publication 638A, PA Safety Predictive Analysis Methods Manual and the HSM analysis tools; so everyone can easily access and use the new SPFs.

Authors	Irfan Ahmed, University of Wyoming Mohamed Ahmed (mahmed@uwyo.edu), University of Wyoming
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	1356
Session Title	Pavement, Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	21-03597
Paper Title	DEVELOPING SAFETY PERFORMANCE FUNCTIONS FOR TWO-LANE TWO-WAY RURAL HIGHWAYS USING MULTIPLE REGRESSION TECHNIQUES- A COMPARATIVE ANALYSIS
Abstract	Developing crash prediction models, also known as Safety Performance Functions (SPFs), for low-volume rural two-lane two-way highways is often a challenging task. The crash data for these roadways are characterized by low sample mean and small sample size. To this point, there has not been a proper guidance on developing SPFs for such roadways in rural states. This study fills this gap by developing 36 crash prediction models using four different types of regression models, namely the Negative Binomial (NB), Zero-Inflated Negative Binomial (ZINB), Tobit, and Conway-Maxwell-Poisson (COM-Poisson). Models were developed using three sets of crash data comprising of crashes between 2007 and 2011: the US-287 roadway segments in Wyoming, Colorado, and the whole corridor combined. The purpose of including Colorado and the combined dataset is to draw a comparison of the model performance on datasets with different sample sizes. The results showed that overall COM-Poisson outperformed other models in terms of model fit. However, for datasets with relatively lower sample means such as in the case of Fatal and Injury (FI) crash models, ZINB can be a suitable alternative. The prediction capability of the developed models was also evaluated with a validation dataset prepared from Wyoming's 2016- 2019 crash data. The analysis further confirms that COM-Poisson is a better performing model. The transferability of Colorado and the combined SPFs to Wyoming data was tested. It can be concluded that the neighboring jurisdictions SPFs can be borrowed without scarifying the accuracy by a large margin.

Authors	Ali Khodadadi (a.khodadadi1994@tamu.edu), Texas A&M University, College Station Ioannis Tsapakis, Texas A&M Transportation Institute Subasish Das, Texas A&M University Dominique Lord, Texas A&M University, College Station Yingfeng Li, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	1356
Session Title	Pavement, Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	21-03829
Paper Title	Application of Different Negative Binomial Parameterizations to Develop Safety Performance Function for Non-Federal Aid System Roads
Abstract	Safety Performance Function (SPF) is the main building block in understanding relationships between the number of crashes and factors influencing crash risk. Many research efforts have focused on high-volume roadways, which typically experience more crashes, and fewer studies have developed SPFs for non-federal aid system (NFAS) roads that include rural minor collectors, rural local roads, and urban local roads. The NFAS roads are characterized with unique features such as limited mobility, lower speeds, shorter segment lengths, and usually experience fewer crashes given the low exposure of these roads. As a result, there is a clear need to investigate safety issues and generate distinct SPFs for NFAS roads. The main objective of this study is to bridge the gap in the literature and develop SPFs for NFAS roads. This study examined the application of both traditional negative binomial and zero-favored negative binomial models, (i.e. Negative Binomial-Lindley). Both groups of models were formulated by different variance and dispersion structures. Using crash, roadway inventory, and traffic volume data for 2014-2018 in Virginia, the results showed that NB-L models performed better compared to traditional NB models. Furthermore, a more flexible variance structure along with a reasonably chosen dispersion structure can further improve model performance.

Authors	Meghna Chakraborty, Michigan State University Timothy Gates (gatestim@egr.msu.edu), Michigan State University
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30) Standing Committee on Transportation Safety Management Systems (ACS10) Joint Subcommittee on Rural Road Safety Policy, Programming, and Implementation (with ACS20, AKD30) (ACS10(4))
Session Number	1356
Session Title	Pavement, Safety, and Traffic Management Developments for Low Volume Road Applications
Paper Number	21-03405
Paper Title	Relationship between Horizontal Curve Density and Safety Performance on Rural Two-Lane Road Segments by Road Jurisdiction and Surface Type
Abstract	This study involved the assessment of the safety impacts associated with horizontal curve density (in terms of number of curves per mile) on rural two-lane state and county road segments in Michigan. Non-animal road segment crashes from 2011 to 2015 were analyzed along with roadway geometry data for greater than 5,556 miles of state highways, 5,890 miles of paved county segments and 2,007 miles of unpaved roads from across Michigan. Several mixed-effects negative binomial regression models with a county- and site-specific random effects combined were generated. The model results indicated a consistent positive association between the density of horizontal curves with design speeds below 55 mph (radius less than 0.191 miles) and crashes across all classes of rural two-lane road segments. Specifically, although the mere presence of a horizontal curve along the segment increases crash occurrence across each of the rural roadway classes analyzed here, the crash occurrence is further increased when the frequency of horizontal curves exceeds 1 per mile for state highways and paved county roads. These results provide further contribution to previous research on the safety effects of horizontal curvature on rural roadways, by suggesting that more frequent changes in horizontal alignment (as indicated by an increasing frequency of curves per mile) increases crash occurrence. This study also further contributes to the limited body of knowledge regarding safety performance on rural secondary roadway segments, including roads under county jurisdictions and unpaved roads.

Authors	Ming Sun (ming.sun1@louisiana.edu), University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette M. Rahman, University of Louisiana, Lafayette Subasish Das, Texas A&M University
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-01696
Paper Title	Calibration and Development of Safety Performance Functions for Two-Way Stop-Control Intersections on Rural Two-Lane Highways in Louisiana
Abstract	The first edition of Highway Safety Manual (HSM) contains a simplistic version of crash prediction model for two-way stop-controlled intersections (TWSC) on rural two-lane highways. This model considers AADT on both major and minor roads with the base conditions simply defined as no intersection skewness, no turning lanes, and no lighting. A crash modification factor (CMF) will be applied if an intersection has the conditions different from the base condition. The HSM model does not take account of curvature. It is well known that curved TWSC intersections are less safe than non-curved ones particularly on rural two-lane roadways. This paper presents the development of crash prediction models incorporating intersection geometrics for TWSC intersections on rural two-lane highways in Louisiana and comparing the results from the developed model with the calibrated HSM model. The negative binomial model was used with 5,126 TWSC intersections verified one by one including both three- and four-leg intersections from all parishes (counties). The estimation results indicate that AADT, curve radius, and intersection skewness angle have a significant impact on expected crash frequency for both three- and four-leg intersections. Cumulative Residuals (CURE) plots, Mean Absolute Error (MAE), and Root Mean Square Error (RMSE) were used for comparative analysis of HSM models, HSM models with calibration and Louisiana-specific models. The results show that Louisiana-specific SPFs outperformed the calibrated SPFs with greater reliability. Calibration factors of 0.58 for three-leg intersections and 0.46 for four-leg intersections are estimated, suggesting that the original HSM model overpredicts crashes in Louisiana.

Authors	Ahmed Abdelrahman, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jinghui Yuan (jinghuiyuan@Knights.ucf.edu), University of Central Florida Ma'en Al-Omari, University of Central Florida
Sponsoring	Standing Committee on Performance Effects of Geometric Design (AKD10)
Committee	Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-00026
Paper Title	SYSTEMATIC SAFETY EVALUATION OF DIVERGING DIAMOND INTERCHANGES BASED ON NATIONWIDE IMPLEMENTATION DATA
Abstract	Diverging Diamond Interchanges (DDIs) are designed as an alternative to the conventional diamond interchange to enhance the operational and safety performance as they have a lower number of traffic conflict points. Since drivers are not familiar with DDIs' operation, which results in many wrong-way maneuvers, there is a need to evaluate the safety performance of this type of interchanges to validate their effect, and to estimate reliable and representative Crash Modification Factors (CMFs). This paper evaluates the safety of DDIs using three methods, which are before-and-after study with comparison group, Empirical Bayes before-and-after method, and cross-sectional analysis. This study was conducted based on a nationwide sample of 80 DDIs in 24 states. The analysis results indicated that converting conventional diamond interchange to diverging diamond interchanges could significantly decrease the total, fatal-and-injury, rear-end, and angle/left turn crashes by 14%, 44%, 11%, and 55%, respectively. Moreover, the developed safety performance functions (SPFs) implied that two types of geometric characteristics (i.e., the distance between crossovers/ramp terminals and freeway exit ramp speed limit) have the potential to reduce the frequency of specific crash types. The study contributes to the existing literature by using a relatively large representative sample size, which provides more statistically significant safety measures. In addition, this study also explored the effects of different traffic and geometric characteristics on the safety performance of DDIs.

Authors	Ahadul Islam, Utah State University Xiaoduan Sun, University of Louisiana, Lafayette Patrick Singleton (patrick.singleton@usu.edu), Utah State University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	1099
Session Title	Exposure to Risk, Stress, Conflicts, and Crashes: Innovative Pedestrian Safety Analysis Methods
Paper Number	21-02609
Paper Title	Evaluating Pedestrian "Safety in Numbers" at Signalized Intersections in Utah with Pedestrian Exposure Data from Traffic Signals
Abstract	The focus of this study is twofold: (1) to estimate models of pedestrian crash frequency and severity at signalized intersections, using pedestrian and traffic volumes and other predictor variables; and (2) to examine whether the "safety in numbers" effect applies to pedestrian safety the US using robust measures of pedestrian exposure. Specifically, the analysis used pedestrian crossing volumes estimated from one year of pedestrian push-button data, and ten years of crash data at signalized intersections in Utah. Data from 919 signalized intersections were used to calibrate a zero-inflated negative binomial model for crash frequency analysis. The model results indicated that signals with longer crossing distances, far-side bus stops, larger shares of residential and commercial land uses, and in neighborhoods with lower-income and larger households saw more pedestrian crashes. To analyze injury severity in pedestrian crashes, an ordered logit model was fitted with 1,483 pedestrian crash observations. The model results indicated that speed limit, vehicle size, number of vehicles, vehicle maneuvering direction, and involvement of DUI/drowsy/distracted driving in crashes had significant effects on severity. The study also found a non-linear relationship where pedestrian-vehicle crash rates decreased with an increase in pedestrian volumes, supporting the "safety in numbers" effect. The authors suggest potential countermeasures, policy alterations, and scope of future research for improving pedestrian safety at signalized intersections.

Authors	Emmanuel James (elj52@nau.edu), Northern Arizona University Brendan Russo, Northern Arizona University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	1099
Session Title	Exposure to Risk, Stress, Conflicts, and Crashes: Innovative Pedestrian Safety Analysis Methods
Paper Number	21-03625
Paper Title	Analysis of Factors Affecting Pedestrian Crash Frequency Considering Demographic, Land Use, and Roadway Characteristics
Abstract	Pedestrian safety has been a prevalent issue across the United States, and especially in regions that experience higher pedestrian activity year-round due to warm climates, such as the state of Arizona. In the past several years, recent trends indicate a steady increase in pedestrian crashes in the city of Phoenix, Arizona. To address this issue, the objective of this study was to investigate factors associated with the frequency of vehicle-pedestrian crashes at the census block level by amalgamating four datasets consisting of crash data, demographic data, land use data, and roadway characteristics. A negative binomial model was estimated to identify factors significantly associated with pedestrian crash frequency. Numerous parameters in the model were found to influence pedestrian crashes, and the general effect (though with differing magnitudes) of most variables were similar to previous studies conducted in other regions, however two specific land use and demographic characteristics were found to be unique to the city of Phoenix. Percent of industrial land use type and percent of persons aged 65 or older were found to have differing effects compared with those found in previous studies. Ultimately, the findings of this study provide new insights that can help frame or amend policies and countermeasures aimed at improving pedestrian safety.

Authors	Ni Dong (dongni@home.swjtu.edu.cn), Southwest Jiaotong University Fanyu Meng, Southern University Jie Zhang, Southwest Jiaotong University S.C. Wong, University of Hong Kong Pengpeng Xu, University of Hong Kong
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers
Paper Number	21-04363
Paper Title	TOWARDS ACTIVITY-BASED EXPOSURE MEASURES IN SPATIAL ANALYSIS OF PEDESTRIAN-MOTOR VEHICLE CRASHES
Abstract	Background: Although numerous efforts have been devoted to exploring the effects of area-wide factors on the frequency of pedestrian crashes in neighborhoods over the past two decades, existing studies have largely failed to provide a full picture of the factors that contribute to the incidence of zonal pedestrian crashes, due to the unavailability of reliable exposure data and use of less sound analytical methods. Methods: Based on a crowdsourced dataset in Hong Kong, we first proposed a procedure to extract pedestrian trajectories from travel-diary survey data. We then aggregated these data to 209 neighborhoods and developed a Bayesian spatially varying coefficients model to investigate the spatially non-stationary relationships between the number of pedestrian–motor vehicle (PMV) crashes and related risk factors. To dissect the role of pedestrian exposure, the estimated coefficients of models with population, walking trips, walking time, and walking distance as the measure of pedestrian exposure were presented and compared. Results: Our results indicated substantial inconsistencies in the effects of several risk factors between the models of population and activity-based exposure measures. The model using walking trips as the measure of pedestrian exposure had the best goodness-of-fit. We also provided new insights that in addition to the unstructured variability, heterogeneity in the effects of explanatory variables on the frequency of PMV crashes could also arise from the spatially correlated effects. After adjusting for vehicle volume and pedestrian activity, road density, intersection density, bus stop density, and the number of parking lots were found to be positively associated with PMV crash frequency, whereas the percentage of motorways and median monthly income had negative associations with the risk of PMV crashes. Conclusions: The use of population or population density as a surrogate for pedestrian exposure when modeling the frequency of zonal pedestrian crashes is expected to produce biased estimations and invalid inferences. Spatial heterogeneity should also not be negligible when modeling pedestrian crashes involving contiguous spatial units.

Authors	Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Yongfeng Tang, Tongji University Mohammed Quddus, Loughborough University Qingya Zhou, Guangzhou Urban Planning and Design Survey Research Institute Xinyi Hou, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers
Paper Number	21-01968
Paper Title	Spatial Models for High-Accurate Hot Zone Identification for E-bikes
Abstract	The use of electric bicycles (e-bikes) has growing rapidly in recent decades, resulting in a significant rise in e-bike crash rates. Therefore, improving the safety of e-bikes is essential to maintain the rapid growth of this sustainable mode of transport. One policy prescription is to focus on area-wide traffic safety management by identifying hot zones for e-bike crashes and their contributory factors. In macro-level safety modelling, the primary explanatory variable – the area of a zone, vary greatly in sizes. This phenomenon poses realistic challenges to the accuracy of macro-level statistical models. Yet, limited studies examined the influence of discrepancy in zone sizes on macro-level safety analysis related to e-bikes. To fill the research gap, this study aims to examine the influence of the size of an area on macro-level modelling. Spatial data on e-bike crash, road network, land use and socio-economic for 213 administrative units in Shanghai were collected. Then three Poisson log-normal Conditional Autoregressive models were developed with different modelling strategies to address the impact of area scale. In Model 1, area was modelled as a regular independent variable. While in Model 2, area was considered as an exposure variable. Finally, in Model 3, independent variables and dependent variable were divided by area. The results indicated Model 2 outperforms other two models. To identify hot zones, Potential for Safety Improvement estimates of three models were aggregated separately. The findings from this study can provide guidelines in considering the influence of area scale in macro-level modelling and hot-zone identification.

Authors	Shujuan Ji, Chang'an University Yuanqing Wang (wyqing@chd.edu.cn), Chang'an University Yao Wang, Chang'an University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers
Paper Number	21-01987
Paper Title	Geographically Weighted Poisson Regression under Linear Model of Coregionalization Assistance: Application to a bicycle crashes study
Abstract	ABSTRACT Cycling benefits individuals and society. However, cyclists are vulnerable road users and its safety concern arises macro-level spatial crash studies. This study intends to investigate the spatial effects of population, land use and bicycle lane infrastructures on the bicycle crashes. This was done by dealing with the issue of spatial correlation and spatial non-stationary simultaneously by developing semi-parametric Geographically Weighted Poisson Regression (sGWPR) model. It is a model combined both constant and geographically varying parameters. For determining which parameters are fixed and non-stationary, previous study suggested monitoring Akaike Information Criterion (AICc) to make decision whether a parameter should vary geographically or not. Yet, only relying on AICc might bury some spatial associations. In this study, we propose Linear Model of Coregionalization (LMC) to assist the decision. Here, we use bicycle crash data across the metropolitan area of Greater Melbourne to establish sGWPR models suggested by AICc and LMC. Comparing the two sGWPR models, we found the sGWPR model under LMC results has better performance, and 30% improvement in the mean squared prediction error (MSPE). It also uncovers more details about spatial relationship between bicycle crashes and bicycle lane intersection density (BLID), which is not suggested under AICc results. The parameters of BLID, a new measurement of bicycle lane facilities proposed by us, are positive and vary over space in majority analysis zones in Greater Melbourne. Keywords: semi-parametric GWPR, spatial non-stationary, spatial correlation, macro-level

Authors	Mashrur Rahman, University of Texas, Austin Kara M. Kockelman (kkockelm@mail.utexas.edu), University of Texas, Austin Kenneth Perrine, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers
Paper Number	21-00955
Paper Title	Predicting Pedestrian Crash Occurrence And Injury Severity In Texas
Abstract	This study investigates pedestrian-involved crashes across Texas from 2010 through 2019. Crashes were mapped to over 708,738 road segments , along with road design, land use, transit, hospital, rainfall and other location features. Negative binomial model results show how total and fatal pedestrian-crash rates and counts rise with a segment's number of lanes, transit stops, population and job densities, as well as proximity to schools and hospitals, while greater median and shoulder widths provide some protection. Higher speed limits are associated with lower crash frequencies but more fatalities. A heteroskedastic ordered probit (HOP) model for injury severity demonstrates how pedestrian crashes are more likely to be severe and fatal at night (8 PM – 5 AM), without overhead lighting, and when the pedestrians or drivers are intoxicated. Use of light-duty trucks (including SUVs, pickup trucks, CUVs, and vans) also significantly increases the risk of pedestrians being severely injured or killed. While newer vehicle safety features may be argued to lower crash severity, newer crash-involved vehicles in Texas are not found to deliver less pedestrian injury. However, being a younger or female pedestrian, on a straight segment, off the state (and interstate) highway system, in the presence of a traffic control device (stop sign or signal) lowers the likelihood of pedestrian injury, when one does become involved in such a crash.

Authors	Jorge Ugan, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai (qingcai@knights.ucf.edu), University of Central Florida Nada Mahmoud, University of Central Florida Ma'en Al-Omari, University of Central Florida Brenda Young, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers
Paper Number	21-03023
Paper Title	Effects of Various Speed Management Countermeasures on Bicycle Crashes for Urban Roads in Central Florida
Abstract	In recent years, cycling has become an increasingly popular mode of transportation around the world. In contrast to other popular modes of transportation, cycling is more economic and energy efficient. Many studies that have focused on bicycle safety, were limited in terms of bicycle exposure data This study tries to improve the current safety performance functions for bicycle crashes at urban corridors by utilizing crowdsource data from STRAVA and on-street speed management countermeasures data. Since there is a disproportion in the representation of cyclists from the STRAVA data, adjustments, using a Tobit model, were done to more accurately represent the cyclists based on video detection data. This study aims to (1) identify a method to get more accurate bicycle exposure data, (2) analyze the effect that speed management countermeasures have on bicycle safety, and (3) incorporate other contributing factors to bicycle safety. To achieve these objectives, a Bayesian hierarchical model was used to predict the frequencies of bicycle crashes and adjust STRAVA data at the same time. Traffic, roadway attributes, on-street speed management countermeasures data, and land use data were considered in the model. The results revealed several key components for bicycle safety at urban intersections. The study concluded that crowdsourced data adjusted based on video detection and on-street speed management countermeasures data are significant when analyzing bicycle safety.

Authors	Hyeonseo Kim (pass782@naver.com), Hanyang University, Ansan Kyeongju Kwon, Hanyang University, Ansan Nuri Park, Hanyang University, Ansan Juneyoung Park, Hanyang University, Ansan Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01202
Paper Title	Exploration and evaluation of crash-and simulation-based safety performance of freeway facilities
Abstract	The main objective of this study is to evaluate the safety effects caused by altering drivers of the lengths of deceleration and acceleration lanes at rest areas on expressways in Korea. Although general conclusions can be found through crash-based safety analysis, to examine more specific optimal conditions considering various traffic conditions, this study proposes a novel framework to explore and evaluate crash-based and simulation-based safety performances. For this purpose, the safety performance function (SPF) and crash modification factor (CMF) were developed to reflect real-world safety impacts. To consider nonlinear trends of the parameters, nonlinearizing link functions were introduced into the analysis. Two types of simulation analyses were conducted to 1) find the combination of surrogate safety measures (SSMs) that best fit with the crash-based safety performance results and 2) determine the optimal lengths of deceleration lane and acceleration lanes for different traffic conditions. The results showed that the best length of deceleration lane of a rest area is between 240 m and 260 m, depending on the traffic conditions. The results also indicated that the optimal length of acceleration lane of a rest area is between 385 m and 400 m, depending on the traffic parameters. The findings of this study could be used to determine the safety solutions with a micro-traffic simulator.

Authors	Robert Schneider (rjschnei@uwm.edu), University of Wisconsin, Milwaukee Schmitz Andrew, University of Wisconsin, Milwaukee Greg Lindsey, University of Minnesota Xiao Qin, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Bicycle Transportation (ACH20) Joint Subcommittee on Emerging Vehicles for Low Speed Transportation (with ACH10, ANB40, and AP020) (ACH20(2))
Session Number	1209
Session Title	Omnibus Bicycle Research Poster Session
Paper Number	21-01569
Paper Title	Exposure-Based Models of Trail User Crashes at Roadway Crossings
Abstract	Multi-use trails are popular for transportation and recreation, but pedestrians and bicyclists are exposed to motor vehicle traffic at locations where these facilities cross roadways, creating the risk of crashes, injuries, and fatalities. Many trail crossing design guidelines suggest best practices to make roadway crossings safe, but few studies have quantified the statistical relationship between trail user crashes and a broad set of trail crossing characteristics. Our study develops one of the first trail crossing crash models using trail user crashes reported at 197 crossings in the City of Minneapolis, Minnesota and in the Milwaukee, Wisconsin region between 2011 and 2018. We take advantage of widespread trail counting programs and historic aerial and street-level imagery to create and test more than 30 theoretically-important potential explanatory variables. We address the challenge that many crossings have small numbers of crashes (or zero crashes) during the study period by using a Poisson-lognormal (PLN) model. Our model shows significant associations between trail crossing crashes and trail traffic volume, roadway motor vehicle volume, three-way intersections where the trail crosses perpendicular to the mainline roadway, and total crossing length. While not statistically significant, signalized intersections and limited sight lines between drivers and trail users near crossings may also be associated with more crashes. Future research can build on this study and expand systemic efforts to improve trail crossing safety.

Authors	Irfan Ahmed, University of Wyoming Mohamed Ahmed (mahmed@uwyo.edu), University of Wyoming
Sponsoring Committee	Standing Committee on Traffic Control Devices (ACP55)
Session Number	1294
Session Title	Traffic Control Devices and Work Zones 2021
Paper Number	21-03721
Paper Title	IMPACT OF ADVERSE WINTRY CONDITIONS ON THE EFFECTIVENESS OF CENTERLINE RUMBLE STRIPS - A CASE STUDY OF WYOMING AND COLORADO USING BEFORE-AFTER EMPIRICAL BAYES DESIGN
Abstract	Head-on crashes contribute towards the highest share of multi-vehicle crashes despite being a small percentage of overall crashes. Over the years, centerline rumbles strips (CLRS) have emerged as a cost-effective countermeasure to prevent head-on or cross-over-the-centerline crashes. The overall safety benefits of CLRS is well-proven in the literature. However, there are some anecdotal evidence of its reduced effectiveness during adverse wintry conditions. Since there was no quantitative research in this matter, this study aims to fill that gap. The overall safety effectiveness of CLRS in Wyoming and Colorado was quantified in this study by season; summer and winter. A before-after Empirical Bayes method was chosen to develop Crash Modification Factors (CMFs). Safety performance functions were developed to predict annual, summer, and winter Total, Property Damage Only, Fatal and Injury, as well as Target crashes. Expected crash reductions in Wyoming were found to be between 23% and 72% and those in Colorado ranged between 41% and 84%. The higher percentage of expected crash reductions were associated with the target crashes, head-on crashes. Results show that the CMFs obtained for Wyoming are higher than the ones for Colorado, which can be attributed to the winter maintenance efforts of the jurisdictions. Furthermore, winter CMFs were found to be higher than the summer CMFs suggesting the impact of accumulated snow or ice on reduced depth accompanied by reduced noise and vibration levels. Active and timely winter maintenance efforts are key to keep the CLRS free of snow or ice, thereby not reducing its effectiveness.

Authors	Qinglin Hu (qhu10@ua.edu), University of Alabama Xiaobing Li, University of Alabama Jun Liu, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00299
Paper Title	A Low-Cost Approach to Identify Hazard Curvature for Local Road Networks Using Open-Source Data
Abstract	ABSTRACT Vehicle crashes are a leading cause of death in the United States. Among those crashes, curvature in local roadway was identified as one of the most significant factors correlated with fatal crashes. Given the large number of local roads and their relatively lower traffic compared with interstates or freeways, most local roads may not receive priorities in the first phase of highway upgrades. However, critical locations, e.g., sharp curves (vertical and/or horizontal), in the network that may be a deadly threat for both new advanced autonomous vehicles and conventional vehicles. In addition, Identifying local roadway curvatures exists various uncertainty by most authorities, such as high budget and lack of data. To fill this gap, this study offers a low-cost approach to constructing three-Dimensional geometric profiles for local roads in a relatively large study area using open-source data. With the profiles, critical road segments, including extreme horizontal and vertical curves and their combinations, can be identified. Our study redefined the local road segments into 20 sub-categories based on the calculated vertical grades and curve radius that were incorporated into a zero-inflated native binomial model. Model results showed that grades or curves were associated with decreased crash frequency compared with straight and flat roads. However, segments with larger horizontal curve radius and low grades were found to associate with increased crash frequency. More implications are discussed in the paper.

Authors	Rebeka Yocum, Pennsylvania State University, University Park Vikash Gayah (gayah@engr.psu.edu), Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01517
Paper Title	Identifying relationships between socioeconomic indicators and crash frequency in Pennsylvania
Abstract	Current crash prediction models utilize roadway and traffic data as independent variables to describe crash frequency on individual roadway segments. Recent work has moved toward predicting crashes within some region as a function of roadway and traffic data, as well as non-traditional variables, such as alcohol, gasoline prices, and socioeconomic measures. This paper aims to introduce measures of wealth into the crash modeling conversation by determining the effect of wealth on total, fatal and injury, and pedestrian crash frequencies in Pennsylvania counties. The analysis presented in this paper will serve as a case study with intentions to promote the development of more robust, wealth-inclusive crash prediction models in the future. The study reveals that population of unemployed individuals, percentage of the population on cash public assistance or receiving SNAP benefits, and the percentage of households without a vehicle are each positively related to the observed frequency of total, fatal + injury and pedestrian crashes in each county. This result not only supports previous work, but expands on that work by considering multiple crash types, and multiple wealth related variables. The existence of a relationship between crash frequency and wealth related variables opens the door to further exploration of including wealth in traditional crash prediction methods. This paper discusses this relationship and offers recommendations for future work.

Authors	Zhicheng Dai, Tongji University Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Wenbin Luo, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02415
Paper Title	Macro Safety Analysis for Non-motorized Vehicles Based on Roadway and Safety Education Improvement Countermeasures
Abstract	Non-motorized vehicles such as bicycles and e-bikes have gained great popularity in recent decades because of their high mobility and economy. Because these road users have a higher risk of injury in a crash, macro safety analyses have been conducted according to crash location. However, this strategy could be inefficient when comprehensive improvements such as traffic safety education programs are considered, due to differences between crash locations and the locations of the crash-involved road users' residences. To improve implementation of such countermeasures, this study proposes a new analysis strategy of separately aggregating crashes for roadway engineering improvement and road users for education improvement. Roadway, socioeconomic and land use characteristics from 213 Shanghai sub-districts were collected as independent variables. The dependent variables of crashes and road users were divided into four subjects by crash severity level: fatal and injury (FI) and property damage only (PDO). A multivariate Poisson lognormal conditional autoregressive (CAR) model was developed to examine the relationships between regional characteristics and traffic safety, and potential safety improvement (PSI) was calculated for each sub-district based on model results. Hot-zone identification showed significant differences in distribution of sub-districts with urgent need for roadway versus education improvement. False positive and false negative indexes were developed to identify the differences quantitatively. Results indicated that nearly half the identified hot zones were inconsistent in unnecessarily prioritizing either engineering or education improvement. The findings of this paper are of great practical significance to better utilize resources for non-motorized vehicle traffic safety improvement.

Authors	Fahmida Rahman (fra228@uky.edu), Kentucky Transportation Cabinet Xu Zhang, Kentucky Transportation Cabinet Mei Chen, Kentucky Transportation Center
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03068
Paper Title	Effect of Speed on Crash Prediction Model of Rural Two-Lane Highways
Abstract	Speed plays an important role in traffic safety. Previous works investigated speed's effect on the crashes of rural two-lane highways using estimated speed due to inadequate speed data. It implies a need to understand the effect using measured speed on these roads. This study filled this gap by utilizing ubiquitous probe speed data. Zero Inflated Negative Binomial model was adopted for accounting the excess zeros in crash dataset. Four speed measures, including average speed, the 85 th percentile speed, difference in average speed and speed limit, and difference in 85 th percentile speed and speed limit, were evaluated. The average speed-based model was found to outperform other speed-based models as well as the traditional model. Later, to evaluate whether speed as a categorizer improves the overall model performance, separate prediction models were developed by dividing the dataset based on three-speed ranges: low, medium, and high speeds. Noticeably, speed becomes more significant for the crashes from low to high speed and is an obvious factor for the high-speed category. Compared to the traditional model, inclusion of speed reduced prediction error by 5% for the high-speed roads. Furthermore, for the medium-speed roads, using AADT as another categorizer resulted in further improvement over the model with speed categorizer only. Finally, the models developed for all three-speed ranges showed the lowest error in comparison to the no categorizer model. Since speed and AADT categorizer models enhance prediction accuracy, such an approach is recommended for developing crash prediction models for rural two-lane highways whenever possible.

Authors	Yingying Pei, Tongji University Xuesong Wang (wangxs@tongji.edu.cn), Tongji University Mingjie Feng, Tongji University Zhixing Zhu, Traffic Police Headquarters of Jiangsu Province Fang Liu, Traffic Police Department of Suzhou City Zhongyang Qie, Traffic Police Department of Suzhou City Paul P. Jovanis, Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03435
Paper Title	Macro-Level Safety Analysis of Crashes and Violations: Influencing Factors and Crash Hotspots
Abstract	Regional traffic safety has been a public concern for many metropolitan areas, and it is urgent to turn this situation around by using an appropriate traffic safety analysis and crash hotspot identification method. Existing studies mainly focus on the effects of engineering-related indicators on regional crashes and violations, neglecting the traffic police enforcement-related factors. Meanwhile, the relationship between crashes and violations is insufficiently recognized. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, and collected socio-economic indicators, road features, land use intensity, facility data, and police enforcement information as independent variables. A Bayesian bivariate negative binomial spatial conditional autoregressive (BNB-CAR) model was developed to capture the association between crashes and violations, as well as their contributing factors. Results showed that (1) there existed a significantly correlated effect between crashes and violations; (2) engineering-related indicators had similar effects on crashes and violations, while some police enforcement-related factors were dual-effective. Based on the model results, this study used the potential for safety improvement (PSI) method to identify the hazardous areas of the 115 towns in Suzhou. It was observed that (1) the spatial distribution of crashes indicated the spatial correlations among the towns; (2) the fringe areas suffered higher crash risks than the downtown areas. Several engineering and enforcement countermeasures were provided for urban planning departments and traffic police to enhance their work effectiveness. Additionally, decision makers and administrators will benefit from this study to improve daily traffic safety management.

Authors	Shefa Arabia Shioma, University of Toledo Ahmad Ilderim Tokey (ahmadtokey@gmail.com), University of Toledo Muhammad Salaha Uddin, University of Toledo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-04448
Paper Title	Assessing the Effectiveness of Built Environment-based Safety Measures by Urban and Rural Area for Reducing the Non-motorist Crashes
Abstract	Built environment (BE)-based safety measures are usually implemented for reducing the non-motorist crashes in urban and rural area. However, their usefulness differing the urban and rural area were not widely explored in literature. Therefore, this study was explored the effectiveness of built environment-based safety measures in urban and rural settings. The study used four years' (2015-2018) non-motorist (pedestrian and bi-cyclist) crash data of Florida and examined the effect of built-environment based safety measures such as sidewalk, distance from the road, bike lane, barrier, land use mix. In this study urban and rural area were classified by applying the multivariate clustering method. The study used the negative binomial and geographically weighted Poisson regression (GWPR) for understanding the effects of BE factors assuming their spatial heterogeneity. The study finds that building the sidewalk only, and existence of intersection expose the people to crash incidents in urban areas while traffic volume works for increasing non-motorist crashes in the rural areas. The analysis also reveals that combinedly sidewalk and barrier can reduce the risks of non-motorist crashes. Signalized intersection also reduces the effect of high traffic volume on the frequency of crashes. Higher percentage of commercial Land uses (LU) in high mixed LU are helpful for ensuring the safety of pedestrian and cyclists. This study findings will be supporting for implementing the BE based safety measures considering their combined effectiveness as well as the urban and rural characteristics of the area.

Authors	Muhammad Khattak, Universiteit Gent Hans De Backer, Universiteit Gent Pieter De Winne, Universiteit Gent Tom Brijs, Universiteit Hasselt Ali Pirdavani (ali.pirdavani@uhasselt.be), Hasselt University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-00755
Paper Title	Investigating the Impact of Road Cross-Section Elements on Crash Occurrence in Urban Areas
Abstract	Appropriate roadway cross-section design is critical due to its impact on safety, capacity, and function of the facility. While it is generally straightforward to assess this impact on capacity and function, it is not always easy for safety evaluation. Literature shows contradictory observations concerning the complex relationship between roadway cross-section elements and crashes, particularly in urban areas. Another important issue is the presence of on-street parking and their safety implications in urban areas. In the current study, safety performance functions were developed to investigate the impact of roadway cross-section elements and on-street parking on crash occurrence using negative binomial distribution framework. A database consisting of six-year crash records, traffic data, and road geometry of urban roads of Antwerp, Belgium was created for modeling. This paper reports how cross-section elements, on-street parking, and exposure contribute to crash occurrence in urban areas and discusses whether the results could be used to improve safety performance of road segments. The results indicated that the effects of number of lanes, segment length, and traffic volume on crash occurrence were significant while that for lane width was not. Parking variable (parking arrangement) was significantly related to "injury", and "injury & fatal" crashes. Roads with higher number of lanes experience more crashes than roads with fewer lanes. Roads with parking were more prone to injury & fatal crashes than no parking settings. To conclude, these findings showed that road cross-section elements and parking settings play an important role in crash occurrence on road segments in urban areas.

Authors	Moataz Bellah Ben Khedher, University of Science and Technology of Lille Dukgeun Yun (dkyun@kict.re.kr), Korea Institute of Civil Engineering and Building Technology (KICT)
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-00971
Paper Title	A Comparative Approach of Crash Frequency Modelling in Two Lane Rural Roads
Abstract	Road accidents are now one of the leading causes of death in the world. Investigating the underlying factors that contribute to increased risk of these accidents is an essential procedure to take effective countermeasures. In this study, we take a particular interest in two lane rural roads in South Korea. Six count data regression models were developed and evaluated for the goodness of fit. Traditionally, the evaluation is performed using information criterion such as Akaike Information Criterion. In this research, assessment of different models performances was carried using additional methods that include machine learning techniques, i.e. data splitting, and graphical tools, i.e. rootgrams. Based on the results of every evaluation technique, negative binomial hurdle model clearly outperformed all other regression models. Therefore, three variables were identified to have a significant impact on crash occurrence in two lane rural roads. These features are safety barrier, shoulder width and Annual Average Daily Traffic.

Authors	Seyedmirsajad Mokhtarimousavi (smokh005@fiu.edu), Florida International University Jason Anderson, Portland State University Mohammed Hadi, Florida International University Atorod Azizinamini, Florida International University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-03739
Paper Title	Hybrid Artificial Intelligence Models for Work Zone Crash Frequency Analysis at Bridge Locations
Abstract	Crash characteristics differ from location to location, as well as over time, along with varying features of participants at fault, environmental and geometrical conditions. Although the impact of work zone presence on crash frequency has been investigated in previous studies, the risk factors associated with work zone crash frequency at bridge locations are not fully understood. With this in mind, this study utilizes a Negative Binomial (NB) regression and a Support Vector Regression (SVR) models trained by Artificial Bee Colony (ABC) optimization algorithm for modeling work zone crash frequency. Incorporating three years of crash records from 2015-2017, road inventory data, bridge geometric and location specification, into a data-driven analysis, work zone crash frequency were investigated on a number of 60 bridge locations in Miami-Dade County. A sensitivity analysis was also conducted considering the black-box characteristic of the SVR and compared to the effects of variables indented through the NB modeling framework. The prediction performance of the developed models was evaluated by three commonly-used criteria including the coefficient of determination (R2), the Mean Absolute Deviation (MAD), the Mean Square Error (MSE), and the Root Mean Square Error (RMSE). The results demonstrated that the proposed SVR models predict work zone crash data more effectively and accurately than traditional NB models. In addition, bridge median type, law enforcement, horizontal curve, bridge surface width indicators were among the most important factors that affects the number of work zone related crashes on bridges.

Authors	Angela Kitali (akita002@fiu.edu), Florida International University Emmanuel Kidando, Cleveland State University Md Asif Raihan, Bangladesh University of Engineering and Technology Boniphace Kutela, Texas A&M Transportation Institute Priyanka Alluri, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-04403
Paper Title	Exploring A Need to Model Two- and Multiple-vehicle Crashes Separately
Abstract	Single-vehicle crashes have been shown to differ from two-plus vehicle crashes. Several studies have discussed the issues with modeling single- and two-plus vehicle crashes together. However, none of the empirical studies have attempted to study two-vehicle (2V), and multiple-vehicle (MV), i.e., three-plus, crash groups to understand their correlation and influencing factors. This study first investigates whether there is a need to develop separate safety performance functions for 2V and MV crashes, in addition to single-vehicle crashes. Then, the correlation and influencing factors of 2V and MV are evaluated. Three regression models – a correlated bivariate negative binomial regression (BNR) model, an uncorrelated bivariate negative binomial regression (NR) models, and a univariate negative binomial regression (UNR) model, are fitted and compared. The analysis is based on the 2011-2015 crash data that occurred on I-4 in Florida. Findings indicate that the BNR model significantly outperformed the NR and the UNR models. The model results suggest that disaggregating these crashes while allowing correlation between the groups for the latent effects in the model best describes the data. Traffic volume, posted speed limit, and median type were found significant in contributing to the occurrence of both 2V and MV crashes. Additional contributing factors included the presence of interchange influence area for 2V crashes and the presence of a vertical curve and the presence of a horizontal curve for MV crashes. Study findings could assist transportation officials implement specific safety countermeasures for road segments that are identified as hotspots for 2V and MV crashes.

5 Crash Severity Prediction

Alfonso Montella, Filomena Mauriello, and Maria Rella Riccardi
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-five papers** dealing with crash severity prediction. The number of papers dealing with crash severity prediction is increasing over time and the number of paper addressing this topic remains still high also in 2021 (19 in 2012, 25 in 2013, 16 in 2014, 29 in 2015, 24 in 2016, 41 in 2017, 40 in 2018, 52 in 2019, 53 in 2020, and 45 in 2021), highliting how this issue is becoming important for the scientific community. Great emphasis is given to serious injuries crashes also at political level. The EU set the target of halving the number of serious injuries in the EU by 2030 from the 2020 baseline using a common definition based on the MAIS 3+ trauma scale.

The papers are scattered across various sessions, with most papers presented at the poster sessions: 1169 Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Tuesday, January 26 11:30 AM – 1:00 PM ET), 1249 Truck and Bus Safety Research (Tuesday, January 26 4:00 PM – 5:30 PM ET), 1304 Transportation Safety Management Systems from Start to Finish (Wednesday, January 27 2:30 PM – 4:00 PM ET), and 1327 Safety Performance and Analysis, Act 4: Methods and Models (Wednesday, January 27 4:00 PM – 5:30 PM ET).

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:

- Binary Logit model (21-00120, 21-00658, 21-02300);
- Multinomial Logit model (MNL) (21-00151, 21-00463, 21-02126, 21-02213);
- Multinomial Probit model (MNP) (21-02126);
- Nested Multinomial Logit model (NMNL) (21-02126);
- Random parameters binary Logit model with Heterogeneity in Means (21-02531);
- Random parameters (mixed) Logit model (21-00151, 21-00357, 21-02126, 21-02503, 21-02553, 21-02932);
- Random parameters (mixed) Logit model with heterogeneity in means and variances (21-00534);
- Generalized Logistic Regression model (21-00950);

- Geographically and Temporally Weighted Regression (GTWR) (21-00151);
- Bayesian Logistic Regression model (BLR) (21-03591);
- Bayesian mixed Logit model (21-03641);
- Hierarchical Bayesian Logistic Regression model (21-00044, 21-04444);
- Hybrid latent segmentation-based random parameters Logit (LSRPL) model (21-03310), and
- Recursive Bivariate Probit (RBP) (21-02758).

The following **ordered regression modelling approaches** were used:

- Ordered Logit model (21-02213, 21-03462);
- Ordered Probit model (21-00151);
- Heteroskedastic Ordered Probit (HOP) model (21-00955);
- Random parameters (mixed) Ordered Logit model with Heterogeneity in Means and Variances (21-03928);
- Random parameters (mixed) Ordered Probit model (21-00388, 21-01444, 21-03621);
- Random parameters (mixed) Ordered Probit model with Heterogeneity in Means (21-01432);
- Correlated Random parameters (mixed) Ordered Probit model (21-01376);
- Random parameters hierarchical Ordered Probit model (21-00137);
- Latent Segmentation-based Ordered Logit (LSOL) model (21-00934);
- Partial Proportional Odds (PPO) Logit model (21-02213, 21-03669);
- Generalized Ordered Logit model (21-02552);
- Geographically-Temporally Weighted Ordered Logistic Regression (GTWOLR) (21-00399), and
- Uncorrelated Random parameters (mixed) Ordered Probit model with (21-01376).

Some papers used **data mining techniques**, such as:

- Adaboost (21-01415);
- Association Rule Analysis (21-04421);
- Bayesian Network Approach (21-03456, 21-04058);
- Cluster Analysis (21-00061, 21-01782);
- Crash Tree Analysis (21-01428, 21-03591);
- Decision Tree (DT) (21-00754, 21-01584);
- Extremely Randomized Trees (ET) (21-01415);
- Gaussian Naïve Bayes (GNB) (21-03591)
- Gradient Boosting Machine (GBM) (21-03591);
- Gradient Boosting Decision Tree (GBDT) (21-01415);
- K-Nearest Neighbor (KNN) (21-03591);
- Latent Class Analysis clustering method (21-00826);
- Multilayer Perceptron (MLP) (21-00754);

- Random Forest (21-00220, 21-01415, 21-01584, 21-02300, 21-03591);
- Structure Equation Models (SEM) (21-00754);
- Support Vector Machine (SMV) (21-00754), and
- XGBoost model (21-03397).

One paper used a zero-inflated negative binomial model (21-00299) to investigate injury severity on local roads. Another paper used linear regressions and t-tests (21-00491) to explore the strength and statistical significance of trends regarding pedestrian fatalities, serious injuries, and minor injuries. Another paper used a Negative binomial model and a Heteroskedastic Ordered Probit (HOP) (21-00955) to map pedestrian crashes and investigate their injury severity.

One paper applied Categorical Principal Components Analysis (CATPCA) (21-04213) to understand the structure of a set of variables and to reduce the dataset dimensionality to a predefined number of dimensions and components affecting pedestrians' crash likelihood and injury severity. Another paper used Taxicab Correspondence Analysis (TCA) (21-01776) to identify several factors related to rail grade crossing fatal crashes.

Another paper employed random forest based binomial logit regression with a comparative variance inflation factor-based regression (21-02300) to assess risk factors significantly associated with injury involved crashes in freeway tunnels. Another paper used buffer analysis (21-03669) to identify potential factors influencing truck crash injury severity.

One paper used a combination of Multinomial Logit (MNL) and Latent Class Analysis (LCA) (21-00463) to identify distinct classes of events, each of which had distinct factors that influenced ROR crash severity. Another paper used the correlated random parameters ordinal probit model and the uncorrelated random parameters ordinal probit model with interaction effects (21-01376) to assess the injury severity risks of two-lane highway crashes. Another paper used logistic regression model (21-02846) to evaluate the likelihood of a severe pedestrian injury whereas another one employed a regression discontinuity design analysis (21-01593) to investigate the impact of Daylight Savings Time Transitions on the total average road casualty and fatal casualty.

One paper developed the marginal probability density functions of various exogenous and endogenous variables (21-00219) to investigate the combined effects of various driving conditions on work-zone crash severity.

One paper used the Latent Class Analysis clustering method (21-00826) to cluster crash collisions into a set of clusters, in which the different factors impact pedestrian collision severity in a similar manner and then, the Poisson-Lognormal model was developed to assess the impact of each explanatory variable on pedestrian fatalities and injuries in each cluster.

One paper used XGBoost model and SHAP technique (21-03397) to extract associations of several variables with pedestrian time-to-death.

One paper used an integrated spatiotemporal analytical approach (21-00061) to mine comprehensive statewide 20 years' motorcycle-involved traffic crashes.

One paper used a wealth-inclusive crash prediction model (21-01517) to determine the effect of wealth on total, fatal and injury, and pedestrian crash frequencies.

One paper used different natural language processing (NLP) tools (e.g., text mining, topic modelling) and Cluster Analysis (21-03150) to gain injury level specific insights.

One paper conducted Chis-square analyses (21-03851) to determine the relationship between adult vehicle occupant's seatbelt use, vehicle type and age, and injury severity.

From an **application point of view**, the papers addressed:

- Environmental factors (21-00044, 21-00120, 21-00219, 21-00220, 21-00357, 21-00491, 21-00534, 21-00754, 21-00819, 21-00826, 21-00950, 21-00955, 21-01376, 21-01428, 21-01432, 21-01444, 21-01584, 21-01776, 21-02126, 21-02213, 21-02300, 21-02503, 21-02531, 21-02553, 21-02758, 21-02846, 21-02932, 21-03150, 21-03310, 21-03397, 21-03591, 21-03621, 21-03641, 21-03669, 21-03928, 21-04213, 21-04421, 21-04444);
- Highway characteristics (21-00044, 21-00120, 21-00137, 21-00220, 21-00299, 21-00357, 21-00388, 21-00534, 21-00754, 21-00819, 21-00934, 21-00950, 21-00955, 21-01415, 21-01428, 21-01432, 21-01444, 21-01517, 21-01584, 21-01776, 21-02126, 21-02300, 21-02503, 21-02552, 21-02758, 21-02846, 21-02932, 21-03150, 21-03310, 21-03397, 21-03456, 21-03462, 21-03591, 21-03621, 21-03641, 21-03928, 21-04213, 21-04444);
- Road users' characteristics and behaviour (21-00044, 21-00061, 21-00137, 21-00151. 21-00219, 21-00220, 21-00357, 21-00388, 21-00399, 21-00463, 21-00534, 21-00658, 21-00819, 21-00826, 21-00934, 21-00950, 21-00955, 21-01376, 21-01428, 21-01432, 21-01444, 21-01517, 21-01584, 21-02213, 21-02300, 21-02503, 21-02531, 21-02552, 21-02553, 21-02758, 21-02846, 21-02932, 21-03150, 21-03310, 21-03397, 21-03462, 21-03625, 21-03669, 21-03851, 21-03928, 21-04058, 21-04213, 21-04421, 21-04444);
- Roadside features (21-00388, 21-00463, 21-00955, 21-01415, 21-01444, 21-02758,);
- Traffic control devices (21-00120, 21-00137, 21-00819, 21-00955, 21-01428, 21-02531, 21-02758, 21-03150, 21-03397, 21-03456, 21-03928);
- Traffic characteristics (21-00934, 21-00955, 21-01428, 21-01444, 21-01517, 21-02846, 21-02932, 21-03591, 21-03928, 21-04421, 21-04444);
- Vehicle characteristics (21-00044, 21-00061, 21-00120, 21-00137, 21-00357, 21-00819, 21-00955, 21-01376, 21-01444, 21-02213, 21-02300, 21-02553, 21-03150, 21-03310, 21-03669, 21-03851, 21-03928, 21-04213); and
- Workzone characteristics (21-00219, 21-00220, 21-01584, 21-02552).

Nineteen papers investigated **vulnerable road users**, such as:

- Cyclists (21-01432);
- Motorcyclits (21-00061, 21-01376, 21-02553, 21-02758, 21-03150); and
- Pedestrians (21-00491, 21-00819, 21-00826, 21-00934, 21-00950, 21-00955, 21-01517, 21-01584, 21-02213, 21-02846, 21-03397, 21-04058, 21-04213).

Below, for each of the forty-five papers involving crash severity prediction, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract. Papers are ordered according their ID number.

Authors	Muhammad Tahmidul Haq, University of Wyoming Milan Zlatkovic (mzlatkov@uwyo.edu), University of Wyoming Khaled Ksaibati, University of Wyoming
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-00044
Paper Title	Investigating Commercial Truck Driver Injury Severity based on Unsafe Driving Actions on a Mountainous Freeway: A Hierarchical Bayesian Random Intercept Approach
Abstract	Disaggregate modeling approach is a new trend in the literature to analyze the injury severity of truck-involved crashes. The assessment of truck driver injury severity based on driver action is still missing in the literature. This paper presents an extensive exploratory analysis that highlights significant variability in the truck driver injury severity based on various action types (i.e. aggressive driving, failure to keep proper lane, driving too fast, and no improper driving). Binary logistic regression with the Bayesian random intercept approach was developed to examine the contributing factors to fatal or any injuries of the truck drivers using ten years (2007-2016) of historical crash data in Wyoming. The log-likelihood ratio tests were performed to justify that separate models by various driving action types are warranted. The results demonstrated the effects of various vehicle, driver, crash, and roadway characteristics, combined with truck driver-specific action, on the corresponding driver injury severity. The gross vehicle weight (GVW), age and gender of the driver, time of day, lighting condition, and the presence of junctions were found to have significantly different impacts on the truck driver injury severity in various driving action related crashes. With the incorporation of the random intercept in the modeling procedure, the analysis found a strong presence (27% – 33%) of intra-crash correlation in driver injury severity within the same crash. Finally, based on the findings of this study, several recommendations are suggested.

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Jun Liu, University of Alabama Zihe Zhang, University of Alabama Allen Parrish, Alabama Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00061
Paper Title	A Spatiotemporal Analysis of Motorcyclist Injury Severity: Implications from 20 Years' Traffic Crashes in Pennsylvania
Abstract	Motorcyclists face higher risks of severe injuries in crashes compared to motor vehicle drivers who are often protected by seatbelts and airbags during collisions. A report by the National Highway Traffic Safety Administration reveals that motorcyclists have 27 times the risk of fatality in traffic crashes relative to motor vehicle drivers. Previous studies have identified a list of risk factors associated with motorcyclist injury severity and generated valuable insights for countermeasures protecting motorcyclists in crashes. These studies have shown that wearing helmets, motorcycle-specific reflective clothing and boots, alcohol/drug-free driving, obeying traffic regulations are good practices for safe motorcycling. However, these practices and other risk factors are likely to interact with local geographic, socio-economic, and cultural contexts, leading to diversified correlations with motorcyclist injury severity, which remains under-explored. Such correlations may exhibit variations across space and time. The objective of this study is to revisit the correlates of motorcyclist injury severity with a focus on the spatial and temporal variations of correlations between risk factors and injury severity. This study employed an integrated spatiotemporal analytical approach to mine comprehensive statewide 20 years' motorcycle-involved traffic crashes (N=50,823) in Pennsylvania. Non-stationarity tests were performed to examine the significance of variations in spatially and temporally local correlations. The results show that most factors such as helmet, engine size, vehicle life, pillion passenger, at-fault striking, and speeding hold significant non-stationary relationships with motorcyclist injury severity. Furthermore, cluster analysis of estimations reveals the regional similarities of correlates, which may help practitioners develop regional motorcyclist safety countermeasures.

Authors	Fanyu Meng (fymeng91@gmail.com), Southern University Zhou Zichu, Tongji University Nang-Ngai Sze, Hong Kong Polytechnic University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-00120
Paper Title	Revisiting crash injury severity in freeway tunnels: a comparative study in guizhou, china
Abstract	With the rapid development of transportation infrastructures in precipitous areas, the mileage of freeway tunnels in China has been mounting during the past decade. Provided the semi-constrained space and the monotonous driving environment of freeway tunnels, safety concerns still remain. This study aims to investigate the uniqueness of the relationships between crash severity in freeway tunnels and various contributory factors. The information of 10,081 crashes in the entire freeway network of Guizhou Province, China in 2018 is adopted, from which a subset of 591 crashes in tunnels is extracted. To address spatial variations across various road segments, a two-level binary logistic approach is applied to model crash severity in freeway tunnels. A similar model is also established for crash severity on general freeways as a benchmark. The uniqueness of crash severity in tunnels mainly includes three aspects: (1) the road-segment-level effects are quantifiable with the environmental factors for crash severity in tunnels, but only exist in the random effects for general freeways; (2) tunnel has a significantly higher propensity to cause severe injury in a crash than other locations of a freeway; and (3) different influential factors and levels of contributions are found to crash severity in tunnels compared with on general freeways. Factors including speed limit, tunnel length, truck involvement, rear-end crash, rainy and foggy weather and sequential crash have positive contributions to crash severity in freeway tunnels. Policy implications for traffic control and management are advised to improve traffic safety level in freeway tunnels.

Authors	Ehsan Rahimi (erahim4@uic.edu), University of Illinois, Chicago Ali Shamshiripour, University of Illinois, Chicago Amir Samimi, Sharif University of Technology Abolfazl Mohammadian, University of Illinois, Chicago
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-00137
Paper Title	Analyzing the Severity of Truck Crashes Using a Random-Thresholds Random-Parameters Hierarchical Ordered Probit Approach
Abstract	Trucking plays a vital role in economic development in every country, especially countries where it serves as the backbone of the economy. The fast growth of economy in Iran as a developing country has also been accompanied by an alarming situation in terms of fatalities in truck-involved crashes, among the drivers and passengers of the trucks as well as the other vehicles involved. Despite the sizable efforts to investigate the truck-involved crashes, very little is known about the safety of truck movements in developing countries, and about the single-truck crashes worldwide. Thus, this study aims to uncover significant factors associated with injury severities sustained by truck drivers in single-vehicle truck crashes in Iran. The explanatory factors tested in the models include the characteristics of drivers, vehicles, and roadways. A random threshold random parameters hierarchical ordered probit model is utilized to consider heterogeneity across observations. Several variables turned out to be significant in the model, including driver's education, advanced braking system deployment, presence of curves on roadways, and high speed-limit.

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Jun Liu, University of Alabama
Sponsoring Committee	Standing Committee on Traffic Law Enforcement (ACS30)
Session Number	1390
Session Title	Enforcement Design, Safety, and Reportingaffic Control Devices and Work Zones 2021
Paper Number	21-00151
Paper Title	Spatio-temporal Instability in Injury Severity Analysis of Red-light Running Crashes at Signalized Intersections
Abstract	Red-light running (RLR) at signalized intersections remains a traffic safety challenge. Besides implementing countermeasures (e.g., red-light enforcement cameras) that prevent RLR occurrence, researchers and practitioners also undertake efforts to reduce injury severity in RLR crashes given the fact that RLR crashes are potentially more severe than other traffic crashes. Studies have identified many contributing factors associated with RLR crash injury severity such as driving under influence (DUI) and distracted driving. Traffic crashes often interact with local geographic contexts; therefore, spatial and temporal instability may exist in correlations between these factors and RLR crash severity, which was under-explored in literature. The objective of this study is to revisit the contributing factors to RLR crash severity with a focus on the spatial-temporal instability of correlates. This study leverages the powerful computational tools and comprehensive statewide crash data for spatiotemporal modeling. Specifically, an integrated Geographically and Temporally Weighted Regression (GTWR) is employed in this study to model over 30,000 RLR crashes in Georgia from 2013 to 2018. This modeling technique involves a non-stationarity test to examine whether the correlates of RLR crash severity vary substantially across space and time. Modeling results confirmed some factors (e.g., DUI) are related to increased RLR crash severity. More importantly, GTWR modeling results reveal some factors (including DUI) exhibit strong spatio-temporally instable correlations with RLR crash severity. These findings are valuable for decision-makers and practitioners to develop regional strategies considering the spatio-temporal trends in improving traffic safety at signalized intersections. More implications are discussed in the paper.

Authors	Seyed Hooman Ghasemi (hooman.ghasemi@auburn.edu), Washington State University Ji Yun Lee, Washington State University Mohammad Jalayer, Rowan University Parisa Hosseini, Rowan University Pooyan Khajehshahzanian, Amirkabir University of Technology
Sponsoring Committee	Standing Committee on Traffic Control Devices (ACP55)
Session Number	1294
Session Title	Traffic Control Devices and Work Zones 2021
Paper Number	21-00219
Paper Title	Work-Zone Crash Severity Analysis: Development and Use of the Joint Distribution of Crash-Related Variables
Abstract	Over the past few decades, work-zone crashes have been perceived as one of the pivotal concerns in improving roadway safety. Each year, traffic accidents in construction and maintenance zones result in hundreds of fatalities and thousands of injuries, and accordingly, many studies have investigated the statistical properties of work-zone crashes as part of efforts to reduce the numbers of fatalities and injuries. The primary goal of this study is to investigate the combined effects of various driving conditions on work-zone crash severity so that maximum speed in construction zone can be adjusted to meet the pre-defined safety. To this end, the paper first filters and clusters work-zone crash data and develops the marginal probability density functions of various exogenous and endogenous variables. In this study, vehicle speed and driving conditions (e.g., road surface, light and weather conditions) are identified as the key independent variables in crash severity analysis. Finally, the distributions of total work-zone crash cost conditioned on vehicle speed and various driving conditions are developed to specify the allowable speed limit of vehicles with the goal of reducing the crash costs. The proposed cost-based crash severity analysis can be further utilized in an online speed limit system considering various driving conditions.

Authors	Huthaifa Ashqar (hiashqar@vt.edu), Virginia Polytechnic Institute and State University Qadri Shaheen, Eastern Michigan University Suleiman Ashur, Eastern Michigan University Hesham Rakha, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Traffic Control Devices (ACP55)
Session Number	1294
Session Title	Traffic Control Devices and Work Zones 2021
Paper Number	21-00220
Paper Title	Impact of risk factors on work zone crashes using logistic models and Random Forest
Abstract	Work zone safety is influenced by many risk factors. Consequently, a comprehensive knowledge of the risk factors identified from crash data analysis becomes critical in reducing risk levels and preventing severe crashes in work zones. This study focuses on the 2016 severe crashes that occurred in the State of Michigan (USA) in work zones along highway I-94. The study identified the risk factors from a wide range of crash variables characterizing environmental, driver, crash and road-related variables. The impact of these risk factors on crash severity was investigated using frequency analyses, logistic regression statistics, and a machine learning Random Forest (RF) algorithm. It is anticipated that the findings of this study will help traffic engineers and departments of transportation in developing work zone countermeasures to improve safety and reduce the crash risk. It was found that some of these factors could be overlooked when designing and devising work zone traffic control plans. Results indicate, for example, the need for appropriate traffic control mechanisms such as harmonizing the speed of vehicles before approaching work zones, the need to provide illumination at specific locations of the work zone, and the need to establish frequent public education programs, flyers, and ads targeting high-risk driver groups. Moreover, the Random Forest algorithm was found to be efficient, promising, and recommended in crash data analysis, specifically, when the data sample size is small.

Authors	Qinglin Hu (qhu10@ua.edu), University of Alabama Xiaobing Li, University of Alabama Jun Liu, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00299
Paper Title	A Low-Cost Approach to Identify Hazard Curvature for Local Road Networks Using Open-Source Data
Abstract	Vehicle crashes are a leading cause of death in the United States. Among those crashes, curvature in local roadway was identified as one of the most significant factors correlated with fatal crashes. Given the large number of local roads and their relatively lower traffic compared with interstates or freeways, most local roads may not receive priorities in the first phase of highway upgrades. However, critical locations, e.g., sharp curves (vertical and/or horizontal), in the network that may be a deadly threat for both new advanced autonomous vehicles and conventional vehicles. In addition, Identifying local roadway curvatures exists various uncertainty by most authorities, such as high budget and lack of data. To fill this gap, this study offers a low-cost approach to constructing three-Dimensional geometric profiles for local roads in a relatively large study area using open-source data. With the profiles, critical road segments, including extreme horizontal and vertical curves and their combinations, can be identified. Our study redefined the local road segments into 20 sub-categories based on the calculated vertical grades and curve radius that were incorporated into a zero-inflated native binomial model. Model results showed that grades or curves were associated with decreased crash frequency compared with straight and flat roads. However, segments with larger horizontal curve radius and low grades were found to associate with increased crash frequency. More implications are discussed in the paper.

Authors	Nabeel Al-Bdairi (nsaleem@uowasit.edu.iq), University of Wasit Jason Anderson, Portland State University Salvador Hernandez, Oregon State University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-00357
Paper Title	Injury Severity Analysis of Drivers of Large Trucks at Unsignilized Intersections
Abstract	Although there has been a growing interest in comprehending large-truck crash severity in recent years, what is still not completely understood is the relationship between crash-related factors, injury severity, and unsignalized intersections. Therefore, this research seeks to discuss these relationships and fill a critical gap in the large-truck crash injury severity literature. In this study, a mixed logit model is used to capture the effects of contributing factors on injury severity of large-truck drivers at unsignalized intersections while accounting for unobserved factors (i.e., unobserved heterogeneity). The data used in this study are large-truck-involved crashes that occurred at unsignalized intersections between 2007 and 2013 in the state of Washington. Injury severity sustained by truck drivers are categorized into three categories: severe injury (fatal and incapacitating), minor injury (non-incapacitating and possible injury), and no injury. The results reveal that three parameter estimates, namely, wet roadway surfaces, left turning movements, and drivers who were sober at the time of the crash, are randomly and normally distributed. Moreover, 18 estimated parameters are found to be fixed across observations (i.e., fixed value of the estimated parameter in the mixed logit model). Among these parameters, overcast (i.e., cloudy) weather, driver sobriety, and no restraining systems in vehicles are associated with severe injury, and crashes that occurred in daylight conditions increase the probability of no injury. Results of this study provide a flexible framework to overcome the inherent shortcomings in crash data that lead to biased model estimates and erroneous corresponding inferences by accounting for unobserved heterogeneity.

Authors	James Smith, Western Kentucky University Mehdi Hosseinpour, Western Kentucky University Ryan Mains, Western Kentucky University Nathanael Hummel, Western Kentucky University Kirolos Haleem (kirolos60@hotmail.com), Western Kentucky University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-00388
Paper Title	Investigating Head-On Crash Severity Involving Commercial Motor Vehicles in Kentucky
Abstract	This study takes the initiative and examines various features affecting the severity associated with commercial motor vehicle "CMV" (i.e., large truck and bus) head-on collisions on Kentucky highways. Recent five-year (2015-2019) crash data and variables rarely-explored before (e.g., presence of centerline rumble strips, type of passing zone, and terrain type) were collected and prepared using Google Maps. A total of 378 CMV-related head-on collisions were analyzed. The generalized ordered probit (GOP) model was employed to identify the significant factors affecting the severity level resulting from CMV head-on collisions. The model allows the coefficients to vary across the injury severity categories for reliable parameter estimations. From the preliminary investigation, rolling terrains had the highest share of severe CMV head-on crashes (62% and 71% for multilane and two-lane roadways, respectively). The presence of centerline rumble strips could reduce severe crash outcomes along multilane and two-lane facilities. The GOP model identified various significant predictors of minor and severe injuries from CMV head-on crashes. Occupants wearing seatbelt were 39.3% less likely to sustain severe head-on crash injuries. From the roadway characteristics, presence of median cable and concrete barriers could significantly reduce the probability of severe head-on crash injuries, with median cables being more effective. Regarding the driver characteristics, drug impairment and speeding increased the risk of sustaining fatal/serious injuries by 39.5% and 26.4%, respectively. Necessary safety recommendations are proposed to reduce the severity of CMV head-on-related collisions. One example is installing median cable barriers along roadway stretches with high history of head-on CMV-related crashes.

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Jun Liu, University of Alabama Qifan Nie, University of Alabama Xing Fu, University of Alabama Shashi Nambisan, University of Nevada, Las Vegas Asad J. Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-00399
Paper Title	The Role of Truckers' Behaviors in Traffic Crashes: An Integrated Spatio-temporal Injury Severity Analysis
Abstract	Truck drivers face many dangers on roadways. Truck-involved traffic crashes may not only threaten the lives of truck drivers but also greatly affect the trucking industry which currently faces a massive truck driver shortage. To improve truck driver safety, studies have been focused on understanding the roles of truck driver behaviors prior to traffic crashes, called pre-crash trucker behaviors. These studies attempted to uncover relationships between pre-crash trucker behaviors and crash severities through modeling traffic crash data. Traffic crashes exhibit complex spatial and temporal patterns interacting with diversified socio-economic, cultural, and geographic contexts, which have not been fully captured in previous studies. The objective of this study is to revisit the roles of pre-crash truck driver behaviors with a focus of examining the spatiotemporal variations in relationships between the behaviors and injury severities. This study employed an integrated spatial-temporal modeling approach, namely the Geographically-Temporally Weighted Ordered Logistic Regression (GTWOLR), to model a Pennsylvania statewide crash database with over 56,000 truck-involved crashes. The results indicate some risk behaviors such as speeding, driving under influence, non-restraint, and cellphone usage were associated with an increased truck driver injury severity. In the spatiotemporal variations, some freight routes or time periods are highlighted for particular behaviors due to the extra high estimation magnitudes, such as I-76 near Pittsburg and the years after 2013 for speeding. The findings are useful for practitioners in developing localized safety improvement programs. More implications are discussed in the paper.

Authors	Shiyi Liu (sl9hm@virginia.edu), University of Virginia Tianyang Han, University of Tokyo Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-00463
Paper Title	Modeling the Severity of Rural Run-Off-Road Crashes with Latent Class Analysis: Accounting for Differences in Driver Behavior
Abstract	Run-off-road (ROR) crashes represent the majority of fatalities on rural roadways. Identifying factors contributing to ROR crashes and their influence on injury severity has been a significant focus of past studies. Typically, past studies of ROR crashes have assumed that crashes are the outcomes of a variety of factors related to roadway design, traffic operations, pavement conditions, and environmental characteristics, while driver behavior factors have often been neglected. In this study, driver behavior is examined using 7 crash report fields pertaining to the driver: improper actions, driving speed, defects, distraction, safety equipment deployment, and alcohol/drug usage. Considering both conventional factors used in previous studies and driver behavior factors, the crash severity of ROR crashes are modeled. After comparing various modeling techniques, a combination of Multinomial Logit (MNL) and Latent Class Analysis (LCA) are employed in this study. The crash data from rural areas of Virginia from 2019 are utilized for model development. The MNL model estimations show the significance of the driver behavior impact on ROR severity. Results also show that the combined LCA and MNL models can effectively discover the underlying patterns behind crash data that are not apparent from the MNL model developed using the entire dataset. The LC-MNL model identified two distinct classes of events, each of which had distinct factors that influenced crash severity. The findings from these classes and their implications for countermeasure selection are discussed.

Authors	Nick Ferenchak (ferenchak@unm.edu), University of New Mexico Risa Gutierrez, University of New Mexico Patrick Singleton, Utah State University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-00491
Paper Title	The Role of Lighting Condition Across the Pedestrian Injury Severity Spectrum
Abstract	Pedestrian fatalities in the United States increased 53% from 2009 to 2018. 89% of those additional fatalities occurred in the dark. Have similar increases occurred across the pedestrian injury severity spectrum? Has lighting condition had a similarly strong relationship with those outcomes? We analyzed pedestrian fatalities, serious injuries, and minor injuries that occurred in Pennsylvania from 1999 to 2018 using linear regressions and t-tests to explore the strength and statistical significance of trends. Findings suggest that all pedestrian injury severities have experienced increases over the last decade, although increases were sharper for less severe injuries. For each severity level, pedestrian crashes increased faster at night than during the day. However, this difference in trend is most noticeable for pedestrian fatalities – deaths are increasing in the dark but not in daylight conditions – whereas dark and daylight pedestrian injuries are increasing at more similar (and larger) rates. A pedestrian injured in the dark is 2.5 times more likely to be killed than a pedestrian injured during the day. Morbidity and mortality outcomes have gotten worse, with injured pedestrians now less likely to be minorly injured and more likely to be seriously or – in the dark – fatally injured. A lack of street lighting does not seem to be the cause of the disproportionate increase in pedestrian injuries at night, since collisions of all severity levels with a street light increased at higher rates than those without a street light.

Authors	Miao Yu (fishmiaof@163.com), Hohai University Changxi Ma, Lanzhou Jiaotong University Jinxin Shen, Hohai University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-00534
Paper Title	Factors Affecting Driver Injury Severity in The Wrong-Way Crash: Accounting for Potential Heterogeneity in Means and Variances of Random Parameters
Abstract	Due to the high percentage of fatalities and severe injuries in the wrong-way driving (WWD) crashes, numerous studies have focused on identifying contributing factors to the occurrences of WWD crashes. However, a limited number of research efforts investigated the factors associated with the driver injury-severity in WWD crashes. This study intends to bridge the gap using a random parameter logit model with heterogeneity in means and variances approach that can account for the unobserved heterogeneity in the dataset. Police-reported crash data collected from 2014-2017 in North Carolina is used. Three injury severity levels are defined: severe injury, minor injury, and no injury. Explanatory variables, including driver characteristics, roadway characteristics, environmental characteristics, and crash characteristics, are used. Estimation results demonstrate that factors, including the involvement of alcohol, minor arterial, principal arterial, rear-end collision, cross centerline collision, and head-on collision, significantly increase the severity levels in WWD crashes. Several policy implications are designed and recommended based on findings.

Authors	Shraddha Sagar (shraddha.sagar@greshamsmith.com), Gresham Smith and Partners Nick Stamatiadis, Kentucky Transportation Center Arnold Stromberg, University of Kentucky
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00658
Paper Title	Effect of Socioeconomic and Demographic Factors on Crash Occurrence
Abstract	Road traffic crashes are a leading cause of death in the United States. In Kentucky, per capita crash rates and crash-related fatalities have outpaced the national average for over a decade. Researchers have argued that the region's unique socioeconomic conditions provide a compelling explanation for these trends. This study examined the relationship between highway safety and socioeconomic characteristics using crash data from Kentucky. This research sought to identify at-risk drivers based on the socioeconomic and demographic attributes of their residence zip codes. Using the quasi-induced exposure approach, binary logistic regression was used to predict the probability of be the at-fault driver in a single- and two-unit crashes based on socioeconomic characteristics of their residence zip code. Statistical analysis found that variables such as income, education level, poverty level, employment, age, gender, rurality, and number of traffic-related convictions of a driver's zip code influence the likelihood of their being at fault in a crash, while educational attainment is observed to have an impact only on single-unit crash occurrence. Finally, it is concluded that younger and older drivers residing in zip codes with low socioeconomic conditions have a higher likelihood of causing a crash for both single- and two-unit crashes. This finding can be used to identify zip codes or groups of drivers with higher likelihood to be involved in crashes and develop targeted and efficient safety programs.

Authors	Xiaoyan Shen, Chang'an University Shanshan Wei (weishan1995@foxmail.com), Chang'an University Yuqing Feng, Chang'an University Fan Zhang, Chang'an University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-00754
Paper Title	Risk Analysis of Road Transport Accidents of Hazardous Materials by Machine Learning
Abstract	The safe movement of hazardous materials is receiving increasing attention because various sudden and devastating hazardous material accidents have resulted in substantial injury to humans, damage to property and environmental pollution. The aim of this paper is to explore a suitable method for analyzing road transport accidents involving hazardous materials and to study the main risk factors for accidents of different severities (property damage only (PDO), injury (INJ) and fatality (FAT)). Initially, we assessed three classification algorithms, i.e., decision tree C5.0 (C5.0), support vector machine (SVM) and multilayer perceptron (MLP), using a hazardous material transportation accident dataset. The results reveal that the predictions of C5.0 algorithms are superior to those of SVM and MLP. Hence, C5.0 algorithm was applied to extract the probable risk factors and associations between these factors and 3 different severities of hazardous material transportation accidents. The results showed that direct accident form (DAF), indirect accident form (IAF), and road section (RS) all have significant effects on accidents involving only property damage.Direct accident form (DAF), indirect accident form (IAF), road type (RT), road segment (RS) and time (TIME) all have a substantial effect on injury accidents. Direct accident form (DAF), indirect accident form (IAF), hazardous material type (HMT) and road surface condition (SC) are important factors in the occurrence of fatal accidents. The above results provide a theoretical basis for discussing safety problems in hazardous materials transport activities and offer valuable suggestions for measures to reduce the severity of accidents.

Authors	Zade Koch (zadekoch@mit.edu), Massachusetts Institute of Technology Jinhua Zhao, Massachusetts Institute of Technology (MIT) Sirisha Rangavajhala, Charles Stark Draper Laboratory Inc Peter Miraglia, Charles Stark Draper Laboratory Inc
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-00819
Paper Title	A Comparison of Pedestrian Injury Severity Crash Factors at Intersections and Non-Intersection Locations
Abstract	Despite the frequent application of data-mining techniques to pedestrian injury severity analysis, few studies have compared the magnitude of injury severity factors between crash location types. In this study, the magnitude of pedestrian injury factors are compared between intersections and non-intersection locations. Data was taken from NHTSA's 2016-2018 Crash Report Sampling System (CRSS) database, containing a nationwide sample of vehicle-pedestrian crashes. Two logit models were created using 7 independent variables: weather, lighting condition, speed limit, speeding violation, vehicle body type, driver impairment, and pedestrian age. One model was fit to 4,828 injured pedestrians at intersections. The other model was fit to 4,663 injured pedestrians at non-intersection locations. The average marginal effect of each crash factor on the probability of severe injury was calculated for both models. The difference of marginal effects was examined to determine if the factors influencing injury severity vary in magnitude at intersection or non-intersection locations. The difference between the two location types for nearly all factors was not statistically significant. This suggests that the 7 independent variables influence injury severity similarly at both intersections and non-intersection locations. The lack of a statistically significant difference may be due to limitations in the data source and warrants further investigation.

Authors	Nazmul Arefin Khan, Dalhousie University Muhammad Habib (ahsan.habib@dal.ca), Dalhousie University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-00934
Paper Title	How Built Environment Characteristics of Pedestrian-Vehicle Collision Locations Affect Pedestrian Injury Severity Involving Distracted Driving?
Abstract	This study develops an injury severity model that demonstrates level of pedestrians' injury severity during pedestrian-vehicle collisions, specifically those involving distracted driving. It uses data from a police-reported collision database that contains pedestrian-vehicle collision information from 2007 to 2011 in Nova Scotia, Canada. A latent segmentation-based ordered logit (LSOL) model is developed in this paper that comprehensively examines the influence of built environment characteristics on pedestrian injury severity. It estimates a latent segment allocation model within LSOL modeling framework to capture unobserved heterogeneity across pedestrians. Two latent segments, high- and low-risk segments, are identified probabilistically based on pedestrian characteristics and action, driver action, and collision attributes. Results suggest that higher mixed land-use, transit stop density, length of sidewalk in the collision locations, and collisions occurring near schools yield lower pedestrian injury severity. In contrast, pedestrian-vehicle collisions in arterial roads, curved roads, sloped roads, and roundabouts tend to result in severe injuries. Interactions between distracted driving type and built environment characteristics are examined in this study. For example, using a communication device while driving on straight roads increases likelihood of higher pedestrian injury severity. This study also confirms the existence of heterogeneity across latent segments. For instance, higher percentage of people commuting by walking in the collision areas yield severe pedestrian injury in high-risk segments and lower injury severity in low-risk segments. The findings of this study will assist transportation planners and road safety stakeholders in developing effective and prioritized policies to reduce pedestrian injury severity involving distracted driving incidents.

Authors	Raju Thapa, Louisiana Department of Transportation and Development Julius Codjoe (Julius.Codjoe@la.gov), Louisiana Department of Transportation and Development Paul Kornyoh, Jacobs
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-00950
Paper Title	Investigating Factors Affecting Pedestrian Crash Severity at High Speed Urban Arterial Roadways: A Case Study of Louisiana
Abstract	Pedestrian fatalities on roadways is a key public safety concern, especially since overall trends point to higher fatalities for the period 2013 to 2017. In 2016, the state of Louisiana was ranked as the sixth worst state in pedestrian fatalities. Though previous studies have identified several factors contributing to severity of pedestrian crashes, none were found purposely modeled to address contributing factors on high-speed urban roadways. This study focused on identifying factors contributing to the severity of pedestrian crashes on high-speed urban arterials, using the state of Louisiana as a test case. A total of 1,337 crashes of different severity levels occurring on the defined roadways between 2013 to 2017 were extracted from the database. A generalized logistic regression model was developed to model a binary dependent variable, comprising combined severity levels A and B, against combined Levels C to E, as a factor of various independent variables. The result showed younger pedestrians less vulnerable to severe crashes compared to older pedestrians. The opposite was the case for younger drivers. Pedestrian actions, such as working on vehicle in road, playing, getting off from the vehicle, and standing alongside the roadway were found to be more dangerous. Distracted conditions of both pedestrians and drivers were found to result in mostly severe crashes. Presence of shoulder also affected the severity of crashes. Intersection crashes were found less fatal when compared to those at non-intersections. Crashes at dark were found to be more severe compared to day-time crashes.

Authors	Mashrur Rahman, University of Texas, Austin Kara M. Kockelman (kkockelm@mail.utexas.edu), University of Texas, Austin Kenneth Perrine, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-00955
Paper Title	Predicting Pedestrian Crash Occurrence And Injury Severity In Texas
Abstract	This study investigates pedestrian-involved crashes across Texas from 2010 through 2019. Crashes were mapped to over 708,738 road segments, along with road design, land use, transit, hospital, rainfall and other location features. Negative binomial model results show how total and fatal pedestrian-crash rates and counts rise with a segment's number of lanes, transit stops, population and job densities, as well as proximity to schools and hospitals, while greater median and shoulder widths provide some protection. Higher speed limits are associated with lower crash frequencies but more fatalities. A heteroskedastic ordered probit (HOP) model for injury severity demonstrates how pedestrian crashes are more likely to be severe and fatal at night (8 PM – 5 AM), without overhead lighting, and when the pedestrians or drivers are intoxicated. Use of light-duty trucks (including SUVs, pickup trucks, CUVs, and vans) also significantly increases the risk of pedestrians being severely injured or killed. While newer vehicle safety features may be argued to lower crash severity, newer crash-involved vehicles in Texas are not found to deliver less pedestrian injury. However, being a younger or female pedestrian, on a straight segment, off the state (and interstate) highway system, in the presence of a traffic control device (stop sign or signal) lowers the likelihood of pedestrian injury, when one does become involved in such a crash.

Authors	Ahmed Farid, University of Wyoming Anas Alrijjal, University of Wyoming Khaled Ksaibati (khaled@uwyo.edu), University of Wyoming
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-01376
Paper Title	Two-lane highway crash severities: correlated random parameters modeling versus incorporating interaction effects
Abstract	Two-lane highways represent the majority of highways in the U.S. and their safety is of a critical concern. Even though road safety researchers intensively evaluated two-lane highway safety, past studies were challenged by a methodological hindrance, namely that of correlated random parameters modeling methods. Random parameters models capture unobserved heterogeneity effects of crash contributing factors while correlated random parameters models offer the additional benefit of taking into account correlations among variables inducing such unobserved heterogeneity effects. However, correlated random parameters models do not permit excluding statistically insignificant variables describing cross-correlations among specific regressors. Therefore, in this research, both the correlated random parameters ordinal probit model and the uncorrelated random parameters ordinal probit model with interaction effects were compared, in terms of fit, when assessing the injury severity risks of two-lane highway crashes in Wyoming. With that, both models captured the combined effects of parameters. The results of this research indicated that the latter model exhibited a better fit. Furthermore, speeding, head-on collisions, sideswipe opposite-direction collisions, intersecting direction collisions, motorcycle involvement, impaired driving, distracted driving, the interaction effect of speeding with motorcycle involvement, that of head-on collisions with impaired driving and that of head-on collisions with commercial vehicle involvement all raised the likelihood of severe injuries. On the other hand, leaving the scene of the crash, proper seatbelt use, wet road surfaces and the interaction effect of impaired driving with motorcycle involvement were attributed to reduced severe injury risk. Mitigation measures were recommended based on this research's findings.

Authors	Yanyan Chen (cdyan@bjut.edu.cn), Beijing University of Technology Yuntong Zhou, Beijing University of Technology Jianming Ma, Texas Department of Transportation
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-01415
Paper Title	Crash Injury Severity Prediction and Analysis Based on Comparison of Four Machine Learning Methods
Abstract	Traffic crashes remain a major concern and challenge in countries worldwide. Numerous research studies have attempted to identify contribution factors of traffic crashes and reduce traffic crash injury severity. This paper compares four machine learning (ML) models to predict traffic crash injury severity and investigates factors affecting injury severity of crashes. The analysis uses 2015 crash data from police records in Beijing, China, including mobile location data and points of interest (POIs) data from Google Maps. The model results suggest that the Extremely Randomized Trees (ET), and the Random Forest (RF) perform similarly better compared to the Gradient Boosting Decision Tree (GBDT) and the Adaboost. Meanwhile, the highest overall detection accuracy was found to be 78.07%, while the recall was 42.84% using the ET model when all the features were included in the model. Specifically, minor injuries are the most difficult to distinguish and predict. Moreover, the density of roadway networks, resident population, employment, as well as the density of supermarkets were found to be factors that have a significant impact on traffic crash injury severity. As a result, based on the findings of this study, several countermeasures are recommended.

Authors	Mehdi Hosseinpour, Western Kentucky University Kirolos Haleem (kirolos60@hotmail.com), Western Kentucky University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-01444
Paper Title	Examining Driver Injury Severity in Single-Vehicle Road Departure Crashes Involving Large Trucks
Abstract	Road departure (RD) crashes are among the most severe crashes that could result in fatal or serious injuries. However, little research has been conducted to investigate RD crash injury severity, especially involving large trucks. Besides, most previous studies neglected to incorporate both roadside and median hazards into RD crash severity analysis. The objective of this study was to identify the significant factors affecting driver injury severity in single-vehicle RD crashes involving large trucks. A random-parameters ordered probit (RPOP) model was developed using extensive crash data collected on roadways in the state of Kentucky between 2015 and 2019. The RPOP model results showed that the effect of local roadways, natural logarithm of annual average daily traffic (AADT), presence of median concrete barriers, cable barrier-involved collisions, and dry surfaces were found to be random across the crash observations. The results also showed that older drivers, ejected drivers, and drivers trapped in their truck were more likely to sustain severe single-vehicle RD crashes. Other variables increasing the probability of driver injury severity have included rural areas, dry road surfaces, higher speed limits, single-unit truck types, principle arterials, overturning-consequences, fired trucks, segments with median concrete barriers, and roadside fixed object strikes. On the other hand, wearing seatbelt, local roads and minor collectors, higher AADT, and hitting median cable barriers were associated with lower injury severities. Potential safety countermeasures from the study findings include installing median cable barriers and flattening steep roadside embankments along those roadway stretches with high history of RD large truck-related crashes.

Authors	Rebeka Yocum, Pennsylvania State University, University Park Vikash Gayah (gayah@engr.psu.edu), Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01517
Paper Title	Identifying relationships between socioeconomic indicators and crash frequency in Pennsylvania
Abstract	Current crash prediction models utilize roadway and traffic data as independent variables to describe crash frequency on individual roadway segments. Recent work has moved toward predicting crashes within some region as a function of roadway and traffic data, as well as non-traditional variables, such as alcohol, gasoline prices, and socioeconomic measures. This paper aims to introduce measures of wealth into the crash modeling conversation by determining the effect of wealth on total, fatal and injury, and pedestrian crash frequencies in Pennsylvania counties. The analysis presented in this paper will serve as a case study with intentions to promote the development of more robust, wealth-inclusive crash prediction models in the future. The study reveals that population of unemployed individuals, percentage of the population on cash public assistance or receiving SNAP benefits, and the percentage of households without a vehicle are each positively related to the observed frequency of total, fatal + injury and pedestrian crashes in each county. This result not only supports previous work, but expands on that work by considering multiple crash types, and multiple wealth related variables. The existence of a relationship between crash frequency and wealth related variables opens the door to further exploration of including wealth in traditional crash prediction methods. This paper discusses this relationship and offers recommendations for future work.

Authors	Rajesh Gupta, University of Lucknow Hamidreza Asgari, Florida International University Ghazaleh Azimi, Florida International University Alireza Rahimi (arahi013@fiu.edu), Florida International University Xia Jin, Florida International University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-01584
Paper Title	Analysis of Truck-Involved Work Zone Crash Fatalities in Florida
Abstract	Truck drivers face many dangers on roadways. Truck-involved traffic crashes may not only threaten the lives of truck drivers but also greatly affect the trucking industry which currently faces a massive truck driver shortage. To improve truck driver safety, studies have been focused on understanding the roles of truck driver behaviors prior to traffic crashes, called pre-crash trucker behaviors. These studies attempted to uncover relationships between pre-crash trucker behaviors and crash severities through modeling traffic crash data. Traffic crashes exhibit complex spatial and temporal patterns interacting with diversified socio-economic, cultural, and geographic contexts, which have not been fully captured in previous studies. The objective of this study is to revisit the roles of pre-crash truck driver behaviors with a focus of examining the spatiotemporal variations in relationships between the behaviors and injury severities. This study employed an integrated spatial-temporal modeling approach, namely the Geographically-Temporally Weighted Ordered Logistic Regression (GTWOLR), to model a Pennsylvania statewide crash database with over 56,000 truck-involved crashes. The results indicate some risk behaviors such as speeding, driving under influence, non-restraint, and cellphone usage were associated with an increased truck driver injury severity. In the spatiotemporal variations, some freight routes or time periods are highlighted for particular behaviors due to the extra high estimation magnitudes, such as I-76 near Pittsburg and the years after 2013 for speeding. The findings are useful for practitioners in developing localized safety improvement programs. More implications are discussed in the paper.

Authors	Josie Bianchi (josie.bianchi@upr.edu), Recinto Universitario de Mayaguez Universidad de Puerto Rico Didier Valdés, Recinto Universitario de Mayaguez Universidad de Puerto Rico Raúl Macchiavelli, Recinto Universitario de Mayaguez Universidad de Puerto Rico
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01782
Paper Title	KABCO Severity Cost Estimation by Cluster Analysis for Injury-Only Crashes in Puerto Rico
Abstract	The costs associated with crash injuries in Puerto Rico are based on the Highway Safety Manual 2010 version and the Federal Highway Administration data. They follow the crash-injury severity scale named KABCO. The model is based on a 2005 study of the Federal Highway Administration that used a 2001-dollar value that did not include Puerto Rico. However, Puerto Rico's transportation and police agencies only use three types of crashes in their crash type distinction: fatal, injury, and property-damage-only. To adequately address road safety efforts in Puerto Rico, a crash-cost injured severity estimation was developed. This process was based on medical expenses and associated costs for each type of crash by revising the KABCO injury scale for injury-only motor vehicle crashes on Puerto Rico. A K-means cluster analysis was performed with the medical service data from traffic-related injuries to ascertain if the three-level KABCO categorization for traffic-related injuries fits the Puerto Rico data. As a result, the best cluster or group configuration that maximized the distance among groups and minimized the distance within groups was obtained.

Authors	navid nadimi (nadimi.iust@gmail.com), Shahid Bahonar University Amir Amiri, McMaster University moein Askari, K. N. Toosi University of Technology mohammad Shams, McGill University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-02126
Paper Title	Developing An Accident Severity Model Based On Related Crash Type: Comparison Of Four Commonly Used Discrete Choice Models
Abstract	The purpose of the present study is to identify the risk factors responsible for particular crash types likely to result in more severe accidents, and to subsequently propose new strategies or countermeasures to lessen the probability of these kinds of crashes. What makes this study different from previous research is that this research can distinguish between two different crash types with the same type of collision. The results do not endorse the abilities of the traditional approaches, in which the type and severity of the crash were examined separately. Accordingly, the modeling process and results of this study seem to be quite beneficial in providing more effective preventive policies and countermeasures. In addition, this study seeks to compare the capability of different discrete choice techniques to find out which one performs better according to available dataset and study's limitations. To address this goal, the present study employed different types of discrete choice models including MNL, NMNL, ML, and MNP to evaluate this indisputable correlations using R statistical software. In comparison with other discrete choice techniques, ML demonstrated the best fit with the available dataset. Furthermore, since the framework of MLs are straightforward, and simulation of their choice probabilities was computationally simple.

Authors	Shahnewaz Hasanat-E-Rabbi (shahnewaz.rabbi@gmail.com), BUET Md Asif Raihan, Bangladesh University of Engineering and Technology S M Mahmud, Accident Research Institute (ARI) Md. Shamsul Hoque, Bangladesh University of Engineering and Technology
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	1099
Session Title	Exposure to Risk, Stress, Conflicts, and Crashes: Innovative Pedestrian Ssafety Analysis Methods
Paper Number	21-02213
Paper Title	Evaluating the Impact of Exogenous Factors on Pedestrian Injury Severity Using Alternate Modeling Frameworks in the Context of a Developing Urban Metropolis
Abstract	Application of injury severity modeling approach for identifying exogenous factors and their impact on injury severities in a crash is a state of art practice among the safety researchers. However, in the context of urban metropolis of developing countries, this practice is very scarce particularly for pedestrian injury severity- the most vulnerable road users in terms of crashes and injury severities. In this study, a comprehensive comparison exercise has been made of the performance of unordered and ordered response models including Multinomial Logit (MNL), Ordered Logit (OL) and Partial Proportional Odds (PPO) model to identify and examine the impact of exogenous factors on pedestrian injury severity in the context of a developing urban metropolis. Five years reported pedestrian crash data from Dhaka metropolitan city are used in this research. The comparative analysis revels that among these models PPO model identifies more risk factors and performed relatively better for the current data set. The study identifies a range of risk factors that significantly affect the probability of pedestrian injury outcomes. Elasticity impact of those factors are also evaluated which have significant policy implication for improving pedestrian safety in developing cities.

Authors	Soyoung Jung (jung2@dyu.ac.kr), Dongyang University Xiao Qin, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-02300
Paper Title	Evaluation of the Factors Affecting Injury Involved Crashes in Freeway Tunnels
Abstract	Freeway tunnels in South Korea have suffered from frequent injury involved crashes. Recently, the Korea Ministry of Land, Infrastructure and Transport recently provided several strategies for traffic safety management in tunnels. This study intended to quantitatively evaluate the recent government strategies and employed random forest based binomial logit regression with a comparative variance inflation factor based regression. As a result, the following risk factors were found to be significantly associated with injury involved crashes in freeway tunnels: head-on/angle/rear-end collision, tunnel exit, tunnel width, curve radius, adverse weather, heavy vehicle, fatigued and distracted drivers. By confirming each government strategy specifications based on the identified risk factors, this study quantitatively supports decision-making to modify the government strategies. For future research, the current study suggests comparing random forest and its variation of tree growth algorithm with more tunnel crash data and driver surveys.

Authors	Amjad Pervez (amjadpervez04@yahoo.com), Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-02503
Paper Title	Exploring Factors Affecting Injury Severity of Crashes in Freeway Tunnel Groups
Abstract	In mountainous freeways, some tunnels are located adjacent to each other resulting in a tunnel group where the safety conditions are more challenging compared to the single tunnels. However, limited research efforts have been made to investigate traffic safety in the tunnel groups. This study aims to investigate factors influencing the injury severity of crashes in the freeway tunnel groups. The analysis is based on five years of police-reported data (2012-2016) collected from six tunnel groups in Hunan Province, China. A mixed logit model was developed as an alternative to the conventional logit model to account for the unobserved heterogeneity. Results indicate that the daytime, weekdays, entrance zone, downgrades, speeding, fatigue driving, and rollover collisions are positively while winter, curves, and sideswipe are negatively associated with severe crashes and have signs consistent with engineering intuition. More importantly, due to the complex driving environment of the tunnel groups the summer, access zone, connecting zones and drivers with less driving experience tends to increase the likelihood of severe crashes. Multiple countermeasures are recommended to improve the safety in tunnel groups, including provision of variable message signs to provide information to the drivers regarding the distance to the tunnel and speeding limitations, periodic maintenance of the illumination according to the light guidelines in the different zones of the tunnel groups, implementation of the automatic section speed control for speeding, and public awareness about the complex driving environment of the tunnel groups.

Authors	Zhenyu Wang (wonstran@hotmail.com), University of South Florida Abhijit Vasili, University of South Florida Runan Yang, University of South Florida
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-02758
Paper Title	A Recursive Bivariate Probit Analysis of Injury Severity and Non-Truck Fault Actions in Large Truck-related Crashes on Florida Suburban Roads
Abstract	This study investigated the hierarchical connection among injury severity, non-truck improper actions, and contributing factors in large-truck-involved crashes. Data for four years (2011-2014) of crashes that involved a large truck (≥10,000 pounds) and a non-truck vehicle were collected from suburban roads in Florida. A recursive bivariate probit (RBP) model was fitted with collected data to identify the cause-effect chain, including contributing factors influenced by improper actions, the effects of improper actions on injury severity, and contributing factors indirectly impacting injury severity in large truck-related crashes. Study results indicate that non-truck vehicle improper actions such as excessive speed, careless driving, failure to yield right-of-way, etc., significantly increase the likelihood of fatal and severe injury in large-truck crashes, and factors such as crash month, darkness, intersection-related, surface and shoulder width, truck parking, truck driver age, non-truck driver age, and non-truck alcohol/drug impaired indirectly influence injury severity through their impacts on non-truck improper actions. Two factors—truck right-turn and non-truck driver physical defects—impact injury severity and non-truck improper actions simultaneously. Other factors, including crash year, Annual Average Daily Traffic (AADT), speed limit, crash type, truck type, truck speed, truck alcohol/drug-impaired, and motorcycle involvement, directly contribute to injury severity in large-truck crashes and have no influence on non-truck improper actions.

Authors	Brian Peck, WSP USA Corp Rebecca Sanders (rebecca@safestreetsresearch.com), Arizona State University Deborah Salon, Arizona State University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	1099
Session Title	Exposure to Risk, Stress, Conflicts, and Crashes: Innovative Pedestrian Ssafety Analysis Methods
Paper Number	21-02846
Paper Title	Dangerous Streets: An Analysis of Factors Associated with Pedestrian Crash Severity in Phoenix, Arizona
Abstract	Phoenix, Arizona, is consistently identified as one of the most dangerous U.S. cities for pedestrians, prompting urgent research into pedestrian safety issues and potential improvements. This paper presents the results of a recent safety study aiming to identify key contributors to pedestrian crash severity in order to inform a strategy for pedestrian safety improvements in Phoenix both at hotspots and system-wide. Our study has two main contributions. Methodologically, we used crowd-sourced speed data to identify prevailing vehicle speeds at the time of the crashes in order to better understand the relationship between speed and pedestrian crash severity. Substantively, our logistic regression model indicates that the likelihood of a severe pedestrian injury in Phoenix is significantly impacted by vehicle speeds over 35 mph (56 kph), pedestrian and driver intoxication, darkness, age, and pedestrians crossing outside of the crosswalk. We also found a significant increased likelihood of crash severity during the morning rush hour, unexplained by light conditions, as well as a protective relationship between crash severity and higher amounts of commuting by transit. We also find higher rates of pedestrian crashes and severe pedestrian crashes in census tracts that are minority non-Hispanic white and that have a higher percentage of lower-income households, zero-vehicle households, and transit and walk commuters. These findings underscore the need to use an equity lens to substantially rethink roadway design in Phoenix and prioritize efforts to slow speeds and enable pedestrians to safely walk and cross the street.

Authors	Subasish Das (s-das@tti.tamu.edu), Texas A&M University Anandi Dutta, University of Texas, San Antonio Ioannis Tsapakis, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03150
Paper Title	Motorcycle Crash Causation Study: Exploratory Topic Models from Crash Narrative Reports
Abstract	The Motorcycle Crash Causation Study (MCCS) is a matched case-control study that contains a very wide list of crash contributing factors associated with motorcycle crash occurrences. It contains information such as motorcycle information, rider information, motorcycle information, and associated trip information. This study also provides crash narrative information that presents in-depth narrative discussion of the crash causation. Due to the plethora of information, it is critical to investigate MCCS related data. Some studies examined the structured information in MCCS datasets. There is no in-depth study that has examined the unstructured textual contents in the MCCS data. This study aims to mitigate this research gap by applying different natural language processing (NLP) tools (e.g., text mining, topic modeling). Fatal and non-fatal crash narratives are clustered separately to gain injury level specific insights. The findings of this study will contribute to the on-going studies on MCCS to better understand the crash causation mechanism associated with motorcycle crashes.

Authors	Bijoy Saha, University of British Columbia, Okanagan Mahmudur Fatmi (mahmudur.fatmi@ubc.ca), University of British Columbia Md. Mizanur Rahman, Bangladesh University of Engineering and Technology
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-03310
Paper Title	Modeling Injury Severity of Unconventional Vehicle Occupants: A Hybrid of Latent Segment and Random Parameters Logit Model
Abstract	Unconventional vehicles such as human-pulled and engine-operated three-wheeler vehicles are popular travel modes in developing countries. These slower moving vehicles have limited safety features, posing significant injury risks to their occupants. This study investigates injury severity of unconventional vehicle occupants (UVOs). A hybrid latent segmentation-based random parameters logit (LSRPL) model is developed utilizing 5-year police reported collision records from Dhaka, Bangladesh. LSRPL model captures multi-dimensional heterogeneity by allocating victims into discrete latent segments (i.e. inter-segment heterogeneity) and allowing a continuous distribution of parameters within the segments (i.e. inter-segment heterogeneity). The model is estimated for two segments using victim and crash attributes: segment one is a lower-risk segment, and segment two is a higher-risk segment. The model results suggest that victim and driver profile, crash attributes, environmental factors, road network attributes, and transportation infrastructure and land use attributes influence injury severity of UVOs. For example, human-pulled three-wheeler vehicle and engine-operated three-wheeler paratransit passengers, head-on and right-angle collisions, and crashes at 3-way and 4-way intersections have a higher likelihood to result in severe injury. The model confirms the existence of significant inter-segment heterogeneity. For example, mid-block crashes are more likely to result in severe injury in higher-risk segment, and show a lower likelihood for severe injury in lower-risk segment. The model further confirms intra-segment heterogeneity for higher mixed land use. For example, in the case of mid-block crashes, higher mixed land use shows significantly lower mean for high-risk segment, revealing a lower likelihood of severe injury in higher mixed land use areas.

Authors	Mohammad Razaur Rahman Shaon (mrrshaon@email.arizona.edu), University of Arizona Xiao Qin, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-03462
Paper Title	Modeling the effects of drive error and impairment on crash injury severity
Abstract	Driver errors are widely cited as one of the critical reasons for crash occurrence in safety literature. Despite universal acceptance, the discussion of their effects on crash outcomes is limited. The primary objective of this study is to quantify the effects of driver errors in the crash injury severity model at urban intersections. To obtain research objectives, driver errors were categorized as sequential events in a driving task. Combinations of driver error categories were created and ranked based on their odds-ratios with injury severity levels. Furthermore, driver impairment was considered in the model to explore the compounding effects on crash consequences. Multiple ordered logit models were estimated to quantify the effect of driver errors and their interactions with driver impairment on crash injury at uncontrolled, sign-controlled, and signal-controlled intersections. Improved model performance was observed when driver error combinations were modeled along with typical crash variables. The exploration of multiple model formulations indicated that including driver impairment as an error category can yield informative inferences from both theoretical and modeling perspectives. As a result, appropriate countermeasures were recommended for major contributing factors to improve intersection safety. It is expected that this study can offer specific insights into explanatory variables and help safety professionals to develop effective countermeasures.

Authors	Branislav Dimitrijevic, New Jersey Institute of Technology Sina Darban Khales, New Jersey Institute of Technology Roksana Asadi (ra653@njit.edu), New Jersey Institute of Technology Joyoung Lee, New Jersey Institute of Technology Kitae Kim, New Jersey Institute of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03591
Paper Title	Segment-Level Crash Risk Analysis for New Jersey Highways Using Advanced Data Modeling
Abstract	Highway crashes are the most significant challenge to the goal of providing a safe and efficient highway transportation system. They result in significant societal toll reflected in numerous fatalities, personal injuries, property damage, and traffic congestion. To that end, much attention has been given to developing models to study and predict crash occurrence. More recently advancements have been made in developing proactive crash risk models, aiming to assess crash risks in the short term, and inform traffic management strategies to prevent and mitigate the negative effects of crashes. This study developed and tested several models for segment-level crash risk considering the data available to most transportation agencies in real-time on a regional network scale. The data included roadway geometry characteristics, traffic flow characteristics, and weather condition data. The models included Bayesian Logistics Regression (BLR), Decision Tree (DT), Random Forest (RF), Gradient Boosting Machine (GBM), K-Nearest Neighbor (KNN), and Gaussian Naïve Bayes (GNB). The models were trained and tested using a dataset containing records of 10,155 crashes that occurred on two interstate highways in New Jersey over two years. It was found that for the given dataset the models provided limited predictive value. Keywords: Crash analysis, crash risk forecasting, machine learning

Authors	Amin Mohammadnazar (amoham17@vols.utk.edu), University of Tennessee, Knoxville Iman Mahdinia, University of Tennessee, Knoxville Ramin Arvin, University of Tennessee, Knoxville Asad J. Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-03621
Paper Title	Exploring the Effects of Physical Condition and Driving Errors of At-fault Drivers on Injury Severity of Large Truck Angle Crashes
Abstract	Large trucks play an important part in the US' economic growth by transporting a considerable portion of goods and cargoes across the country. However, according to the U.S Department of Labor, in 2017, trucking industry experienced the highest fatalities among all occupations in 2017. Over 75 percent of these fatalities were related to roadway accidents. Police-reported crashes show that angle crashes are the most frequent type of accidents among large truck fatal crashes, which raises concerns over the safety of occupants involved in these types of crashes. Drivers' physical conditions and driving errors have also been recognized as major factors in truck-involved crashes. Therefore, this study focuses on the effect of at-fault drivers' physical conditions and driving errors on the severity of large truck angle crashes while controlling for crash characteristics and roadway features. To address unobserved heterogeneity in these crashes, a random parameter ordered probit model was estimated using North Carolina crash and inventory data between 2013-2017. Regarding the physical condition of at-fault drivers, the results show that having a medical condition and impaired driving have strong and positive associations with large truck angle crash severity. It was also found that driving error factors such as aggressive driving, disregarding signs and signals, failure to yield the right of way, and speeding increase the probability of experiencing fatal and injury crashes. This can help technology developers in the trucking industry as well as planners and engineers in the transportation field make informed decisions about safety countermeasures.

Authors	Irfan Ahmed, University of Wyoming Mohamed Ahmed (mahmed@uwyo.edu), University of Wyoming
Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	1395
Session Title	Emerging methods in transportation data analysis
Paper Number	21-03641
Paper Title	Injury severity analysis of adverse vs non-adverse weather condition crashes in rural two-lane two-way highways – a random intercept bayesian approach
Abstract	Rural highways fatality rates are always higher than urban highways ones. There are abundant studies in the literature explored the impact of weather effects and the consequent condition such as reduced visibility, wet pavement on crash injury severity. However, research on crash injury severity using disaggregate analysis based on weather conditions on rural two-lane two-way highways is limited. Such analysis provides useful insights to transportation planners in allocating resources based on weather conditions. In this study separate models for adverse and non-adverse weather conditions were developed using crash data of rural two-lane two-way highway corridor in two neighboring states, Wyoming and Colorado. The years of crash data used in this study were between 2007 and 2016. A random-intercept Bayesian logit approach was used to analyze the dichotomous injury severity response and capture the heterogeneity in the variance of the random parameter. An efficient Markov Chain Monte Carlo sampling technique known as No-U-Turn Hamiltonian Monte Carlo was employed to sample the posterior distributions of the parameter estimates. Likelihood Ratio tests indicated that the use of separate models was justified with over 95% confidence. The model results provided valuable insights into the contributing factors of crashes occurring in adverse and non-adverse weather conditions. Findings from the separate models suggest that there are major differences in both the combination and magnitude of the significant contributing factors. The findings and the recommendations from this study could potentially be used to help guide the respective agencies in formulating injury severity mitigation policies and strategies.

Authors	Sarvani Duvvuri, University of North Carolina, Charlotte Sonu Mathew, University of North Carolina, Charlotte Srinivas Pulugurtha (sspulugurtha@uncc.edu), University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-03669
Paper Title	Exploring the Influence of Off-network and On-network Characteristics on Truck Crash Injury Severity
Abstract	The presence of trucks in the traffic stream has a psychological influence on drivers in their vicinity due to their size, dimension, and operating characteristics. Truck crashes account for 11% of the traffic fatalities but are only 4.3% of the vehicles in the traffic stream. Trucking activity in a region is governed by its land use development, population, and area type. This research aims to examine the influence of off-network and on-network characteristics on truck crash injury severity to identify potential countermeasures. Crash data for Mecklenburg County for the years 2013 – 2017 was considered for analysis. Buffer analysis was performed to capture the land use and demographic data within the vicinity of each crash. The risk factors and their likelihood associated with the truck crash injury severity were identified using the backward elimination method in the partial proportionality odds model. The results indicate that dark lighting conditions, driver fatigue/impairment, the presence of a van, flatbed, or other semi-trailer, and driver inattention increase the likelihood of a severe or moderate injury truck crash. Further, the likelihood of a severe or moderate injury truck crash is high in commercial, industrial, recreational, and resource land uses. Contrarily, the likelihood of a severe or moderate injury truck crash is less in single-family residential and office land uses. Potential countermeasures to reduce risk and enhance safety include truck signal priority, variable/dynamic speed limit signs for speed harmonization, truck traffic management strategies, incorporation of advanced driver warning/crash avoidance systems, education, and enforcement.

Authors	Shashi Nambisan (shashi@unlv.edu), University of Nevada, Las Vegas Kwaku Boakye, Arcadis Derek Yu, Purdue University
Sponsoring Committee	Standing Committee on Occupant Protection (ACS40)
Session Number	1394
Session Title	Occupant Protection Posters of Novel, Interesting Engineering Design Ideas, Prototypes and Other Topics
Paper Number	21-03851
Paper Title	Seatbelt Use among Vehicle Occupants in Fatal Crashes in the United States: Does Vehicle Type and Age Affect Injury Outcome?
Abstract	Studies have shown that occupant's injury severity increases with vehicle age and older model year vehicles when a traffic crash occurs. But, does vehicle occupant restraint use play role in the injury outcome? The primary objective of this study was to determine the relationship between adult vehicle occupant's seatbelt use, vehicle type and age, and injury severity using crash data from Fatality Analysis Reporting System (FARS). Five-year crash data (2014 to 2018) were retrieved from FARS for all vehicle occupants involved in fatal crashes for 50 states and the District of Columbia. Chis-square analyses were conducted to test several hypotheses regarding adult seatbelt use. The results of our analysis showed a lower seatbelt use rate among occupants of older vehicles than occupants in newer vehicles. This finding was consistent across all the vehicle types: passenger cars, pickup trucks, and SUV-Minivans. Regardless of how old the vehicle was at the time of the crash (i.e., 1-6 years, 7-11 years, 12-15 years, and > 15 years) and the type of vehicle involved, the seatbelt use rates were consistently lower among fatally injured occupants than those whose suffered no or possible/severe injuries. The findings in this study are important for the development of seatbelt use intervention programs that are persuasive and have the greatest potential for effectiveness.

Authors	Mouyid Islam (mouyid@cutr.usf.edu), University of South Florida Parisa Hosseini, Rowan University Mohammad Jalayer, Rowan University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	1249
Session Title	Truck and Bus Safety Research
Paper Number	21-03928
Paper Title	An analysis of single-vehicle truck crashes on rural curved segments accounting for unobserved heterogeneity
Abstract	Large truck-involved crashes are one of the core emphasis areas in Strategic Highway Safety Plans (SHSP). Large truck crashes, particularly on rural curved roadways, lead to a disproportionately higher number of fatalities and serious injuries relative to other passenger vehicles over time. The intent of this study is to identify and quantify the factors affecting injury severity outcomes for single-truck crashes on rural curved segments in North Carolina. The crash data are extracted from the Highway Safety Information System (HSIS) from 2010 to 2017. This study applied a mixed logit with heterogeneity in means and variances approach to model driver injury severity. The approach accounts for possible unobserved heterogeneity in the data resulting from driver, roadway, vehicle, traffic, and/or environmental conditions. The model results indicate that there is a complex interaction of driver characteristics such as demographics (male drivers, age below 30 years), physical condition (sleepy while driving), actions (unsafe speed, overcorrection and careless driving), restraint usage (lap-shoulder belt usage and unbelted), roadway and traffic characteristics (undivided road, medium right shoulder width, graded surface, low and medium speed limit, low traffic volume), environmental conditions (rainy condition), vehicle characteristics (tractor-trailer), and crashes characteristics (fixed object crashes and rollover crashes). In addition, this study compared the contributing factor leading to driver injury severity for curved and straight rural segments. The results clearly indicate the importance of driving behavior and roadway design concerning curved segments that need to be prioritized in the trucking agency as well as the roadway design and maintenance agency.

Authors	Moinul Hossain (moinul048i@yahoo.com), Islamic University of Technology (IUT) Afia Jahin Prema, Islamic University of Technology Dewan Tanvir Ahammed, Islamic University of Technology Niaz Mahmud, Islamic University of Technology Md Asif Raihan, Bangladesh University of Engineering and Technology Md. Abdullah Al Mamun, Universita degli Studi di Roma La Sapienza
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-04058
Paper Title	Pedestrian Safety Hazard Due to Jaywalking and Cell Phone Induced Distractions: A Synopsis from Highway Intersections in Bangladesh
Abstract	Pedestrian fatalities account for 22% of all road traffic fatalities around the world. The statistics are even grimmer for the developing countries where jaywalking is predominant. There, along with jaywalking, the use of cell phones while crossing the road is acerbating pedestrian casualties. This delves into thought processing of jaywalkers and pedestrians using cell phones while crossing roads to devise countermeasures for improving pedestrian safety. The study observes pedestrian behavior at 32 intersections on national and regional highways of Bangladesh through video data and subsequently interviews 2,016 pedestrians found jaywalking and/or using cell phones while crossing the road. Data on their socio-economic and demographic characteristics, various risk perceptions, physical obstructions forcing jaywalking, distracting cell phone use, road crossing behavior and their knowledge about basic rules of the road were collected. Next, Bayesian Networks (BBN) were constructed to answer 'who', 'why' and 'how' related questions regarding jaywalkers and pedestrians who use a cell phone while road crossing. The findings suggest that jaywalking is more predominant among males, aged between 26-40 years who have received secondary education despite having decent knowledge regarding basic rules of the road. The most influential factors concerning risky jaywalking and using cell phone while road crossing are 'Gender', 'Jaywalker Activities', 'Driving experiences', 'Purposes of Journey', and 'Frequency of visit that area'. The identified high impact variables associated with jaywalking, and also the triggering factors of cell phone-induced jaywalking are expected to assist decision-makers to develop pragmatic pedestrian safety policies in the context of developing countries.

Authors	Hatem Abou-Senna (habousenna@ucf.edu), University of Central Florida Essam Radwan, University of Central Florida Hassan Tahsin, Cairo University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1169
Session Title	Safety Performance and Analysis, Act 1: Pedestrians, Bicyclists, E-Bikes, and Couriers (Act 2, Session 1202; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-04213
Paper Title	Categorical Principal Component Analysis (CATPCA) of Pedestrian Crashes in Central Florida
Abstract	This research investigates the characteristics and contributing causes of pedestrian crashes that occurred in Central Florida over a 5 year-period at intersections and mid-blocks along roadway segments. The factors affecting pedestrian crashes were classified into five main categories; location characteristics, pedestrian factors, driver/vehicle characteristics, environmental-related factors and crash characteristics. Categorical Principal Components Analysis (CATPCA) was applied to understand the structure of a set of variables and to reduce the dimensionality of the dataset to a predefined number of dimensions and components. The analysis showed that majority of the intersection crashes were during night time with pedestrians under influence and failing to yield to the right of way (ROW). They included mainly left-turn and right-turn crashes. In addition, drivers were also found at fault due to vision issues resulting from absence of lighting at intersections and categorized as failure to yield to the ROW. At midblock locations, major crash types were through moving vehicles hitting pedestrians crossing and walking along the roadway especially during night time conditions. However, majority of the crashes were at locations away from the designated crossings likely due to the long distances between legal locations and pedestrian's failure to utilize them. The findings of this research and examining the factors affecting pedestrians' crash likelihood and injury severity can lead to better crash mitigation strategies, countermeasures and policies that would alleviate this growing problem in Central Florida.

Authors	Jing Zhang (220194471@seu.edu.cn), Southeast University Chengcheng Xu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models (Act 1, Session 1169; Act 2, Session 1202; Act 3, Session 1295)
Paper Number	21-04421
Paper Title	Investigating the Typical Scenarios and Contributory Factors to Crash Severity of Autonomous Vehicle Involved Collisions Using Association Rule Analysis
Abstract	Autonomous vehicles (AVs) are considered to have the potential to bring considerable benefits to the transportation system, involving the improvement of traffic safety and traffic efficiency, as well as the reduction of congestion and emissions. However, the AVs are posing considerable uncertainty on road safety, especially when AVs and conventional vehicles are operating on the public road together. This study aimed to identify typical scenarios of collisions and contributory factors to human-injured collisions involved with an autonomous vehicle. The association rule analysis was used to identify common collision patterns using the autonomous vehicle involved collision reports from the California Department of Motor Vehicles (CDMV). Six typical scenarios have been identified based on collision types, including 1 broadside collision, 1 sideswipe collision and 4 rear-end collision scenarios. Moreover, down-slope, night time, multi vehicles, and high-density traffic were found to be the four main contributory factors to human-injured collisions involved with an autonomous vehicle. Based on the results of association rule analysis, potential implications for preventing AV involved crashes and reducing collision severity were identified.

Authors	Emmanuel Kidando, Cleveland State University Angela Kitali (akita002@fiu.edu), Florida International University Boniphace Kutela, Texas A&M Transportation Institute Alican Karaer, Florida State University Mahyar Ghorbanzadeh, Florida A&M University-Florida State University College of Engineering Mohammadreza Koloushani, FAMU-FSU College of Engineering Eren Ozguven, Florida A&M University-Florida State University College of Engineering
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data (Act 1, Session 1169; Act 3, Session 1295; Act 4, Session 1327)
Paper Number	21-04444
Paper Title	Use of Real-Time Traffic and Signal Timing Data in Modeling Occupant Injury Severity at Signalized Intersections
Abstract	This study explored the use of real-time traffic events and signal timing data in understanding factors influencing the injury severity of vehicle occupants at intersections. The analysis was based on three years (2017-2019) of the crash and high-resolution traffic data. The best fit regression was first identified by comparing the conventional regression model with the hierarchical Bayesian logistic models. The hierarchical model with a heavy-tailed distribution was shown to best fit the dataset and was used in the variable assessment. The model results revealed that about 13.6% of the unobserved heterogeneity comes from site-specific variations, which underlines the need for the use of the hierarchical model. Among the real-time traffic events and signal based variables, approach delay, and platoon ratio were found to significantly influence the injury severity of vehicle occupants at 90% Bayesian credible interval. Additionally, manner of collision, occupant seat position, number of vehicles involved in a crash, gender, age, lighting condition, and day of the week were found to significantly impact the vehicle occupant injury. The study findings provide valuable insights to transportation agencies for developing countermeasures to proactively mitigate the crash severity risk.

6 Crash Modification Factors

Alfonso Montella, Filomena Mauriello, and Maria Rella Riccardi
University of Naples Federico II

Crash Modification Factors (CMFs) are used to evaluate safety effectiveness of countermeasures on road safety.

The subcommittee identified eighteen papers dealing with Crash Modification Factors (CMFs).

The papers are scattered across various sessions, with most papers presented at the poster sessions 1295 Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Wednesday, January 27 1:00 PM – 2:30 PM ET) and 1435 Strengthening the Linkages between Geometric Design and Roadway Performance (Friday, January 29 11:30 AM – 1:00 PM ET).

Most papers used both before-after approach and Empirical Bayes before-after approach (i.e., 21-00013, 21-00026) to ensure reliable results. Another paper used before-after approach, Empirical Bayes before-after method, and cross-sectional analysis (21-00026) to estimate reliable and representative Crash Modification Factors.

From a **methodological perspective**, the approaches used were:

- Before-After approach (21-00013, 21-00026, 21-03363, 21-03488);
- Empirical Bayes Before-After approach (21-00013, 21-00026, 21-00179, 21-03721, 21-03723, 21-03955);
- Full Bayes before-after approach (21-01619, 21-03950);
- Bayesian generalized negative binomial (BGNB) approach (21-00190), and
- Cross-sectional analysis (21-00026, 21-00962).

The evaluated countermeasures mainly included two groups of countermeasures: geometric treatments and traffic control devices.

The evaluated geometric treatments especially focused on intersection safety improvement and included:

- Diverging diamond interchanges instead of conventional diamond interchange (21-00026), finding a significant decrease in total, fatal-and-injury, rear-end, and angle/left turn crashes by 14%, 44%, 11%, and 55%, respectively.
- New intersection design named “Shifting Movements” (SM) intersection to replace the RCUT implementation under moderate and heavy minor road traffic volume (21-00246);
- Right-turn lanes (21-01619);

- Road diet conversion from a four-lane roadway to a three-lane roadway with added bike lanes (21-03955), finding CMFs equal to 0.61 for total crashes and 0.59 for fatal and injury crashes;
- Super 2 corridors with passing lanes (21-03176) providing passing opportunities and reducing delay and crashes, and
- Unsignalized stop-controlled RCUTs in the rural areas (21-03723), observing a 64.86% reduction in the total number of crashes and a 73.39% reduction in the number of fatal and injury crashes.

The evaluated **traffic control devices** included:

- Adaptive traffic signal control (ATSC) to mitigate traffic congestion and improve travel time reliability (21-00176);
- Centerline rumbles strips (CLRS) effectiveness during adverse wintry conditions (21-03721);
- Delineation lighthing at intersections (21-01619);
- Dynamic speed feedback signs (DSFS) to reduce speed on freeway interchange ramps (21-03363);
- Snowplowable reflective pavement markers (SRPMs) to determine optimum pavement marker solutions (21-01327);
- Permitted, protected only (PO), left turn signal phasing and protected/permitted left turn (PPLT) to manage the left turning movements (21-00962);
- Traditional traffic control devices (TCDs) on preventing Wrong-Way Driving (WWD) at two partial cloverleaf (parclo) off-ramp terminals (21-03488);
- Transit signal priority (TSP) (21-03950), and
- Variable Speed Limit System (VSLS) on provincial rural highways (21-00013).

One paper investigated four typical cross-sections including 1) non-traversable medians; 2) two-way-left-turn lanes; 3) 4-ft flush medians, and 4) undivided roadways with double-yellow lines (21-00190) finding CMFs varying significantly across different contexts.

One paper used Bayesian generalized negative binomial (BGNB) modeling approach to form SPFs for CMF estimations (21-00190) for alternative cross-sections of rural four-lane roadways.

One paper used CMFs including the driveway characteristics (21-04402) to predict the crash number.

One paper investigated how Bareinboim and Pearl's tools for "transportability" analysis can be used to adapt existing safety knowledge to new situations (21-02494).

Authors	Mohamed El Esawey (m.elesawey@eng.asu.edu.eg), British Columbia Ministry of Transportation and Infrastructure Joy Sengupta, British Columbia Ministry of Transportation and Infrastructure John Babineau, British Columbia Ministry of Transportation and Infrastructure Emmanuel Takyi, British Columbia Ministry of Transportation and Infrastructure Mohamed Essa, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-00013
Paper Title	Safety Evaluation of Variable Speed Limit System in British Columbia
Abstract	Adverse weather conditions create a difficult environment for drivers to navigate safely. This study reports the safety impacts associated with the installation of Variable Speed Limit System (VSLS) on provincial rural highways in in British Columbia (BC), Canada. A VSLS is an advanced intelligent transportation system (ITS) scheme that can be employed to increase the safety level of highway facilities by varying the speed limit according to downstream operational condition and/or current weather conditions. The analysis made use of police-attended serious crashes (i.e. fatal + injury) that took place during winter seasons (October to March). Three winter seasons were available as a before-implementation period, and three winter seasons were available as an after-implementation period. The results of a simple-before-and-after were promising where overall reductions of 35.8% and 36.8% in winter serious collision (WSC) frequency and rate, respectively, were found for the evaluation corridors. An Empirical Bayes (EB) before-and-after safety evaluation was also carried out to ensure that the results are reliable. Safety Performance Functions (SPFs) were developed using data collected at similar sites. The EB analysis showed an overall statistically significant reduction of 34.4% in WSC. An economic assessment of the system was undertaken and the results showed that the benefits of implementing a VSLS exceeded the system cost with an overall benefit-cost (B/C) ratio of 4.3 and a NPV of C$34.41 million. The results of this study may motivate transportation agencies and stakeholders who are interested in pursuing similar systems for mitigating weather-related safety challenges.

Authors	Ahmed Abdelrahman, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jinghui Yuan (jinghuiyuan@Knights.ucf.edu), University of Central Florida Ma'en Al-Omari, University of Central Florida
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-00026
Paper Title	Systematic safety evaluation of diverging diamond interchanges based on nationwide implementation data
Abstract	Diverging Diamond Interchanges (DDIs) are designed as an alternative to the conventional diamond interchange to enhance the operational and safety performance as they have a lower number of traffic conflict points. Since drivers are not familiar with DDIs' operation, which results in many wrong-way maneuvers, there is a need to evaluate the safety performance of this type of interchanges to validate their effect, and to estimate reliable and representative Crash Modification Factors (CMFs). This paper evaluates the safety of DDIs using three methods, which are before-and-after study with comparison group, Empirical Bayes before-and-after method, and cross-sectional analysis. This study was conducted based on a nationwide sample of 80 DDIs in 24 states. The analysis results indicated that converting conventional diamond interchange to diverging diamond interchanges could significantly decrease the total, fatal-and-injury, rear-end, and angle/left turn crashes by 14%, 44%, 11%, and 55%, respectively. Moreover, the developed safety performance functions (SPFs) implied that two types of geometric characteristics (i.e., the distance between crossovers/ramp terminals and freeway exit ramp speed limit) have the potential to reduce the frequency of specific crash types. The study contributes to the existing literature by using a relatively large representative sample size, which provides more statistically significant safety measures. In addition, this study also explored the effects of different traffic and geometric characteristics on the safety performance of DDIs.

Authors	Houjun Tang, Pennsylvania State University, University Park Vikash Gayah (gayah@engr.psu.edu), Pennsylvania State University Eric Donnell, Pennsylvania State University, University Park
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-00179
Paper Title	Crash Modification Factors for Adaptive Traffic Signal Control: An Empirical Bayes Before-After Study
Abstract	Adaptive traffic signal control (ATSC) is often deployed at high-volume intersections in order to mitigate traffic congestion and improve travel time reliability. While past studies have demonstrated its operational effectiveness, relatively few have focused on safety performance. Those that have tend to suffer from limitations including small sample sizes, insufficient study designs, or the lack of consideration of potential temporal and corridor effects after ATSC installation. Furthermore, results from previous studies are mixed: while many studies point to a safety improvement, more recent studies seem to indicate that ATSC systems might increase crash frequency. In this study, a comprehensive Empirical Bayes (EB) before-after observational study was conducted using ATSC data collected throughout Pennsylvania. Crash modification factors (CMFs) were estimated based on the following different case scenarios: crash severity levels and crash types (total, fatal and injury, rear-end, and angle crashes); intersection locations (all intersections and intersections along corridors only); and, intersection configurations (3-leg and 4-leg). Corridor-level CMFs were also developed to quantify changes in safety performance along corridors with ATSC installed. The results suggest that ATSC is associated with a nominal increase in total and angle crashes, and an expected decrease in fatal plus injury crashes and rear-end crashes. However, the results were not statistically significant. The safety effect estimates are similar when considering intersection locations and configurations. Finally, the magnitude of the corridor-level CMFs are slightly lower than the intersection-level CMFs, except for rear-end crashes.

Authors	Xiaobing Li (xli158@ua.edu), University of Alabama Jun Liu, University of Alabama Chenxuan Yang, University of Alabama Timothy Barnett, University of Alabama
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-00190
Paper Title	Context-based Crash Modification Factors for Medians on Rural Four-Lane Roadways: A Bayesian Approach
Abstract	Rural four-lane roadways provide important transportation accessibility and mobility to populations in rural areas. Practitioners are often challenged to determine cross-section types when both benefits and costs need to be considered. The Crash Modification Factors (CMFs) are often developed to evaluate safety effectiveness of alternative designs. However, safety effectiveness could vary significantly across contexts. Thus, the study aims to estimate CMFs for alternative cross-sections of rural four-lane roadways under different contexts characterized by traffic volume, truck percentage, and access point density. Using Georgia state-wide crash data, this study developed Safety Performance Functions (SPFs) to predict crash frequencies for different contexts. Considering linearity and independence assumptions of traditional negative binomial SPFs, this study adopts the Bayesian generalized negative binomial (BGNB) modeling approach to relax those assumptions and only follows the Bayes rule to form SPFs for CMF estimation. This study focuses on four typical cross-sections including 1) non-traversable medians; 2) two-way-left-turn lanes; 3) 4-ft flush medians; and 4) undivided roadways with double-yellow lines (the base cross-section). The results show that CMFs vary significantly across different contexts. Compared with base cross-section design, safety benefits of other three designs can be either positive or negative under different traffic or road conditions. For example, 4-ft flush medians are found to have positive safety benefits (CMF < 1) under lower average daily traffic volumes (e.g., <=6,000); but negative benefits (CMF >1) under greater average daily traffic volumes (e.g., >=15,000). The findings offer practitioners insights that cross-section designs may need to be varied for different contexts.

Authors	Ma'en Al-Omari (mmaalomari@knights.ucf.edu), University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-00246
Paper Title	Evaluation of a New Intersection Design "Shifting Movements"
Abstract	Several unconventional designs have been suggested to enhance traffic operation and safety at intersections. However, the operational benefits of implementing some of them are achieved only under certain traffic conditions. For instance, the operational performance of the restricted crossing U-turn (RCUT) intersection design manifests only under highly unbalanced traffic conditions. The RCUT intersection outperforms conventional intersections that are subjected to high major traffic and light minor traffic volumes, while its operational performance fades at intersections with moderate to heavy minor road traffic. In this technical paper, a new innovative 4-leg intersection design has been proposed to replace the RCUT implementation under moderate and heavy minor road traffic volume. The new intersection design which has been named "Shifting Movements" (SM) intersection has a low number of conflict-points compared to conventional intersections, but similar to the RCUT. Therefore, similar safety benefits are expected to be achieved by the implementation of the SM intersection. Operation evaluation and comparison between conventional, RCUT, and SM intersections have been conducted in the microscopic simulation environment. Different traffic volume levels and left-turn proportions have been assumed to represent the peak hour with moderate to high left-turn traffic. The results indicated that the SM intersection design significantly outperforms conventional and RCUT intersections that are subjected to high traffic volumes in terms of average control delay and throughput. Four hundred ft. for the side street length is sufficient at the SM intersection design, while 500 ft. length is recommended for very heavy traffic volumes.

Authors	Md Asaduzzaman, Louisiana Transportation Research Center (LTRC) Raju Thapa, Louisiana Department of Transportation and Development Julius Codjoe (Julius.Codjoe@la.gov), Louisiana Department of Transportation and Development
Sponsoring Committee	Standing Committee on Traffic Signal Systems (ACP25)
Session Number	1210
Session Title	Signal Timing Performance
Paper Number	21-00962
Paper Title	Safety Effectiveness of Protected Only over Permitted/Protected Left Turn Phasing in Louisiana
Abstract	Roadway intersections are high risk areas in a roadway network accounting for significant number of traffic fatalities. Of the total fatalities, intersection fatalities account for around 24% each year, with left turning vehicles making up the majority of these crashes. To manage the left turning movements, various left turn signal phasing like permitted, protected only (PO), and protected/permitted left turn (PPLT) are currently in use. Though conversion to PO left turn phase has shown positive effects, their overall effectiveness has not been well established in Louisiana. The paper evaluated the safety effectiveness of PO over PPLT phase in Louisiana. A total of 42 four legged signalized intersections were selected with 21 intersections (treatment) having PO left turn phase at all the approaches and 21 intersection (control) with PPLT phase at all the approaches. Treatment and control sites were selected to closely match with their geometry, traffic volume, and roadway classification. A cross-sectional study design was undertaken to develop a safety performance function, using Negative Binomial model, for total and only left turn crashes at various severity levels. The result shows positive safety benefits of adding PO over PPLT phase, specifically in reducing injury and fatal crashes for both total and left turn crashes (CMF = 0.567 and 0.309 respectively). However, the result for total and left turn crashes was mixed for other severity levels. Nevertheless, installation of PO left turn phase clearly helps to meet the goal of state agencies to reduce zero deaths from roadway crashes.

Authors	Carmine Dwyer (cdwyer@ara.com), Applied Research Associates, Inc. (ARA) Kelly Morse, Illinois Department of Transportation Kyle Armstrong, Illinois Department of Transportation
Sponsoring Committee	Standing Committee on Traffic Control Devices (ACP55)
Session Number	1294
Session Title	Traffic Control Devices and Work Zones 2021
Paper Number	21-01327
Paper Title	Investigating the Performance of Snowplowable Reflective Pavement Markers in Illinois
Abstract	The Illinois Department of Transportation (IDOT) investigated the installation and performance of snowplowable reflective pavement markers (SRPMs) to determine optimum pavement marker solutions and policies for roadways in Illinois. The research evaluated the performance of five traditional cast-iron and two plastic SRPMs on test sections of both asphalt and concrete pavements. All five iron markers and one plastic marker had a traditional raised face for the reflective lens, and the other plastic marker was completely recessed in the pavement. Analysis included 1) comparisons of casting design, casting material, and groove design; 2) assessments on how each factor contributed to pavement marker performance; and 3) development of crash modification factors (CMFs) for quantifying any safety improvement from SRPM use. Due to a lack of crash data, the CMF development was limited to freeway sections with six or more lanes (combined directions). The results of the SRPM performance evaluation and CMF development were used to provide recommended updates to IDOT's guidelines for the use of raised pavement markers and to IDOT's raised reflective pavement marker inspection policy. This paper presents the SRPM performance assessment methods and results.

Authors	Darren Torbic, Texas A&M Transportation Institute Richard Porter, VHB Jeff Gooch (jgooch@vhb.com), VHB Kristin Kersavage, VHB
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-01532
Paper Title	Safety Performance of Crossroad Ramp Terminals at Single-Point and Tight Diamond Interchanges
Abstract	Single-point diamond interchanges and tight diamond interchanges are two alternative interchange types that are considered in urban areas where right-of-way is usually limited. The Highway Safety Manual (HSM) predictive methods for freeways and interchanges could currently address freeway mainline, freeway-ramp terminal, and ramp proper safety performance associated with these interchange types. However, limited research has been conducted to compare the safety performance of the crossroad ramp terminals for these two alternative interchange designs, as would be necessary fora performance-based approach to interchange alternatives analysis. Planners, designers, and safety managers would benefit by having tools to compare the safety performance of these crossroad ramp terminals to make more informed decisions regarding their use and application in the urban environment. Research was undertaken with the objective to develop new intersection crash prediction models for crossroad ramp terminals at single-point diamond interchanges and crossroad ramp terminals at tight diamond interchanges. In general, it was found that the crash prediction models for crossroad ramp terminals at single-point diamond interchanges predict more crashes than the models for crossroad ramp terminals at tight diamond interchanges in higher volume conditions. The differences are primarily driven by the property-damage-only crash models. Comparisons of the crash prediction models suggest that the two sets of models appear compatible and provide reasonable results over the range of applicable traffic volume conditions.

Authors	Emanuele Sacchi (emanuele.sacchi@usask.ca), University of Saskatchewan Saeid Tayebikhorami, University of Saskatchewan
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01619
Paper Title	Evaluating the Effectiveness of the Safety Improvement Program in Saskatchewan Using a Full-Bayes Before-After Study
Abstract	Improving and maintaining acceptable levels of safety for rural roads is a major task for local highway agencies. For instance, the FHWA's "Safety Improvements on High Risk Rural Roads" manual assists local agencies in selecting the most effective ("proven") countermeasures and recommends an organized and systematic process for specific safety-related programs in a rural setting. A key step in this process is to determine whether the frequency and/or severity of collisions at the treatment sites have been reduced after the implementation of the program. This research focused on evaluating the safety performance of a sample of 50 locations that have been improved under the Saskatchewan Ministry of Highways and Infrastructure's (MHI) Safety Improvement Program (SIP). SIP projects were designed to reduce the frequency and severity of collisions on provincial highways in rural areas through the implementation of proven safety countermeasures. The methodology adopted for estimating the safety benefits was a before-after study with the full Bayes method. Overall, SIP was found to reduce total collisions by 14.8% and to reduce severe (fatal-plus-injury) collisions by 25.4%. The reduction of non-severe (property-damage-only) collisions was not found to be statistically significant at the 90% and 95% confidence levels. Also, crash modification factors (CMFs) for the two most frequent SIP treatments, i.e., right-turn lanes and delineation lighting at intersections, were estimated and compared to the results of the literature.

Authors	Linda Lim (ll9fu@virginia.edu), University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-02494
Paper Title	Development of Road Diet Segment and Intersection Crash Modification Factors
Abstract	Safety-based roadway design requires predictions of a design's safety consequences. In the USA, the tools for making these predictions are essentially empirical summaries of the driver and vehicle mix prevalent during the last 20 years or so, which are likely to change as vehicle automation becomes widespread. A major challenge facing safety researchers will then be to adapt, if possible, this extensive existing research to new and different conditions. This paper presents an exploratory investigation into how Bareinboim and Pearl's tools for "transportability" analysis can be used to adapt existing safety knowledge to new situations. Analytic results are presented and then applied to the problem of transporting a crash modification factor, associated with a change in left-turn lane offset, from a situation where no vehicle automation is present to a new situation containing vehicles equipped with automated emergency braking. Such analyses are feasible, when one has at hand a quantitative explanation of how a safety-related modification achieves its effect.

Authors	Marcus Brewer (m-brewer@tti.tamu.edu), Texas A&M Transportation Institute David Florence, Texas A&M Transportation Institute Brianne Glover, Texas A&M Transportation Institute Kay Fitzpatrick, Texas A&M Transportation Institute Steven Venglar, Texas A&M Transportation Institute Timothy Barrette, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Access Management (ACP60)
Session Number	1435
Session Title	Strengthening the Linkages between Geometric Design and Roadway Performance
Paper Number	21-03176
Paper Title	Super 2 Passing Lane Design: Operational and Economic Benefits
Abstract	Super 2 corridors with passing lanes provide operational benefits to traditional two-lane highways by creating passing opportunities and reducing delay and crashes, leading to increased use of Super 2 corridors across Texas. However, as more passing lane length is added, the more it may resemble a traditional four-lane alignment and reduce the unique benefits of a Super 2. Recent research investigated operational and economic benefits of Super 2 corridors compared to traditional four-lane and two-lane cross-sections. Researchers analyzed the operational performance of a simulated 40-mile corridor with varying average daily traffic (ADT); heavy vehicle volumes; and length, number, and spacing of passing lanes to identify benefits in key scenarios. Operational and benefit-cost inputs formed the basis of a model to quantify the relative economic benefits of Super 2 corridors. Operational analysis showed that, at volumes up to 17,000 vehicles per day, Super 2 cross-sections provided higher average minimum speeds and lower delay than other options with less than four lanes, though the two-lane cross-section with left-turn lanes had similar performance as Super 2 for volumes of 15,000 vehicles per day or higher. Economic analysis showed that Super 2 had the highest benefit-cost ratios in all scenarios. In both the economic and operational analyses, the findings agreed with previous research that adding shorter passing lanes to a Super 2 corridor is more beneficial than providing fewer but longer passing lanes.

Authors	Md Shakir Mahmud, Michigan State University Matthew Motz, Michigan State University Travis Holpuch, Michigan State University Anthony Ingle, Michigan State University Timothy Gates (gatestim@egr.msu.edu), Michigan State University Peter Savolainen, Michigan State University
Sponsoring Committee	Standing Committee on Traffic Control Devices (ACP55)
Session Number	1294
Session Title	Traffic Control Devices and Work Zones 2021
Paper Number	21-03363
Paper Title	Driver Response to a Dynamic Speed Feedback Sign on Freeway Exit Ramps based on Sign Location, Interchange Type, and Time of Day
Abstract	Roadway segments that include horizontal curves experience a disproportionate number of crashes compared to straight segments. Many of these crashes are lane departure-related, and excessive speed is often a contributing factor. One particularly vulnerable area for such crashes is freeway interchange ramps, which require a substantial reduction in speed to be safely negotiated. While dynamic speed feedback signs (DSFS) have been found to be an effective speed and crash reduction countermeasure at horizontal curves, the use of such signs on freeway interchange ramps has been limited nationwide. Consequently, the effectiveness of DSFS as a speed reduction countermeasure in such settings has remained largely untested. A before-and-after field evaluation was performed at three freeway exit ramps to assess the impacts of a DSFS on driver speed selection and braking characteristics while approaching and entering the ramp curves. The effectiveness of the feedback sign was tested across various conditions, including sign location, interchange type, time of day, light condition, and vehicle type. In general, the greatest benefits to driver behavior were achieved with the DSFS positioned at the point of curvature, during which curve entry speeds were reduced by approximately 2 mph compared to the pre-DSFS condition. These findings were consistent between the system- and service-interchanges and across all vehicle types. The DSFS was also found to be most effective during daytime off-peak periods compared to peak periods and at night. Based on the study findings, the continued use of DSFS as a speed reduction treatment at freeway exit ramps is recommended.

Authors	Qing Chang (qzc0010@tigermail.auburn.edu), Auburn University Md Atiquzzaman, Auburn University Huaguo Zhou, Auburn University Yukun Song, Auburn University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-03488
Paper Title	A Before-and-After Evaluation of Traditional Traffic Control Devices for Preventing Wrong-Way Driving at Freeway Off-Ramps
Abstract	This paper presents a before-and-after study of the effectiveness of traditional traffic control devices (TCDs) on preventing Wrong-Way Driving (WWD) at two partial cloverleaf (parclo) off-ramp terminals in Alabama. These two locations were selected because (1) they were identified as the high-risk locations for WWD; and (2) the traditional TCDs have been improved to mitigate the WWD activities. WWD incident data was collected from more than 800 hours of video surveillance before-and-after the countermeasures implementations at each location. At I-65 Exit 284 Southbound (SB) off-ramp terminal, the pavement marking was improved, including (1) repainted double yellow line and newly painted left-turn skip strips, and (2) yield line for off-ramp right-turn lane and stop bar for the left-turn lane at the end of the exit ramp. At I-65 Exit 208 SB off-ramp terminal, a raised-curb channelizing island was implemented as the first stage of improvement. At the second stage, the additional signages were installed on the channelizing island, and the double yellow line on the crossroad was repainted. For I-65 Exit 284 SB ramp, the improvements reduced 60% of the total and approximately 75% of nighttime WWD incidents. For I-65 Exit 208 SB ramp, the channelizing island alone implemented at the first stage resulted in an approximately 80% increase in WWD incidents, however the number decreased by approximately 50% after the improvements at the second stage.

Authors	Irfan Ahmed, University of Wyoming Mohamed Ahmed (mahmed@uwyo.edu), University of Wyoming
Sponsoring Committee	Standing Committee on Traffic Control Devices (ACP55)
Session Number	1294
Session Title	Traffic Control Devices and Work Zones 2021
Paper Number	21-03721
Paper Title	Impact of adverse wintry conditions on the effectiveness of centerline rumble strips - a case study of wyoming and colorado using before-after empirical bayes design
Abstract	Head-on crashes contribute towards the highest share of multi-vehicle crashes despite being a small percentage of overall crashes. Over the years, centerline rumbles strips (CLRS) have emerged as a cost-effective countermeasure to prevent head-on or cross-over-the-centerline crashes. The overall safety benefits of CLRS is well-proven in the literature. However, there are some anecdotal evidence of its reduced effectiveness during adverse wintry conditions. Since there was no quantitative research in this matter, this study aims to fill that gap. The overall safety effectiveness of CLRS in Wyoming and Colorado was quantified in this study by season; summer and winter. A before-after Empirical Bayes method was chosen to develop Crash Modification Factors (CMFs). Safety performance functions were developed to predict annual, summer, and winter Total, Property Damage Only, Fatal and Injury, as well as Target crashes. Expected crash reductions in Wyoming were found to be between 23% and 72% and those in Colorado ranged between 41% and 84%. The higher percentage of expected crash reductions were associated with the target crashes, head-on crashes. Results show that the CMFs obtained for Wyoming are higher than the ones for Colorado, which can be attributed to the winter maintenance efforts of the jurisdictions. Furthermore, winter CMFs were found to be higher than the summer CMFs suggesting the impact of accumulated snow or ice on reduced depth accompanied by reduced noise and vibration levels. Active and timely winter maintenance efforts are key to keep the CLRS free of snow or ice, thereby not reducing its effectiveness.

Authors	Raunak Mishra, University of North Carolina, Charlotte Srinivas Pulugurtha (sspulugurtha@uncc.edu), University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-03723
Paper Title	Evaluating the Safety Effectiveness of Restricted Crossing U-turn (RCUT) Intersections
Abstract	The focus of this paper is on evaluating the safety effectiveness of restricted crossing U-turn (RCUT) intersections. Both unsignalized and signalized RCUT intersections were evaluated using the Empirical Bayes (EB) before-after evaluation method. The forty-two RCUT intersections considered in this research were converted from a two-way stop-controlled (TWSC) intersection or signalized intersection in the rural and suburban areas. The results show a 73.27% reduction in the total number of crashes and a 79.42% reduction in the number of fatal and injury crashes at unsignalized stop-controlled RCUTs in the rural area. In the suburban areas, a 64.86% reduction in the total number of crashes and a 73.39% reduction in the number of fatal and injury crashes was observed. Further, a 10.15% and a 31.08% reduction in the total number of crashes, and an 84.26% and 31.13% reduction in the number of fatal and injury crashes was observed at signalized RCUTs in the rural and suburban areas, respectively. Overall, the unsignalized RCUTs in the rural areas with a larger sample size were found to be more safer than was observed by researchers in the past. These findings are useful to researchers and practitioners for making informed decisions and implementing RCUTs from a safety perspective.

Authors	MD Sultan Ali (mali043@fiu.edu), Florida International University Angela Kitali, Florida International University John Kodi, Florida International University Priyanka Alluri, Florida International University Thobias Sando, University of North Florida
Sponsoring Committee	Standing Committee on Bus Transit Systems (AP050)
Session Number	1393
Session Title	Bus System Operations, Technology, and Applications, Part 2 (Part 1, Session 1375)
Paper Number	21-03950
Paper Title	Safety Effects of Transit Signal Priority Using the Full Bayesian Approach
Abstract	Transit signal priority (TSP) is a strategy that prioritizes the movement of transit vehicles through a signalized intersection to provide better transit travel time reliability and minimize transit delay. Although TSP is primarily intended to improve the operational performance of transit vehicles, it may also have substantial safety benefits. This study explored the potential safety benefits of the TSP strategy deployed at various locations in Florida. An observational before-after full Bayes (FB) approach with a comparison-group was adopted to estimate the crash modification factors (CMFs) for total crashes, rear-end crashes, sideswipe crashes, and angle crashes. The analysis was based on 12 corridors equipped with the TSP system and their corresponding 29 comparison corridors without the TSP system. The deployment of TSP was found to reduce total crashes by 7.2% (CMF = 0.928), rear-end crashes by 5.2% (CMF = 0.948), and angle crashes by 21.9% (CMF = 0.781), and these results are statistically significant at a 95% Bayesian credible interval (BCI) except for the rear-end crashes. On the other hand, sideswipe crashes increased by 6% (CMF = 1.060) although the increase was not significant at a 95% BCI. Overall, the results indicated that TSP improves safety. The findings of this study may present key considerations for transportation agencies and practitioners when planning future TSP deployments.

Authors	Linda Lim (ll9fu@virginia.edu), University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-03955
Paper Title	Development of Road Diet Segment and Intersection Crash Modification Factors
Abstract	Road diets can offer potential safety improvements for both pedestrians and vehicles. The additional space provided by reducing the number of vehicular through-lanes can be reallocated into other uses such as bicycle lanes, parking, sidewalks, transit use, turn lanes, curb extensions, parklets, or pedestrian refuge islands. This study evaluated the safety effectiveness of road diets in Virginia using the Empirical Bayes (EB) method, focusing on the common road diet conversion from a four-lane roadway to a three-lane roadway with added bike lanes. A total of 37 segment sites and 39 intersections were identified in Virginia where road diet installations were implemented between the years 2009 to 2018. The analysis showed segment crash modification factors (CMFs) of 0.65 for total crashes and 0.41 for fatal and injury (FI) crashes. Across all intersection types, the CMFs were 0.61 for total crashes and 0.59 for FI crashes. All CMFs were found to be statistically significant at a 95% confidence level. When intersections where separated into signalized and unsignalized intersections, no significant safety benefit was found for unsignalized intersections, however. Based on the results, it is concluded that road diets can potentially reduce crashes and public agencies should consider the safety benefits of road diets when justifying roadway improvements.

Authors	Clemson University Wayne Sarasua, Clemson University Afshin Famili, Clemson University Jennifer Ogle, Clemson University William Davis, Citadel Military College Devesh Kumar, Clemson University Saurabh Basnet, Clemson University Emmanuel Adjei, Clemson University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1295
Session Title	Safety Performance and Analysis, Act 3: Evaluations, SPFs, and CMFs (Act 1, Session 1169; Act 2, Session 1202; Act 4, Session 1327)
Paper Number	21-04402
Paper Title	Assessing the Predictability of Short Segment Crash Analysis in the State of South Carolina
Abstract	The main objective of this research is to evaluate the predictability of a short segment peak search method with lengths of less than 0.1 miles for the statewide screening of midblock crash locations. Three different approaches (Based on HSM SPFs) are used to evaluate the short segment method. These approaches include state-specific SPFs, Driveway SPFs (using only AADT), and driveway SPFs with adjusted CMFs. Frequency-based identification of short segments stratified by six different roadway types (R2U, R4D, U2U, U4D, U3T, and U5T) has been compared with three SPF based screening methods to determine segments with the highest excess predicted average crash frequency. For short segment sites with highest crash frequencies (3 for U3T, U4D, and U2U; 4 for U5T and 2 for R4D and R2U), the comparison showed similar results (Top 90% agreement). Thus, should insufficient data be available to conclude SPFs, a frequency-based approach will likely identify the top sites. While this method works relatively well with top sites, the reliability of this method will wane with lower-ranked sites.

7 Surrogate Measures of Safety

Andrew P. Tarko, Raul Andres Pineda Mendez, Qiming Guo, and Xueqian Shi
Purdue University

Twenty-six papers related to surrogate safety measures were identified for this year. In most of the studies, the surrogate measures of safety were used as a primary approach to the safety analysis, whereas in a few studies it complemented the traditional crash-based approach.

From the review, the studies can be classified in five main topics: **intersections or interchanges**, **pedestrians**, **bicyclists and other non-motorized users**, **surrogate measures applications** (implementing the actual measures or proposing frameworks), **real-time safety monitoring** and **safety simulation**. Nine papers involved safety at **intersections or interchanges** (Ma et al., 21-01109; Hunter et al., 21-01539; Xu et al., 21-02527; Nassereddine et al., 21-03550; Samara et al., 21-03654; Wu et al., 21-00964; Chang et al., 21-03246; Zhang & Fricker, 21-01638; Xin et al., 21-01294). Likewise, **pedestrians, bicyclists and other non-motorized users** were investigated in three papers (Beauchamp et al., 21-01851; Zhang & Fricker, 21-01638; Xin et al., 21-01294). **Real-time safety monitoring** was investigated in five papers (Li & Abdel-Aty, 21-01697; Osman & Hajij, 21-03024; Samara et al., 21-03654; Azizi & Hadi, 21-02546; Peng et al., 21-01116). In addition, three papers were involved with **safety simulation** (Jiang et al., 21-01009; Svancara et al., 21-01459; He et al., 21-04355). Different **motion measures** such as acceleration, deceleration, braking, etc. were the main indicator or a complementary in fourteen articles (Park et al., 21-00094; Shen et al., 21-00588; Hunter et al., 21-01539; Prevedouros et al., 21-01590; Li & Abdel-Aty, 21-01697; Shangguan et al., 21-02639; Bharadwaj et al., 21-03149; Khattak et al., 21-03292; Gershon et al., 21-00800; Beauchamp et al., 21-01851; Pawar & Velaga, 21-01268; Osman & Hajij, 21-03024; Peng et al., 21-01116; Xin et al., 21-01294), while **surrogate measures applications** were addressed in seven papers (Park et al., 21-00094; Shen et al., 21-00588; Prevedouros et al., 21-01590; Shangguan et al., 21-02639; He et al., 21-04355; Chang et al., 21-03246; Ke et al., 21-04141).

Related to the surrogate measures of safety, **traffic encounters or conflicts** were used in fifteen papers (Zhang & Fricker, 21-01638; Xin et al., 21-01294; Jiang et al., 21-01009; Ma et al., 21-01109; Prevedouros et al., 21-01590; Xu et al., 21-02527; Bharadwaj et al., 21-03149; Khattak et al., 21-03292; Nassereddine et al., 21-03550; Svancara et al., 21-01459; Gershon et al., 21-00800; Beauchamp et al., 21-01851; Wu et al., 21-00964; Peng et al., 21-01116; Ke et al., 21-04141). As main traffic conflict indicator, **time-to-collision (TTC)** and **post-encroachment time (PET)** were used in ten articles. In two papers, the **TTC and PET** were used together as evaluation measures (Nassereddine et al., 21-03550; Beauchamp et al., 21-01851), in six papers the **TTC** value was used as main safety measure (Xu et al., 21-02527; Bharadwaj et al., 21-03149; Svancara et al., 21-01459; Osman & Hajij, 21-03024; Azizi & Hadi, 21-02546; Peng et al., 21-01116), while **PET** was used alone or as a complementary measure in two

articles (Ma et al., 21-01109; Wu et al., 21-00964). Also, three papers were found to use **other crash nearness measures** (Prevedouros et al., 21-01590; Beauchamp et al., 21-01851; Pawar & Velaga, 21-01268).

Regarding to the input data, ten papers had **video data** as primary source (Ma et al., 21-01109; Prevedouros et al., 21-01590; Nassereddine et al., 21-03550; Gershon et al., 21-00800; Beauchamp et al., 21-01851; Samara et al., 21-03654; Wu et al., 21-00964; Chang et al., 21-03246; Zhang & Fricker, 21-01638; Xin et al., 21-01294). **Vehicle trajectories** were used in eight articles (Shen et al., 21-00588; Xu et al., 21-02527; Nassereddine et al., 21-03550; Beauchamp et al., 21-01851; Wu et al., 21-00964; Peng et al., 21-01116; Chang et al., 21-03246; Xin et al., 21-01294). Information from **user trajectories** is used by Xin et al., 21-01294. **Naturalistic driving data** was the input of seven articles (Prevedouros et al., 21-01590; Shangguan et al., 21-02639; Bharadwaj et al., 21-03149; Khattak et al., 21-03292; Gershon et al., 21-00800; Osman & Hajij, 21-03024; Ke et al., 21-04141). **Ranging sensors** were used as main source of information in two articles (Nassereddine et al., 21-03550; Peng et al., 21-01116). **GPS and smartphones** data were utilized by four papers (Shen et al., 21-00588; Jiang et al., 21-01009; Hunter et al., 21-01539; Li & Abdel-Aty, 21-01697).

In terms of the data analysis, **statistical methods** were used in twelve articles (Park et al., 21-00094; Shen et al., 21-00588; Jiang et al., 21-01009; Xu et al., 21-02527; Shangguan et al., 21-02639; Bharadwaj et al., 21-03149; Nassereddine et al., 21-03550; Svancara et al., 21-01459; Gershon et al., 21-00800; Beauchamp et al., 21-01851; Pawar & Velaga, 21-01268; Zhang & Fricker, 21-01638). Also, **Machine learning algorithms** were implemented in ten papers (Shen et al., 21-00588; Li & Abdel-Aty, 21-01697; Khattak et al., 21-03292; Osman & Hajij, 21-03024; Azizi & Hadi, 21-02546; Wu et al., 21-00964; Peng et al., 21-01116; Chang et al., 21-03246; Ke et al., 21-04141; Xin et al., 21-01294).

Below, for each of the twenty-six papers involving surrogate measures of safety, the following information is provided: authors, sponsporing committee, session number, session title, paper number, paper title, and abstract. Papers are ordered according to their ID numbers.

Authors	Subin Park, Hanyang University, Ansan Cheol Oh, Hanyang University Shinhye Joo, Korea Transportation Safety Authority Sungmin Hong, Korea Transportation Safety Authority
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-00094
Paper Title	An Indicator for Evaluating Regional Safety Performance using In-vehicle Hazardous Driving Event Data
Abstract	The evaluation of traffic safety levels is a fundamental aspect of supporting the establishment of safety policies and technical countermeasures by local governments. Existing safety indices that use actual crash data have limitations for the achievement of more active safety enhancement because long-term data collection is required to obtain sufficient samples. A promising alternative is to use indirect safety measures, which can be further upgraded in the era of big data, in the evaluation of traffic safety. This study proposes a novel safety indicator based on in-vehicle hazardous driving event data that is obtained from on-board devices, called digital tachographs (DTG), in Korea. The DTG-based indicatorex for evaluating traffic safety (DIETS), which is a probabilistic measure for quantifying the safety levels of local governments, was developed based on binary logistic regression (BLR) analyses. Hazardous driving events identified from DTG data were analyzed to derive independent variables in BLR modeling. DIETS is expected to facilitate the effective decision-making of local governments for the development and implementation of safety policies.

Authors	Sijun Shen, Nationwide Children's Hospital Simon Lin, Research Institute at Nationwide Childrens Hospital Motao Zhu, Research Institute at Nationwide Childrens Hospital
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-00588
Paper Title	Using Machine Learning Algorithms and Fine Geo-resolution Vehicle Telemetric Data to Predict Crash Spots
Abstract	Background: The prevalence of mobile sensing platforms allows researchers to evaluate individual driver safety using vehicle telemetric data. However, no study has assessed the feasibility of using aggregated vehicle telemetric data to predict crash spots. Objectives: The objective of this study is to determine if the aggregated fine geo-resolution vehicle telemetric data can be used to predict crash likelihood for roadway segments. Methods: The telemetric data from the GEOTAB company were used. The GEOTAB company recorded the frequency of harsh acceleration, harsh braking, harsh cornering, and the average magnitude of those harsh events for every 150×150 meter2 roadway segments within Columbus, Ohio between January and April 2018. Crash history were obtained from the 2018-2019 Ohio Policy Accident Report. Regularized logistic regression (RLR) with lasso penalty and boosted decision tree (BDT) algorithms were used to develop the predicting models. Results: Aggregated vehicle telemetric data provided effective predictions for crash spots (Area under curve [AUC] ≥ 0.73). Models' predictive performance can be further improved if both vehicle telemetric variables and crash history were included in the models (AUC ≥ 0.77). The BDT models had superior predictive performance than the RLR models, due to its capability of incorporating complex relationships (e.g., non-linearity and all-way interactions) between predicting and predicted variables. Conclusion: Our study demonstrates the utility of geo-resolution vehicle telemetric data to predict crash spots. Aggregated vehicle telemetric data provide valuable information for crash likelihood monitoring and thereby, enable implementation of timely safety interventions by police and city planner.

Authors	Pnina Gershon, Massachusetts Institute of Technology (MIT) Johnathon Ehsani, Johns Hopkins University Kellienne Sita, National Institutes of Health Chunming Zhu, National Institutes of Health Sheila Klauer, VTTI Tom Dingus, VTTI Bruce Simons-Morton, VTTI
Sponsoring Committee	Standing Committee on Vehicle User Education, Training, and Licensing (ACH60)
Session Number	1070
Session Title	Individual Presentations on Driver Safety for High Risk Drivers
Paper Number	21-00800
Paper Title	Vehicle Access of Novice Teen Drivers and The Risk for Crash/Near-Crash Events
Abstract	Introduction: To develop safe driving skills, novice teens need to drive to accumulate experience, at the same time crash risk increases the more one drives, so to what extent should extensive driving early in licensure be encouraged? This study examines the association between vehicle access, driving exposure, and the subsequent crash/near-crash risk during teens first year of independent driving. Methods: Real-world driving data were collected in a naturalistic cohort study of 82 newly-licensed teens (16.48 years-old, SD=0.33). Participants' private vehicles were equipped with data acquisition systems that documented driving kinematics, miles driven, and video recordings of the driver and the driving environment. Vehicle access was determined by an objective evaluation of the primary vehicle user. A Multivariable Cox proportional hazard regression model was used to estimate adjusted hazard ratio [aHR] for a crash/near-crash event according to vehicle access. Results: During the first year of licensure, teens with primary vehicle access (67%) drove about five times more miles and had four times more crash/near-crash events than teens with shared access. While crash/near-crash rates per miles driven between groups were similar, the cumulated risk for crash/near-crash involvement was more than double for teens with primary compared to teens with shared vehicle access (aHR: 2.02, 95%CI: 1.14-3.57). Discussion: Novice teens learn to drive mainly through experience over time. Concentrated exposure early after licensure, which characterize teens with primary vehicle-access, is associated with elevate crash/near-crash risk. Parental involvement in titrating teens' vehicle access at least during their first year of independent driving is recommended.

Authors	Yina Wu, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Ou Zheng, University of Central Florida Jinghui Yuan, University of Central Florida
Sponsoring Committee	Standing Committee on Information Systems and Technology (AED30)
Session Number	1250
Session Title	Information Systems and Technology
Paper Number	21-00964
Paper Title	Road Safety Diagnostics using Roadside Video Data Based on Car Pose Detection
Abstract	Near miss identification and analysis is prevalent in recent years. Video data that could provide high-resolution trajectories is one of the important data sources to identify near misses that happen on roadways. This study proposed a framework named "Near Miss Event Detection System (NMEDS)" for road safety diagnostics using video data collected from roadside video cameras. The proposed framework could obtain more accurate vehicles' trajectory and better identify conflicts/near misses from the video images. Mask-RCNN and Channel and Spatial Reliability Tracking (CSRT) multi-object tracking are used to detect and track the vehicles in videos. Occlusion-Net is employed to detect and predict the key points of vehicles, including right-front headlight, left-front headlight, right-back taillight, and left-back taillight. The key points could provide more precise vehicle occupying locations compared with the bounding boxes generated based on Mask-RCNN. Moreover, the locations of the occluded key points are modified based on 2D bird views. Then, more precise post-encroachment time (PET) values could be calculated based on the modification. Near misses/conflicts could be identified by comparing the PET values and thresholds. A case study is presented at a typical intersection. The results indicate that the proposed framework has better performance for vehicle localization. Besides, more reasonable near misses could be obtained. It is expected that the proposed methods could help diagnose road safety problems using roadside video cameras. Moreover, the proposed method could be incorporated with Connected Vehicle Systems and provide information to nearby drivers based on Infrastructure-to-Vehicle (I2V) technologies.

Authors	Shan Jiang, Rutgers University Mohsen Jafari, Rutgers University Mohammad Jalayer, Rowan University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01009
Paper Title	Safe Route Mapping of Roadways Using Multiple Sourced Data
Abstract	The use of systematic techniques with historical crash data and qualitative measures has long been a common practice to identify the problematic road features and develop countermeasures to mitigate the crash risk in crash-prone locations. This paper proposes a novel approach, Safe Route Mapping (SRM) model that integrates crash-based estimates with conflict risks computed from driver-based data to score the safety of roadways. An advanced Safety Performance Function (SPF) estimates the number of crashes, and a driver-based model calculates dynamic conflict risk measures from driver and traffic data. In real-life implementations of the proposed methodology, the driver-based data and traffic data can be collected from vehicles or infrastructure-based data sources, including smartphones. We demonstrated the methodology using real historical crash data and simulated driver-based data obtained from VISSIM and SSAM. We show safety risk heat maps for the example roadway and illustrate how these maps change with driver types and traffic volumes. The proposed methodology fills the existing gaps in the use of near real-time dynamic data to designate safe corridors, dispatch law enforcement, and plan safety projects. Drivers can also use the road heat maps for situational awareness and trip planning. Keywords: Safe Route Mapping, Crash prediction, Real-time risk scoring, Safety Performance Function, Dynamic risk heat map.

Authors	Yanli Ma, Harbin Institute of Technology Jieyu Zhu, Harbin Institute of Technoloy Ke Chen, Heilongjiang Provincial Highway Survey and Design Institute
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01109
Paper Title	Left-turn Conflict Identification at Signal Intersections Based on Vehicle Trajectory Reconstruction Via Kalman Filtering
Abstract	To reduce traffic accidents at signal intersections, it is significant to investigate the conflict identification between left-turning vehicles and straight vehicles in the opposite direction. The trajectory data of vehicles can be used to identify real-time conflicts in intersections. To perform such identification, accurate vehicle localisation should be obtained to clearly recognise the conflicts between left-turning vehicles and straight vehicles in the opposite direction at the signal control intersection. On the basis data collection of coordinate position, velocity, acceleration and yaw Angle of vehicles, Kalman filter algorithm was used to estimate the vehicle trajectory to obtain the vehicle kinematics information via the on-board system. The traffic conflict areas of the left-turning vehicles and straight vehicles in the opposite direction were determined through vehicle trajectory extrapolation, and the left-turn collision at the signal intersection was identified using the post-encroachment time algorithm and vehicle movement information. In addition, Anderson–Darling and modified Kolmogorov–Smirnov tests were performed to verify the goodness of fit of the data. Results show that the vehicle speed and localisation errors of the proposed method decreased by 66.67% and 83.33% compared with the results before filtering, respectively. Moreover, the results of the conflict recognition method based on trajectory reconstruction is consistent for both goodness of fit tests. This study can provide driving decision for drivers of left-turning vehicles and provide technical support for the research and development of left-turn anti-collision systems.

Authors	Lingfeng Peng, Wuhan University of Technology Nengchao Lyu, Wuhan University of Technology Chaozhong Wu, Wuhan University of Technology
Sponsoring Committee	Standing Committee on Information Systems and Technology (AED30)
Session Number	1250
Session Title	Information Systems and Technology
Paper Number	21-01116
Paper Title	Predicting crash risk in real-time using vehicle trajectory and Surrogate Safety Measures
Abstract	An effective real-time crash prediction model (RTCPM) is crucial to active traffic safety management systems. RTCPMs use real-time traffic flow status to predict crashes in a critically brief time window. Traditional RTCPMs are usually based on actual crash records from specific locations and aggregated traffic data within a certain period. However, actual crash records are comparatively rare to normal traffic records, and aggregated traffic data does not reflect interaction between vehicles. This paper proposes a new feature parameter framework based on driving trajectories, surrogate safety measures (SSM), and machine learning to establish a real-time crash risk prediction model for use by traffic management to implement safety strategies. and then uses machine learning to establish a real-time crash risk prediction model for predicting conflicts. A microwave radar detector was used to obtain the real-time positions and speeds of vehicles in the detection area, and traffic trajectory data processing was used to extract the traffic flow parameters and several typical SSMs. Through the combination of time-to-collision (TTC)s value, rapid deceleration rates and manual observations, crash risk events were extracted. The feature parameters from 1-2 minutes before conflict events and normal traffic were used as the model input to construct a sample set. The random forest algorithm (RF) and synthetic minority oversampling technique (SMOTE) were used to process the sample set, filter the most important features and balance the number of positive and negative samples. Finally, a real-time crash risk prediction model based on the support vector machine (SVM) was established. The results show that the prediction model proposed herein detected conflict events with a 94.7% accuracy, 95.2% recall and 5.8% false-positive rate. As such, it can be reliably used for active traffic safety management.

Authors	Nishant Pawar, Indian Institute of Technology, Bombay Nagendra Velaga, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-01268
Paper Title	A Proactive Safety Approach to Assess Overtaking Behavior and Crash Risk of Drivers under Time Pressure Situations
Abstract	The aim of the current study is to assess the driving behavior, overtaking and crash probabilities of drivers during a car-following situation. Three different time pressure conditions (i.e., No Time Pressure (NTP), Low Time Pressure (LTP), and High Time Pressure (HTP)) were considered to analyze driving behavior during car-following and overtaking as well as crash probabilities. Minimum Time-to-Line Crossing (TLC) and Coefficient of Variation in Speed (CVS) were considered to examine driving behavior while following the lead vehicle. Further, minimum TLC and CVS were considered as explanatory variables to explore their influence on overtaking and crash probabilities. Minimum TLC was modelled using parametric survival analysis. CVS, overtaking and crash probabilities were modelled using Generalized Linear Mixed Models. The results showed that minimum Time-to-Line crossing reduced by 36.7% and 63.8% in LTP and HTP driving conditions, respectively. The Coefficient of Variation in Speed increased by 3.437% in HTP (no significant effect in LTP). The drivers using a car for work purpose and non-professional drivers showed aggressive driving behavior with low minimum Time-to-Line Crossing and Coefficient of Variation in Speed. The increase in overtaking probability (with time pressure) exposed drivers to greater collision risks which increased the likelihood of crashes. In general, male drivers showed more risky driving decisions than female drivers under time pressure conditions. However, it was observed that female drivers were more prone to crashes than male drivers. Overall, the results suggest that drivers take more risk to complete the driving task under time pressure conditions.

Authors	Feifei Xin, Tongji University Chongjing Sun, Tongji University Xiaobo Wang, Tongji University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	1099
Session Title	Exposure to Risk, Stress, Conflicts, and Crashes: Innovative Pedestrian Safety Analysis Methods
Paper Number	21-01294
Paper Title	Risk Analysis and Evaluation for Conflicts between Crossing Pedestrians and Right-turning Vehicles at Intersections
Abstract	In recent years, the conflicts between crossing pedestrians and right-turning vehicles have become more severe at intersections in China, where right-turning vehicles are usually not controlled by traffic signals. Pedestrian safety is increasingly important, but few studies have addressed this issue. In this study, we propose a quantitative method for evaluating the conflict risk between pedestrians and right-turning vehicles at intersections based on micro-level behavioral data obtained from field surveys and video recordings. A typical intersection in Shanghai was selected as the study site. In total, 670 min of video were recorded during the peak hours from 7:30 AM to 9:30 PM. After processing the video information, we obtained vehicle and pedestrian tracking data, including the velocity, acceleration, deceleration, time, and location coordinates. Based on these data, we proposed several conflict indicators and extracted these indicators automatically using MATLAB to identify pedestrian–right-turning vehicle conflicts and to determine the severity of the conflicts identified. We identified 93 conflict examples. The conflict risks were quantitatively classified using the K-means fuzzy clustering method and all of the conflicts were assigned to five grades. We also analyzed the characteristics of the conflict distribution and the severity of different types of conflict, which showed that conflicts on different areas on the crosswalk differed in their severity.

Authors	Austin Svancara, University of Alabama, Birmingham Rajesh Kana, University of Alabama Haley Bednarz, University of Alabama, Birmingham Gabriela Sherrod, University of Alabama, Birmingham Kristina Visscher, University of Alabama, Birmingham Benjamin McManus, University of Alabama, Birmingham Despina Stavrinos, University of Alabama, Birmingham
Sponsoring Committee	Standing Committee on Vehicle User Education, Training, and Licensing (ACH60)
Session Number	1070
Session Title	Individual Presentations on Driver Safety for High Risk Drivers
Paper Number	21-01459
Paper Title	Time-to-Collision Estimations Among Drivers with Developmental Disabilities: Learning Effects and Cognitive Factors
Abstract	Background: Drivers with Autism Spectrum Disorder 1 (ASD) and Attention-Deficit/Hyperactivity Disorder 2 (ADHD) have a higher crash risk compared to typically developing (TD) individuals. The elevated crash risk may be due to their associated, but distinct, symptomologies (e.g., cognitive functioning 3,4). One aspect of driving not well-explored among drivers with developmental disabilities is the ability to judge time-to-collision (TTC), an important perceptual ability that precedes vehicle braking/maneuvering to avoid collisions. 5 Large TTC estimates could present potential safety risks to drivers. The goal of the present project was to examine TTC estimates among drivers with ASD and ADHD and the potential learning effects that may occur within a TTC estimation task, and to identify cognitive correlates of TTC estimations among these at-risk drivers. Methods: Fifty-five licensed drivers (n ASD = 16, n ADHD = 20, n TD = 19) were recruited into three age, gender, and IQ matched groups (M age = 20.63, 60% male, M IQ = 107.89). Performance-based cognitive abilities were assessed using a Time Reproduction task (time perception [TP]), the Useful Field of View – Selective Attention subtest (selective attention [SA]), Wechsler Adult Intelligence Scale – Digit Span (working memory [WM]), Wechsler Abbreviated Scale of Intelligence – Vocabulary and Matrix Reasoning (intelligence [IQ]), and executive function (EF) was measured with the Behavior Rating Inventory of Executive Function – Self Report. Participants completed 60 trials on a TTC estimation task in a high-fidelity driving simulator (during half of the trials the vehicle moved 30mph and 60mph for the other half). As the participant moved forward, a vehicle would intermittently appear and disappear ahead of them. The gap between the participant and the moment of disappearance was the true TTC interval. Participants pressed a button when they thought a collision would have occurred had the target vehicle remained on screen. TTC accuracy (a ratio of the TTC estimate and the true TTC interval) was calculated for each TTC trial. Results: Drivers with ASD (p <.001) and drivers with ADHD (p <.001)

	reported greater EF difficulty compared to TD drivers, there were no differences on performance-based cognitive measures. A linear mixed regression revealed drivers with ASD produced larger TTC estimates over time (β=0.02, p =.040), and with higher speed (β=0.09, p =.013). Across all groups, higher TTC accuracy scores were significantly predicted by higher TP accuracy (β=0.05, p =.04), poorer SA (β=-0.05, p =.020), higher IQ (β=0.06, p =.008), and greater reported EF difficulty (β=0.11, p <.001). See Figure 1 and Table 1 to view group differences on all outcomes. Discussion: Drivers with ASD, compared to TD drivers, produced larger TTC estimates in the 60mph condition, which may present an area of safety concern for this group of vulnerable drivers. A larger TTC estimate may result in smaller windows for braking. Performance-based cognitive measures suggest higher cognitive functioning is associated with larger TTC estimates. Individuals with higher cognitive functioning may perceive themselves better capable to react to impending collisions. However, self-perceived EF difficulty is also related to larger TTC estimates. Future research should explore how individuals with higher and lower cognitive functioning use TTC information to inform their driving.

Authors	Margaret Hunter, Purdue University Enrique Saldivar-Carranza, Purdue University Jairaj Desai, Purdue University Jijo Mathew, Purdue University Howell Li, Purdue University Darcy Bullock, Purdue University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01539
Paper Title	A Proactive Approach to Evaluating Intersection Safety Using Hard-braking Data
Abstract	Typical safety improvements at signalized intersections are identified and prioritized using crash data over 3-5 years. Enhanced probe data that provides date, time, heading, and location of hard-braking events has recently become available to agencies. In a typical month, over six million hard-braking events are logged in the state of Indiana. This study compared rear-end crash data over a period of 4.5 years at 8 signalized intersections with weekday hard-braking data from July 2019. Using Spearman's rank-order correlation, results indicated a strong correlation between hard-braking events and rear-end crashes occurring more than 400 ft upstream of an intersection. The paper concludes that hard-braking events occurring at a far distance from the stop bar may be a useful tool to screen potential locations of rear-end crashes and follow up with mitigation measures quicker than the 3-5 year cycle used by agencies that rely on crash data. Now that hard-braking data is commercially available in the United States, these techniques scale quite easily to state and national levels for near immediate implementation.

Authors	Panos Prevedouros, University of Hawaii Braxton Chong, University of Hawai'i, Manoa Luana Pereira,, University of Hawai'i, Manoa
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01590
Paper Title	Analysis of Speed Profiles of Near-Misses from On-Board Cameras in Taxicabs
Abstract	Partly due to the pre-Covid-19 booming economy and the increasing numbers of distracted motorists and other road users, safety risk (and insurance premiums) increased substantially making liability reduction via monitoring, evaluation and coaching necessary for professional drivers. The CEE Department at the UH, in collaboration with taxi and tour operators in Hawaii have deployed state-of-the-art in-vehicle video monitoring equipment; the UH team assists in the creation of a naturalistic driving database based on accelerometer-triggered "harsh events" that record video clips starting ten seconds before the harsh event and ending ten seconds after the event. Near misses are manually inspected and then coded recorded harsh events with an observable traffic safety risk which could have caused property damage or more serious outcomes. A number of variables are recorded for each near miss event including description of the event, the vehicles and people involved, environmental and roadway factors, and accelerometer/onboard data such as g-force and speed profile. The goal of this research was to analyze the speed profiles by type of incident and level of speed: up to 20 mph, 21 to 35 mph, and over 35 mph and present observable trends and differences in the speed profiles. Nearly 300 speed profiles were subjected to a preliminary analysis herein. The accumulation of more cases is necessary for statistically significant inferences.

Authors	Yunchang Zhang, Purdue University Jon Fricker, Purdue University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	1099
Session Title	Exposure to Risk, Stress, Conflicts, and Crashes: Innovative Pedestrian Safety Analysis Methods
Paper Number	21-01638
Paper Title	Incorporating Conflict Risks in Pedestrian-Motorist Interactions: A Game Theoretical Approach
Abstract	At "semi-controlled" crosswalks with yield signs and markings, negotiations as to the right-of-way occur frequently between pedestrians and motorists, to determine who should proceed first. This kind of "negotiation" often leads to traffic delay and potential conflicts. To minimize misunderstandings between pedestrian and motorist that can have serious safety consequences, it is essential that we understand the decision-making process as they interact in real street-crossing situations. This paper employs a game-theoretic approach to investigate the joint behaviors of pedestrians and motorists from the perspective of safety. Assuming bounded rationality for each player, the quantal response equilibrium is a special kind of game with incomplete information. Explanatory variables such as conflicting risks and time savings can be incorporated into the payoff functions of the "players" via expected utility functions. Finally, model parameters can be estimated using an expectation maximization algorithm. The game-theoretic framework is applied to model pedestrian-motorist interactions at a semi-controlled crosswalk on a university campus. The estimation results indicate that the likelihood of pedestrian-vehicle conflict can be quantified. The results can lead to control measures that facilitate the negotiation between pedestrian and motorist and reduce the conflict risk at semi-controlled crosswalks.

Authors	Pei Li, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-01697
Paper Title	Trajectory Fusion-based Real-Time Crash Likelihood Prediction Using LSTM-CNN with Attention Mechanism
Abstract	Real-time crash likelihood prediction plays a crucial role in the proactive traffic safety management system. Most of the existing studies obtained traffic data from fixed devices, such as loop detectors, Bluetooth detectors, cameras, etc. However, these devices are not flexible enough to deploy at a large-scale and collect city-wide traffic data. With the help of mobile sensing technologies, vehicle-based data (e.g., GPS trajectory, connected vehicles data) are becoming more popular. Nevertheless, only a few studies investigated the application of this novel data for crash likelihood prediction with limited vehicle types. In addition, crash likelihood prediction using deep learning methods, especially Recurrent Neural Networks (RNNs), has received much attention in recent years. However, temporal attention, a powerful mechanism for learning time-series data, was ignored by all of the studies related to crash likelihood prediction. This paper utilized data fusion techniques to integrate two real-world trajectory datasets with a variety of vehicles. The traffic conditions of urban arterials were described with various speed-related features (e.g. average speed, standard deviation of speed, etc.). To predict the crash likelihood for arterials, this paper designed a deep learning architecture (TA-LSTM-CNN) containing a Long Short-term Memory (LSTM) with temporal attention and a Convolutional Neural Network (CNN). Experimental results indicated that the proposed method could achieve outstanding performance (e.g. high sensitivity and low false alarm rate) for the real-time crash likelihood prediction with the help of trajectory data fusion. Further, model comparison results suggested that the proposed model outperformed other state-of-the-art models in terms of various metrics.

Authors	Etienne Beauchamp, Ecole Polytechnique de Montreal Nicolas Saunier, Ecole Polytechnique de Montreal Marie-Soleil Cloutier, Institut National de la recherche scientifique
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01851
Paper Title	Study of Automated Shuttle Interactions in City Traffic Using Surrogate Measures of Safety
Abstract	Driving automation is happening at a rapid pace, with different driver assistance systems already available in mass-market cars. However, this rapid development in driving automation leads to concerns and questions about their impact on safety, in particular for vulnerable road users. While previous studies have been restricted to incident reports and simulation tools, the safety of automated vehicles (AVs) is not clearly demonstrated. Instead of crashes, which are extremely rare events, this study uses surrogate measures of safety (SMoS) to analyze the interactions between road users and low-speed automated shuttles that circulated in Montréal and Candiac, in Canada, during two pilot projects in mid and late 2019. Cameras were placed at seven intersections along the routes of the shuttles. More than 70 hours of footage were processed to extract the road user trajectories using computer vision techniques and compute various safety indicators: speed, acceleration, time headway, time-to-collision (TTC) and post-encroachment time (PET). The Kolmogorov–Smirnov test was used to compare the distributions of interactions involving AVs with the distributions of interactions involving motorized vehicles following paths similar to those of the AVs. The results indicate that these automated shuttles behave generally more safely: their speeds and accelerations are lower and their interactions are characterized by higher TTCs and PETs, notably with vulnerable road users. However, small headway times at one site with high speed differentials between the shuttles and other following vehicles raise concerns that warrant further research into the suitable context for these vehicles.

Authors	Xiaoyan Xu, Tongji University Xuesong Wang, Tongji University Xiangbin Wu, Intel Labs China Yu Lin, Shanghai SH Intelligent Automotive Technology Co., Ltd. Xinyi Hou, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-02527
Paper Title	Examining Causal Factors of Traffic Conflicts at Intersections Using Vehicle Trajectory Data
Abstract	Conflict severity is the outcome of complex interactions between roadway and environmental characteristics, and vehicle motion. Understanding how and to what extent a vehicle is influenced by roadway and surrounding road users during a conflict can help to analyze the causal mechanisms of collisions, thus providing insights into roadway safety improvement countermeasures. This study utilized the NGSIM Peachtree Street vehicle trajectory dataset to achieve the objective of investigating causal factors of conflicts at intersections by exploring roadway-to-vehicle and vehicle-to-vehicle interactions. In order to remove the outliers and white noise existing in the raw data, vehicle trajectories were reconstructed by discrete wavelet transform and Kalman filtering. The generalized time-to-collision was adopted to detect and measure the severity of conflicts, and 423 conflict events were finally extracted. Path analysis models were then established to explore in exactly which ways the roadway-to-vehicle and vehicle-to-vehicle interactions were related to conflict severity. Various roadway and environmental characteristics such as traffic flow's average speed, percentage of trucks and intersection skew angle were included in the models. The results indicate the roadway and environmental characteristics have both direct and indirect effects on conflict severity; while for the indirect effects, the conflict vehicle's kinematics such as the average and standard deviation of speed play an intermediate role in linking roadway factors and conflict outcome. The framework of this study can be applied to assessing roadway readiness for both human-driven and automated vehicles.

Authors	Leila Azizi, Central Transportation Planning Staff (CTPS) Mohammed Hadi, Florida International University
Sponsoring Committee	Standing Committee on Intelligent Transportation Systems (ACP15)
Session Number	1110
Session Title	Intelligent Transportation Systems 2021, Part 1
Paper Number	21-02546
Paper Title	Utilizing Traffic Disturbance Metrics to Estimate and Predict Freeway Traffic Breakdown and Safety Events
Abstract	The introduction of connected vehicles, connected and automated vehicles, and advanced infrastructure sensors will allow the collection of microscopic metrics that can be used for better estimation and prediction of traffic performance. This study examines the use of disturbance metrics in combination with the usually used macroscopic metrics for the estimation of traffic safety and mobility. The utilized disturbance metrics are the number of oscillations and a measure of disturbance durations in terms of the time exposed time–to–collision (TET). The study investigates utilizing the disturbance metrics in data clustering for better off-line categorization of the traffic states. In addition, the study utilizes machine-learning based classifiers for the recognition and prediction of the traffic state and safety in real-time operations. The study also demonstrated that the investigated disturbance metrics are significantly related to crash. Thus, this study recommends the use of these metrics as part of decision support tools that support the activation of transportation management strategies to reduce the probability of traffic breakdown, ease traffic disturbances, and reduce the probability of crashes.

Authors	Qiangqiang Shangguan, Tongji University Ting Fu, Tongji University Rui Jiang, Shandong Hi-Speed Group Shou'en Fang, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-02639
Paper Title	Use of Naturalistic Driving Data to Quantify Influencing Factors of Driving Risk based on a New Surrogate Measure of Safety
Abstract	Traditional surrogate measures of safety (SMoS) do not fully consider the crash mechanism or fail to consider the crash probability and consequences at the same time. In addition, driving risks are constantly changing with driver's personal characteristics and environmental factors. However, few studies have considered the impact of driver's behavior characteristics and environmental factors on driving risks. To address the above research gaps, 16,905 car-following events were extracted from Shanghai Naturalistic Driving Database. A new SMoS, named rear-end crash risk index (RCRI), was proposed to identify driving risks. Performance of RCRI and traditional SMoS were compared. Using this measure, a risk comparative analysis was conducted to study the impact of factors from different facets in terms of weather, temporal variables and traffic conditions. Then, a mixed-effects linear regression model was applied to investigate the relationship between various influencing factors and driving risks. Results show that RCRI has better performance over other traditional SMoS because it can describe dynamic changes in risks and can be applied to any car-following scenarios. The comparative analysis indicates that high traffic density, workdays and morning peaks lead to higher risks. Moreover, results from the mixed-effects linear regression model suggest that driver's behavior characteristics, traffic density, day-of-week (workday v.s. holiday) and time-of-day (peak hour v.s. off-peak hour) had significant effects on driving risks. The study provides a SMoS that can better identify driving risks in a more reliable way. Results can be applied to real-time risk prediction and traffic management to improve driving safety.

Authors	Osama Osman, University of Tennessee, Chattanooga Mustafa Hajij, Santa Clara University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-03024
Paper Title	Crash Prediction for Advanced Driver Assistance Systems: Development and Comparative Analysis of Advanced Deep Learning Techniques
Abstract	Motor vehicle crashes have claimed the lives of 38,800 lives and caused 4.4 million injuries in 2019 alone. Studies have shown that 94% of these crashes are because of driver errors. Such a huge contribution of driver errors to crashes points out that efforts to improving safety should be directed towards both vehicles and drivers through advanced driver assistance systems (ADAS) and vehicular technologies. This study investigates the potential realtime data collected through vehicular technologies on driver behavior offer to predict crashes as a first line of defense to avoid them. Three deep learning models were developed including multilayer perceptron neural networks (MLP-NN), long-short-term memory networks (LSTMN), and convolutional neural networks (CNN) using vehicle kinematics time series data extracted from the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS) dataset. The study builds on the hypothesis that crashes are preceded by turbulences that take place over time (turbulence horizon). If these turbulences are detected in a timely manner they can help predict and avoid crashes. Several values were tested for the turbulence horizon and the prediction horizon (how long before the crash impact it can be predicted) to identify the optimal values. The results showed that the CNN model can predict all crashes with a 100% accuracy and zero false alarms 3 seconds before the crash impact time, when a 6-second turbulence horizon is used. This outstanding performance presents the developed model as a promising tool for implementation in ADAS.

Authors	Nipjyoti Bharadwaj, NRC Research Associateship Praveen Edara, University of Missouri, Columbia Carlos Sun, University of Missouri, Columbia, Ellis Library
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-03149
Paper Title	Examining Vehicle Kinematics of Rear-End Safety-Critical Events using Naturalistic Driving Data
Abstract	Car crashes can occur in a variety of ways. A common type of collision involving two vehicles is when one vehicle rear-ends another vehicle. This study describes a methodology to understand the braking judgments in rear-end safety-critical events, i.e., crashes and near-crashes, using naturalistic driving study (NDS) data collected as part of USDOT's Second Strategic Highway Research Program (SHRP 2). A small subset of the rear-end events involving younger drivers (16-19 years old) were used to illustrate the proposed methodology. Kinematic measures such as the inverse time-to-collision (TTC) were used to compare braking performances for crashes and near-crashes. The deceleration of the follower vehicle was modeled using Linear Regression. The independent variables are inverse TTC, deceleration of the lead vehicle, and speed of the follower vehicle. The study also demonstrated that range vs. range rate plots are useful to identify the follower's reaction (i.e., onset of braking) in response to the lead vehicle's deceleration. The average TTC value for the crash and near-crash events at the onset of braking was 0.9 seconds and 1.92 seconds, respectively. All safety-critical events analyzed in this study experienced TTC values lower than 3 seconds. This study also developed representative plots of range versus range rates during braking that clearly delineate the boundaries between a crash and a near-crash. The kinematic differences between a crash and a near crash discerned in this study can be useful for designing collision avoidance and driver assistance systems.

Authors	Qing Chang, Auburn University Jiaxiang Ren, Auburn University Huaguo Zhou, Auburn University Yang Zhou, Auburn University Yukun Song, Auburn University
Sponsoring Committee	Standing Committee on Information Systems and Technology (AED30)
Session Number	1250
Session Title	Information Systems and Technology
Paper Number	21-03246
Paper Title	Identifying Wrong-Way Driving Incidents from Regular Traffic Videos Using Unsupervised Trajectory-based Method
Abstract	Currently, transportation agencies have implemented different Wrong-Way Driving (WWD) detection systems based on loop detectors, radar detectors, or thermal cameras. Such systems are often deployed at fixed locations in urban areas or on toll roads. A majority of rural interchange terminals does not have real-time detection systems for WWD incidents. Portable traffic cameras are used to temporarily monitor WWD activities at rural interchange terminals. However, it has always been a time-consuming task to manually review those videos to identify WWD incidents. The objective of this study is to develop an unsupervised trajectory-based method to automatically detect WWD incidents from regular traffic videos (not limited by mounting height and angle). The principle of the method includes three primary steps: vehicle recognition and trajectory generation, trajectory clustering, and outlier detection. This paper also developed a new sub-trajectory-based metric that makes the algorithm more adaptable regarding vehicle trajectory classification in different road scenarios. Finally, the algorithm has been tested through analyzing 357 hours of traffic videos from 14 partial cloverleaf interchange terminals in 7 states in the U.S. The results suggested that the method could identify all the WWD incidents with 80% accuracy rate. The method significantly reduced man-hours for reviewing the traffic videos. Additionally, The new method can also be applied in detecting and extracting other kinds of abnormal traffic activities, such as illegal U-turns.

Authors	Zulqarnain Khattak, Oak Ridge National Laboratory Michael Fontaine, Virginia Transportation Research Council Asad J. Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-03292
Paper Title	Identification of Safety Critical Events from Vehicle Kinematic Data using Convolutional Neural Networks
Abstract	This study developed a deep learning approach based on 1D convolutional neural networks (CNN) for detection of safety critical events (SCEs) using large-scale naturalistic driving vehicle kinematics data. The data are unique in the sense that such accurate pre-crash data at high fidelity are not available in traditional crash repositories. This study contributes to the literature by providing a first attempt at predicting responses to SCEs by applying Artificial Intelligence techniques. Specifically, the study develops deep learning-based CNN architectures for identification of SCEs using driving volatility based kinematic thresholds. The key contribution lies in developing a CNN input layout that is acceptable to CNN schemes and represents the motion kinematics such as speed acceleration and volatility measures. Several 1D-CNN architectures were developed using layers numbers of convolutions, layer patterns, and kernels. Shallow and deep architectures were tested, revealing higher accuracy of shallow architectures in detecting SCEs. The optimal number of epochs were identified using an early stopping method while the CNN performance was improved by increasing the number of epochs. The ensemble CNN had the highest predictive accuracy of 95.6%, which was 2.5% higher than the optimal CNN using test data. The ensemble CNN also outperformed classical machine learning models and model performance reported in past studies on detection of SCEs. These results have implications for identification of safety hotspots and providing real-time alerts and warnings in connected and automated vehicle environment.

Authors	Hiba Nassereddine, University of Wisconsin, Madison Kelvin Santiago-Chaparro, University of Wisconsin, Madison David Noyce, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1202
Session Title	Safety Performance and Analysis, Act 2: Surrogates, Conflicts, and Other Safety Data
Paper Number	21-03550
Paper Title	Extreme Value Theory to Estimate Safety using Right Turn on Red Conflicts
Abstract	Traffic conflicts and surrogate safety measures have been used as an alternative to crash-based methods to study road safety. The extreme value theory offers a modeling framework for safety surrogates. Using video data, time-to-collision (TTC) values between right-turn-on-red (RTOR) vehicles and through vehicles were evaluated. Using trajectory data collected from radars, post-encroachment-time (PET) values were computed. In this study, six models were developed based on RTOR conflicts; two Univariate Generalized Extreme Value (UGEV), each using TTC and PET, respectively, and two Univariate Generalized Pareto (UGP) models, each using TTC and PET, respectively. Additionally, the two models Bivariate Generalized Extreme Value (BGEV) and Bivariate Generalized Pareto (BGP) which both jointly use TTC and PET were also applied. Using the resulting estimates, the number of crashes was estimated for each model. For the univariate models, the results show that the estimated crashes from UGEV models are closer to the observed number of crashes than those from UGP models. As for the bivariate models, the estimated crashes from BGP are closer to the observed crashes than those from BGEV models. The more accurate BGP crash estimates are attributed to the efficient use of data. UGP and BGEV models underestimated crash estimation while UGEV using PET and BGP has a similar performance estimating crashes. The results show that the UGEV model using TTC performed the best followed by the UGEV model using PET and the BGP model. This study presents a step forward in developing safety models based on several safety surrogates.

Authors	Lana Samara, Transoft Solutions Inc. Paul St-Aubin, Transoft Solutions Inc. Franz Loewenherz, City of Bellevue Noah Budnick, Together For Safer Roads Luis Miranda-Moreno, McGill University
Sponsoring Committee	Standing Committee on Intelligent Transportation Systems (ACP15)
Session Number	1110
Session Title	Intelligent Transportation Systems 2021, Part 1
Paper Number	21-03654
Paper Title	Video-based Network-wide Surrogate Safety Analysis to Support a Proactive Network Screening Using Connected Cameras: Case Study in the City of Bellevue (WA) United States
Abstract	Surrogate road safety approaches, as part of road improvement programs, have gained traction in recent years. Thanks to emerging technologies such as computer-vision and cloud-computing, surrogate methods allow for proactive scanning and detection of safety issues and address them before collisions and injuries occur. The objective of this paper is to propose an automated and continuous monitoring approach for road network screening using connected video cameras and a cloud-based computing analytics platform for large-scale video processing. Using the wide network of traffic cameras from cities, the proposed approach aims to leverage video footage to extract critical data road network screening (ranking and selection of dangerous locations). Using the City of Bellevue as an application environment, different safety metrics are automatically generated in the platform such as traffic exposure metrics, frequency of speeding events, and conflict rates. Using Bellevue's camera network, the proposed approach is demonstrated using a sample of 40 cameras and intersections. The results and platform provide a proactive tool that can constantly look for dangerous locations and risk contributing factors. This paper provides the details of the proposed approach and the results of its implementation. Directions for future work are also discussed.

Authors	Ruimin Ke, University of Washington Zhiyong Cui, University of Washington Yanlong Chen, University of Tokyo Meixin Zhu, University of Washington Yinhai Wang, University of Washington
Sponsoring Committee	Standing Committee on Information Systems and Technology (AED30)
Session Number	1250
Session Title	Information Systems and Technology
Paper Number	21-04141
Paper Title	IoT System for Real-Time Near-Crash Detection for Automated Vehicle Testing
Abstract	Our world is moving towards the goal of fully autonomous driving at a fast pace. While the latest automated vehicles (AVs) can handle most real-world scenarios they encounter, a major bottleneck for turning fully autonomous driving into reality is the lack of sufficient corner case data for training and testing AVs. Near-crash data, as a widely used surrogate data for traffic safety research, can also serve the purpose of AV testing if properly collected. To this end, this paper proposes an Internet-of-Things (IoT) system for real-time near-crash data collection. The system has several cool features. First, it is a low-cost and standalone system that is backward-compatible with any existing vehicles. People can fix the system to their dashboards for near-crash data collection and collision warning without the approval or help of vehicle manufacturers. Second, we propose a new near-crash detection method that models the target's size changes and relative motions with the bounding boxes generated by deep-learning-based object detection and tracking. This near-miss detection method is fast, accurate, and reliable; particularly, it is insensitive to camera parameters, thereby having an excellent transferability to different dashboard cameras. We have conducted comprehensive experiments with 100 videos locally processed at Jetson, as well as real-world tests on cars and buses. Besides collecting corner cases, it can also serve as a white-box platform for testing innovative algorithms and evaluating other AV products. The system contributes to the real-world testing of AVs and has great potential to be brought into large-scale deployment.

Authors	Ziliang He, Tongji University Wanjing Ma, Tongji University Ling Wang, Tongji University Hao Zhong, Tongji University Chunhui Yu, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1327
Session Title	Safety Performance and Analysis, Act 4: Methods and Models
Paper Number	21-04355
Paper Title	Vehicle Group Crash Risk Prediction based Active Traffic Management Strategies for Expressways
Abstract	The safety of expressways is important. This study developed variable speed limits (VSL) and ramp metering (RM) strategies based on the prediction of vehicle group crash risk to improve the safety of expressways. The goal of VSL was to minimize the crash risk of multiple vehicle groups in the next time period, and the updated speed limits were sent directly to the connected vehicles (CV) to adjust the speed of the vehicle group. As for the RM, the metering rate and opening time of ramp control were designed based on mainline occupancy, vehicle group crash risk, and predicted time of vehicle group arriving at the ramp. Considering the impact of RM on flow and the influence of the VSL on the capacity, the coordinated VSL and RM strategy (VSL-RM) was established . These strategies were tested in microsimulations. The crash risk index and the Surrogate Safety Assessment Model (SSAM) were utilized to evaluate the safety effect of these strategies. The results showed that the three strategies improved the safety of the expressway. Additionally, the higher the penetration rate of connected vehicles, the higher the safety benefits of VSL and VSL-RM. Moreover, the VSL-RM was superior to VSL and RM. Keywords : Connected Vehicle, Crash Risk, Variable Speed Limit, Ramp Metering, Coordination of Ramp Metering and Variable Speed Limit

8 Transportation Safety Management

Frank Gross, VHB; Jaeyoung Lee, Central South University; Brendan Russo, Northern Arizona University

Thirty-two papers describing different perspectives of transportation safety management will be presented in Poster Session 1304 titled, ***Transportation Safety Management Systems from Start to Finish*** at the 2021 TRB Annual Meeting. The following is a brief overview of the papers.

Three papers focused on effects of **COVID-19 on traffic crashes**. Chatmon et al. (21-00273) compared the crash statistics after the outbreak with the previous years' using data from Tennesse. Romeo-Garcia et al. (21-01852) performed a similar study using Florida data. Hui et al. (21-03043) explored effects of COVID-19 on traffic crashes in California after controlling traffic volume. The three studies commonly found that the crash frequency or crash risk has significantly reduced but the specific changes are different by condition.

Six papers specifically investigated **socioeconomic or built environment factors affecting traffic safety**. Sagar & Stamatiadis (21-00658) explored the probability of being the at-fault drivers in single- and two-unit vehicle crashes using data from Kentucky. They revealed that various socioeconomic factors such as income, education level, poverty level, employment, age, gender, rurality, and number of traffic-related convictions of a driver's zip code have a significant influence. Yocum & Gayah (21-01517) identified factors affecting the number of crashes in Pennsylvania. The factors include population of unemployed individuals, percentage of the population on cash public assistance or receiving SNAP benefits, and the percentage of households without a vehicle. Dai et al. (21-02415) explored non-motorized vehicle safety using socioeconomic and land-use data in China and proposed a method to evaluate engineering and education countermeasures. Pei et al. (21-03435) analyzed crash and violation frequencies in China at macroscopic level and identified influencing factors and hotspots. Shioma et al. (TRBAM-21-04448) assessed effects of built environments on non-motorist crashes using data from Florida. Agarwala & Vasudevan (21-02224) investigate the relationship between household consumption expenditures and traffic fatalities in rural and urban areas. They found that fuel, non-personal modes of travel, and two-wheeler expenditures, are found to be associated with an increase in traffic fatality in rural areas.

Four studies analyzed effects of **speed on traffic safety**. Ahmad et al. (21-02508) investigated the role of speed volatility for driving errors, violations, and crashes using naturalistic driving data. Cai et al. (21-02861) explored effects of speed management strategies on speeding behavior on urban and suburban arterials using probe data. Rahman et al. (21-03068) studied effects of speed on crash frequency on rural two-lane highways. Lastly, Mahmoud et al. (21-03294) identified factors influencing operating speed on arterials with different context classifications.

Four papers proposed **a new methodology or tool** for visualization, hotspot identification or project prioritization. Hu et al. (21-00299) developed a low-cost method to construct three-dimensional geometric profiles for local roads in a relatively large study area using open-source data. The developed zero-inflated negative binomial indicated that grades or curves are associated with decreased crash frequency, while segments with larger horizontal curve radius and low grades are associated with increased crash frequency. Zhu et al. (21-00981) developed SAVE-T, a web-based tool for safety visualization and evaluation. SAVE-T utilized an on-line crash database and offers various innovative functionalities for analysis and visualization of the crash data. Tsapakis et al. (21-01698) compared alternatives in priotirzing safety improvement projects. They found that the projects selected using the improved incremental benefit-cost-ratio method are more cost-effective than the projects funded by the benefit-cost ratio method. Al-Kaisy & Huda (21-01505) proposed a new approach for network screening on rural low-volume roads.

Four studies analyzed **crash risks** for different situations. Tsyganov & Read (21-01428) studied risk factors for angle crashes in Virgina. Hossain & Medina (21-03366) validated the U.S. Road Assessment Program for run-off and head-on crashes using data from Utah. Dimitrijevic et al. (21-03591) conducted a segment-level crash risk for New Jersey using several data mining techniques. Khattak et al. (21-04104) explored driving errors and violations in diverse built environments using detailed pre-crash sensor data collected in SHRP2 Naturalistic Driving Study.

Three studies evaluated effects of **safety countermeasures**. Sacchi & Tayebikhorami (21-01619) assessed the effectiveness of safety improvement program in Saskatchewan using a full-Bayes before-after study. They found that the program successfully reduced total crashes and severe crashes by 14.8% and 25.4%, respectively. Zhao et al. (21-03046) investigated safety effects of maintenance activites on rural two-lane roads. They concluded that shoulder rumble stripes, shoulder widening and pavement resurfacing significantly improved safety. Dai et al. (21-02415) explored effects of engineering and education countermeasures on non-motorized vehicle crashes in China.

Three papers explored **connected/automated vehicles**' safety. Beauchamp et al. (21-01851) studied automated shuttle interactions in urban traffic setting using surrogate measures of safety. They found that the automated shuttles behave generally more safely: their speeds and accelerations are lower, and their interactions are characterized by higher TTCs and PETs, notably with vulnerable road users. Clamann & Pullen-Seufert (21-01481) summarized five challenges for deploying automated vehicles near school zones, including levels of automation, operational design domain of schools, young students, school transportation stakeholders, and test strategies. Rahman et al. (21-02905) evaluated effects of communication system on traffic safety under the connected and automated vehicle environment. The key finding is that the queue size and transmission power have a significant effect on traffic safety.

Two papers focused on the **school** issue. Hodgson & Chang (21-02436) used an unmanned areal vehicle (UAV) to collect data from K-12 schools. Clamann & Pullen-Seufert (21-01481) addressed challenges for deploying automated vehicles in school zones.

Two studies investigated **motorcycle safety**. Li et al. (21-00061) performed a spatiotemporal analysis of motorcyclist injury severity using 20-years data from Pennsylvania. They found multiple factors including helmet use, engine size, vehicle age, existence of pillion passenger, at-fault, and speeding affecting motorcyclists' injury severity. Das et al. (21-03150) conducted a motorycycle crash causation study using crash narrative reports.

A single paper by Lyu et al. (21-00513) benchmarked **road safety development** cases of OECD countries. The OECD countries were ranked and grouped into several classes based on the overall achievement regarding road safety from the past decade (2009-2018) in the the study.

A single paper by Bianchi et al. (21-01782) estimated the **crash cost** by severity for crashes in Puerto Rico. The study was required because of Puerto Rico's transportation police agencies only use three severity levels: fatal, injury, and property damage only.

A single paper by Hezaveh et al. (21-02442) analyzed effects of **tourist-involved crashes** on tourism industry. The results indicate that an overlooked negative externality of tourism is traffic crashes involving tourists.

Authors	Xiaobing Li, University of Alabama Jun Liu, University of Alabama Zihe Zhang, University of Alabama Allen Parrish, Alabama Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00061
Paper Title	A Spatiotemporal Analysis of Motorcyclist Injury Severity: Implications from 20 Years' Traffic Crashes in Pennsylvania
Abstract	Motorcyclists face higher risks of severe injuries in crashes compared to motor vehicle drivers who are often protected by seatbelts and airbags during collisions. A report by the National Highway Traffic Safety Administration reveals that motorcyclists have 27 times the risk of fatality in traffic crashes relative to motor vehicle drivers. Previous studies have identified a list of risk factors associated with motorcyclist injury severity and generated valuable insights for countermeasures protecting motorcyclists in crashes. These studies have shown that wearing helmets, motorcycle-specific reflective clothing and boots, alcohol/drug-free driving, obeying traffic regulations are good practices for safe motorcycling. However, these practices and other risk factors are likely to interact with local geographic, socio-economic, and cultural contexts, leading to diversified correlations with motorcyclist injury severity, which remains under-explored. Such correlations may exhibit variations across space and time. The objective of this study is to revisit the correlates of motorcyclist injury severity with a focus on the spatial and temporal variations of correlations between risk factors and injury severity. This study employed an integrated spatiotemporal analytical approach to mine comprehensive statewide 20 years' motorcycle-involved traffic crashes (N=50,823) in Pennsylvania. Non-stationarity tests were performed to examine the significance of variations in spatially and temporally local correlations. The results show that most factors such as helmet, engine size, vehicle life, pillion passenger, at-fault striking, and speeding hold significant non-stationary relationships with motorcyclist injury severity. Furthermore, cluster analysis of estimations reveals the regional similarities of correlates, which may help practitioners develop regional motorcyclist safety countermeasures.

Authors	Morgan Chatmon, Tennessee State University Beatriue Cherop, Tennessee State University Deo Chimba, Tennessee State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00273
Paper Title	The Impact of COVID-19 on Traffic Crash trends in Tennessee
Abstract	The first Coronavirus case detected in Wuhan city, Hubei province in China towards the end of 2019. In order to decrease the rate of transmission of COVID-19, the United States passed an order requiring people to work from home, closure of schools and non-essential businesses and barring mass gatherings. The move reduced number of people travelling, and altered travel patterns. The trend of traffic crashes before and during the COVID-19 pandemic is presented in this paper. The analysis of 4-year crash trends covering the months of March, April and May for 2017, 2018, 2019 (averaged as pre- COVID-19) and 2020 (during COVID-19) is presented. The decline in crashes was due to the limited movement and travel which decreased road traffic by more than 38%. Non parametric test was used to compare the mean of crashes before and during COVID-19, the results showed that the mean of crashes during COVID-19 was significantly lower than pre- COVID-19 for the same range of months. The geometric and traffic factors used to analyze the traffic crashes included the number of lanes, AADT, speed limit, land use, population density, median income and weather. Negative Binomial regression was used to model the impact of these factors on crashes. It was found that for each unit increase in the factors, traffic crashes increased with the increase being less for the COVID-19 period. The restrictions put in place to minimize the spread of COVID-19 decreased number of traffic crashes and generally increased road safety.

Authors	Qinglin Hu, University of Alabama Xiaobing Li, University of Alabama Jun Liu, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00299
Paper Title	A Low-Cost Approach to Identify Hazard Curvature for Local Road Networks Using Open-Source Data
Abstract	Vehicle crashes are a leading cause of death in the United States. Among those crashes, curvature in local roadway was identified as one of the most significant factors correlated with fatal crashes. Given the large number of local roads and their relatively lower traffic compared with interstates or freeways, most local roads may not receive priorities in the first phase of highway upgrades. However, critical locations, e.g., sharp curves (vertical and/or horizontal), in the network that may be a deadly threat for both new advanced autonomous vehicles and conventional vehicles. In addition, Identifying local roadway curvatures exists various uncertainty by most authorities, such as high budget and lack of data. To fill this gap, this study offers a low-cost approach to constructing three-Dimensional geometric profiles for local roads in a relatively large study area using open-source data. With the profiles, critical road segments, including extreme horizontal and vertical curves and their combinations, can be identified. Our study redefined the local road segments into 20 sub-categories based on the calculated vertical grades and curve radius that were incorporated into a zero-inflated native binomial model. Model results showed that grades or curves were associated with decreased crash frequency compared with straight and flat roads. However, segments with larger horizontal curve radius and low grades were found to associate with increased crash frequency. More implications are discussed in the paper.

Authors	Jingyang Lyu, University of Chicago Tianye Wang, University of Virginia Faan Chen, Harvard University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00513
Paper Title	Benchmarking Road Safety Development Across OECD Countries: An Empirical Analysis for a Decade
Abstract	Benchmarking performance, monitoring progress, and then recalibrating interventions is widely recognized as a valuable process for achieving continuous improvement in road safety. In this study, a systematic and effective methodology, IV-VIKOR with FNBC, is developed to perform the benchmarking of road safety development in an integrative manner for OECD (Organisation for Economic Co-operation and Development) countries. Linking to other method and measure as the references, 36 OECD Member countries are ranked and grouped into several classes based on their overall achievement regarding road safety from the past decade (2009-2018). This provides government officials and policymakers, across the OECD Member countries, with a flexible tool to comprehensively benchmark road safety development. Providing the ability to identify delays in action plan implementations and proactively redistribute resources toward more effective measures where required. Such a tool can also serve to increase political will and stakeholder accountabilities, at the highest level of government and the private sector for all OECD members: Thereby keeping the implementation of action plans on schedule. It helps OECD Member countries to establish the capacity for sustainable safety management; supporting them in developing future strategies and reforms to create better policies for better lives.

Authors	Shraddha Sagar, Gresham Smith and Partners Nick Stamatiadis, Kentucky Transportation Center Arnold Stromberg, University of Kentucky
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00658
Paper Title	Effect of Socioeconomic and Demographic Factors on Crash Occurrence
Abstract	Road traffic crashes are a leading cause of death in the United States. In Kentucky, per capita crash rates and crash-related fatalities have outpaced the national average for over a decade. Researchers have argued that the region's unique socioeconomic conditions provide a compelling explanation for these trends. This study examined the relationship between highway safety and socioeconomic characteristics using crash data from Kentucky. This research sought to identify at-risk drivers based on the socioeconomic and demographic attributes of their residence zip codes. Using the quasi-induced exposure approach, binary logistic regression was used to predict the probability of be the at-fault driver in a single- and two-unit crashes based on socioeconomic characteristics of their residence zip code. Statistical analysis found that variables such as income, education level, poverty level, employment, age, gender, rurality, and number of traffic-related convictions of a driver's zip code influence the likelihood of their being at fault in a crash, while educational attainment is observed to have an impact only on single-unit crash occurrence. Finally, it is concluded that younger and older drivers residing in zip codes with low socioeconomic conditions have a higher likelihood of causing a crash for both single- and two-unit crashes. This finding can be used to identify zip codes or groups of drivers with higher likelihood to be involved in crashes and develop targeted and efficient safety programs.

Authors	Yuan Zhu, Inner Mongolia University Sami Demiroluk, AgileAssets, Inc. Kaan Ozbay, New York University Kun Xie, Old Dominion University Hong Yang, Old Dominion University Di Sha, New York University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-00981
Paper Title	SAVE-T: Safety Analysis Visualization and Evaluation Tool
Abstract	Traffic crashes are one of the biggest issues which constitute a threat to lives the motorists and disrupt operations of the transportation system. To reduce the number of crashes and alleviate their impacts, it is necessary to scrutinize the factors contributing to the risk of traffic crashes. Lately, visual analytics tools become very popular for data exploration and obtaining insights from the data. In this paper, a new web-based data visualization tool called Safety Analysis Visualization and Evaluation Tool (SAVE-T) was introduced. This tool enables users to interactively create queries and visually explore the results. By utilizing an on-line crash database, it offers various innovative functionalities for analysis and visualization of the crash data such as custom query development module, and a subway-like map for easily visualizing the accident on the roadway segments. This tool provides an effective and efficient way to transportation agencies and professionals for traffic safety analyses and visualizations.

Authors	Alexei Tsyganov, Virginia Department of Transportation Stephen Read, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01428
Paper Title	Emphasis Areas and Risk Factors for Angle Collisions in Virginia
Abstract	Recently the FHWA Office of Safety developed sets of low-cost countermeasures for systemic intersections safety improvements. The suggested basic treatments are low in unit cost and collectively effective in terms of reducing future crash potential. For the effective implementation of the FHWA recommendations, the Virginia Department of Transportation (VDOT) Highway Safety Improvement Program (HSIP) initiated a study targeting analysis of angle collisions, identification of emphasis areas for improvements and associated risk/human factors. The conducted descriptive crash analysis considered multiple factors, such as day, time, highway functional class, traffic control system, travel conditions, crash severity, driver age, driver pre-crash improper action and maneuver, as well as influences of intoxication, distraction, inattention, and vision obstruction. The analysis identifies the emphasis areas for angle collisions related safety improvements and quantify their significance in terms of contribution to the overall statewide highway crashes and severity. The detailed analysis of the 2,122 police crash reports together with the review of crash sites, allowed identification and classification of various pre-crash events, as well as driver risk/human factors, and quantification of their significance. Based on the study results, a procedure for crash tree analysis was developed with the identified risk factors. The study results provide more detailed information for the selection of the most applicable and effective safety improvement strategies and measures targeting angle collisions.

Authors	Michael Clamann, UNC Highway Safety Research Center Nancy Pullen-Seufert, UNC Highway Safety Research Center
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01481
Paper Title	Navigating School Zones: 5 Challenges for Deploying Automated Vehicles Near Schools
Abstract	The variability of conditions among school zones combined with a high density of traffic during peak times operating near pedestrians and bicyclists whose safety is paramount represents a complex operational design domain for automated driving systems (ADS). These characteristics represent safety challenges that should be addressed through technology, design, and regulatory approaches before ADS are deployed. However, these issues have not been comprehensively addressed to date, and to reach the full safety potential of ADS, their design will need to account for the complexity and uncertainty in and around school zones. The goal of this work was to address this gap and characterize the safety challenges to pedestrians that will need to be addressed before ADS can be deployed near schools. Building on an existing research framework, and interviews with school transportation experts, attributes of school transportation infrastructure were cross referenced against safety issues faced by pedestrians and automated vehicles to identify current challenges related to transportation within school zones. The themes that emerged from the results of the analysis consolidated around five challenge areas for schools and automated driving systems including levels of automation, operational design domain of schools, young students, school transportation stakeholders, and test strategies. Addressing these challenges areas now would lay a foundation to prepare for future ADS deployments and addressing some current challenges to pedestrian safety.

Authors	Ahmed Al-Kaisy, Montana State University Kazi Huda, Montana State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01505
Paper Title	Network Screening on Low-Volume Roads: A New Proposed Method
Abstract	This paper presents a proposed new method for network screening on rural low-volume roads. These roads constitute an important and integral part of the rural roadway network by providing access to remote rural areas including farms and ranches. The majority of low-volume roads belong to the lowest functional class (local rural roads) and many were built decades ago, and therefore their geometric features are often considered “substandard” by today’s design practices. The conventional hot spot newtwork screening techniques may not be appropriate for low-volume roads due to the sporadic nature of crashes occurring on these roads. Other approaches for network screening (e.g. Highway Safety Manual preditive methodology, EB method, etc.) require extensive roadway and traffic data that are often unavailable at local agencies for lack of resources, and/or impractical to use for lack of technical expertise. This research attempts to address these obstacles in low-volume roads network screening with the purpose of identifying candidate sites for safety treatments. The research used an extensive low-volume road sample from the state of Oregon and the Empirical Bayes expected number of crashes in developing the proposed models for network screening. The proposed models do not require exact measurement of roadway geometric features as all geometric variables were classified into categories that are easy to compile by local agencies. Further, the method could be used with and without traffic data without much compromising the effectiveness of the network screening process.

Authors	Rebeka Yocum, Pennsylvania State University, Vikash Gayah, Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01517
Paper Title	Identifying relationships between socioeconomic indicators and crash frequency in Pennsylvania
Abstract	Current crash prediction models utilize roadway and traffic data as independent variables to describe crash frequency on individual roadway segments. Recent work has moved toward predicting crashes within some region as a function of roadway and traffic data, as well as non-traditional variables, such as alcohol, gasoline prices, and socioeconomic measures. This paper aims to introduce measures of wealth into the crash modeling conversation by determining the effect of wealth on total, fatal and injury, and pedestrian crash frequencies in Pennsylvania counties. The analysis presented in this paper will serve as a case study with intentions to promote the development of more robust, wealth-inclusive crash prediction models in the future. The study reveals that population of unemployed individuals, percentage of the population on cash public assistance or receiving SNAP benefits, and the percentage of households without a vehicle are each positively related to the observed frequency of total, fatal + injury and pedestrian crashes in each county. This result not only supports previous work, but expands on that work by considering multiple crash types, and multiple wealth related variables. The existence of a relationship between crash frequency and wealth related variables opens the door to further exploration of including wealth in traditional crash prediction methods. This paper discusses this relationship and offers recommendations for future work.

Authors	Emanuele Sacchi, University of Saskatchewan Saeid Tayebikhorami, University of Saskatchewan
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01619
Paper Title	Evaluating the Effectiveness of the Safety Improvement Program in Saskatchewan Using a Full-Bayes Before-After Study
Abstract	Improving and maintaining acceptable levels of safety for rural roads is a major task for local highway agencies. For instance, the FHWA's "Safety Improvements on High Risk Rural Roads" manual assists local agencies in selecting the most effective ("proven") countermeasures and recommends an organized and systematic process for specific safety-related programs in a rural setting. A key step in this process is to determine whether the frequency and/or severity of collisions at the treatment sites have been reduced after the implementation of the program. This research focused on evaluating the safety performance of a sample of 50 locations that have been improved under the Saskatchewan Ministry of Highways and Infrastructure's (MHI) Safety Improvement Program (SIP). SIP projects were designed to reduce the frequency and severity of collisions on provincial highways in rural areas through the implementation of proven safety countermeasures. The methodology adopted for estimating the safety benefits was a before-after study with the full Bayes method. Overall, SIP was found to reduce total collisions by 14.8% and to reduce severe (fatal-plus-injury) collisions by 25.4%. The reduction of non-severe (property-damage-only) collisions was not found to be statistically significant at the 90% and 95% confidence levels. Also, crash modification factors (CMFs) for the two most frequent SIP treatments, i.e., right-turn lanes and delineation lighting at intersections, were estimated and compared to the results of the literature.

Authors	Ioannis Tsapakis, Texas A&M Transportation Institute sushant sharma, Texas A&M Transportation Institute William Holik, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01698
Paper Title	Alternatives in Prioritizing Safety Improvement Projects
Abstract	The Highway Safety Improvement Program (HSIP) aims to reduce the number and severity of fatalities and serious injury crashes by implementing safety improvement projects. The Traffic Operations Division (TRF) of the Texas Department of Transportation (TxDOT) currently administers TxDOT's HSIP. TRF requests HSIP projects from TxDOT districts every year. All proposed projects are subjected to a benefit-cost ratio (BCR), called Safety Improvement Index (SII). After projects are submitted to the program, the TRF prioritizes them based on the SII. Although the structure and main components of TxDOT's HSIP comply with relevant requirements, a review of modern safety assessment methods and tools revealed that there are several areas for improvement, including economic analysis and prioritization of HSIP projects. The objectives of this study are to a) compare TxDOT's BCR-based project prioritization approach against an improved incremental benefit-cost ratio (IBCR) method, recommended by the Highway Safety Manual (HSM), and b) minimize the amount of time and resources required to prioritize HSIP projects. To address the first objective, the researchers applied both methods using data from the 2016 TxDOT HSIP and compared the results. The comparison showed that the projects selected using the IBCR method were more cost-effective than the projects funded by the BCR method. Further, the IBCR method awarded high-cost projects where more crashes had been observed. To address the second objective, the authors developed a prioritization tool that automatically ranks candidate projects using the IBCR method. The average runtime to prioritize 1,000 projects is less than 0.5 seconds.

Authors	Josie Bianchi, Recinto Universitario de Mayaguez Universidad de Puerto Rico Didier Valdés, Recinto Universitario de Mayaguez Universidad de Puerto Rico Raúl Macchiavelli, Recinto Universitario de Mayaguez Universidad de Puerto Rico
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01782
Paper Title	KABCO Severity Cost Estimation by Cluster Analysis for Injury-Only Crashes in Puerto Rico
Abstract	The costs associated with crash injuries in Puerto Rico are based on the Highway Safety Manual 2010 version and the Federal Highway Administration data. They follow the crash-injury severity scale named KABCO. The model is based on a 2005 study of the Federal Highway Administration that used a 2001-dollar value that did not include Puerto Rico. However, Puerto Rico's transportation and police agencies only use three types of crashes in their crash type distinction: fatal, injury, and property-damage-only. To adequately address road safety efforts in Puerto Rico, a crash-cost injured severity estimation was developed. This process was based on medical expenses and associated costs for each type of crash by revising the KABCO injury scale for injury-only motor vehicle crashes on Puerto Rico. A K-means cluster analysis was performed with the medical service data from traffic-related injuries to ascertain if the three-level KABCO categorization for traffic-related injuries fits the Puerto Rico data. As a result, the best cluster or group configuration that maximized the distance among groups and minimized the distance within groups was obtained.

Authors	Etienne Beauchamp, Ecole Polytechnique de Montreal Nicolas Saunier, Ecole Polytechnique de Montreal Marie-Soleil Cloutier, Institut National de la recherche scientifique
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01851
Paper Title	Study of Automated Shuttle Interactions in City Traffic Using Surrogate Measures of Safety
Abstract	Driving automation is happening at a rapid pace, with different driver assistance systems already available in mass-market cars. However, this rapid development in driving automation leads to concerns and questions about their impact on safety, in particular for vulnerable road users. While previous studies have been restricted to incident reports and simulation tools, the safety of automated vehicles (AVs) is not clearly demonstrated. Instead of crashes, which are extremely rare events, this study uses surrogate measures of safety (SMoS) to analyze the interactions between road users and low-speed automated shuttles that circulated in Montréal and Candiac, in Canada, during two pilot projects in mid and late 2019. Cameras were placed at seven intersections along the routes of the shuttles. More than 70 hours of footage were processed to extract the road user trajectories using computer vision techniques and compute various safety indicators: speed, acceleration, time headway, time-to-collision (TTC) and post-encroachment time (PET). The Kolmogorov–Smirnov test was used to compare the distributions of interactions involving AVs with the distributions of interactions involving motorized vehicles following paths similar to those of the AVs. The results indicate that these automated shuttles behave generally more safely: their speeds and accelerations are lower and their interactions are characterized by higher TTCs and PETs, notably with vulnerable road users. However, small headway times at one site with high speed differentials between the shuttles and other following vehicles raise concerns that warrant further research into the suitable context for these vehicles.

Authors	Amy Romeo-Garcia, Florida International University John Kodi, Florida International University Angela Kitali, Florida International University Priyanka Alluri, Florida International University Albert Gan, Florida International University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-01852
Paper Title	Impacts of COVID-19 Pandemic on Traffic Crashes in Florida
Abstract	The novel COVID-19 pandemic outbreak has brought significant impacts on all aspects of peoples' lives in the entire world. While this pandemic is still unfolding, it has already had unprecedented health, social, and economic consequences. The virus being easily transmittable from person-to-person, social distancing through stay-at-home orders is considered as effective in containing the rapid spread of the disease. For example, in Florida the stay-at-home orders came into effect on April 01, 2020. These strategies have resulted in drastic changes in the traffic pattern and travel behavior which in turn has led to significant changes in traffic safety. This study investigated the impacts of the COVID-19 pandemic on traffic crashes. Traffic crashes for March and April (2018-2020) in Florida were analyzed to identify if there was a significant change in traffic crashes following the outbreak of the pandemic and statewide directives to prohibit person-to-person interaction. Compared to similar days in 2018 and 2019, the overall statewide traffic crashes dropped significantly by 10% and 45% in the first and last two weeks of March 2020 respectively, and by 58% in April 2020. A similar significant decrease was observed in the fatal and injury crashes although as a percentage of all crashes they increased in 2020 compared to 2018 and 2019. Also, a decrease in the rear-end crashes and an increase in the run-off-road and non-motorist crashes were observed. This study helps to understand the early impacts of the pandemic and may be useful in operational and strategic planning for future pandemics.

Authors	Ruchika Agarwala, Indian Institute of Technology, Bombay Vinod Vasudevan, University of Alaska, Anchorage
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02224
Paper Title	Relating Household Consumption Expenditures to Road Traffic Fatalities: A Rural-Urban Study
Abstract	Traffic fatality risk is higher in rural areas than in urban areas. In developing countries, vehicle ownership and investments in public transportation typically increase with economic growth. These two factors together increase the vehicular population, which in turn impacts traffic safety. However, the impacts of personal and non-personal modes of travel on traffic safety in rural versus urban areas in developing countries is still unexplored. This paper fills this gap in the literature by presenting a study focused on the relationship of various factors—including household consumption expenditure data—with traffic fatality in rural and urban areas. An exhaustive panel data modelling approach is adopted. One important finding of this study is that evidence exists of a contrasting relationship between economy and traffic fatality in rural and urban areas. Increases in most expenditure variables, such as fuel, non-personal modes of travel, and two-wheeler expenditures, are found to be associated with an increase in traffic fatality in rural areas.

Authors	Zhicheng Dai, Tongji University Xuesong Wang, Tongji University Wenbin Luo, Traffic Police Headquarters of Shanghai Public Security Bureau
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02415
Paper Title	Macro Safety Analysis for Non-motorized Vehicles Based on Roadway and Safety Education Improvement Countermeasures
Abstract	Non-motorized vehicles such as bicycles and e-bikes have gained great popularity in recent decades because of their high mobility and economy. Because these road users have a higher risk of injury in a crash, macro safety analyses have been conducted according to crash location. However, this strategy could be inefficient when comprehensive improvements such as traffic safety education programs are considered, due to differences between crash locations and the locations of the crash-involved road users' residences. To improve implementation of such countermeasures, this study proposes a new analysis strategy of separately aggregating crashes for roadway engineering improvement and road users for education improvement. Roadway, socioeconomic and land use characteristics from 213 Shanghai sub-districts were collected as independent variables. The dependent variables of crashes and road users were divided into four subjects by crash severity level: fatal and injury (FI) and property damage only (PDO). A multivariate Poisson lognormal conditional autoregressive (CAR) model was developed to examine the relationships between regional characteristics and traffic safety, and potential safety improvement (PSI) was calculated for each sub-district based on model results. Hot-zone identification showed significant differences in distribution of sub-districts with urgent need for roadway versus education improvement. False positive and false negative indexes were developed to identify the differences quantitatively. Results indicated that nearly half the identified hot zones were inconsistent in unnecessarily prioritizing either engineering or education improvement. The findings of this paper are of great practical significance to better utilize resources for non-motorized vehicle traffic safety improvement.

Authors	Cody Hodgson, University of Idaho Kevin Chang, University of Idaho
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02436
Paper Title	Using Drone Technology to Collect School Transportation Data
Abstract	Travel tally surveys are administered by elementary, middle, and high (K-12) schools to collect data that measure how students arrive and leave school each day. This data can be used to determine both transportation safety and mobility needs. Collecting this data is usually accomplished by asking teachers to collect a tally in their classrooms; the data are then compiled to determine a representative result for each school. This process requires advanced planning from school administrators and teachers to ensure that information gathering is coordinated and relies on the personal input of each student. Since the age of elementary school students may be as little as six or seven years old, this approach may not always be reliable.In this study, a new method using a quadcopter drone was examined. For comparison purposes, participatory student tally surveys and drone videos were collected on the same day at three different elementary school sites, and the results and effectiveness of each counting method were compared and analyzed. The study concluded that the survey and drone results did not always yield similar results for all modes, so an explanation as to why these deviations occurred and what it means for researchers and practitioners is discussed. Given that drone technology continues to evolve, the lessons learned from this study can be applied toward future school transportation and other mobility studies.

Authors	Amin Mohamadi Hezaveh (Corresponding Author), North Carolina Department of Transportation Christopher Cherry, University of Tennessee, Knoxville Candace Brakewood, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02442
Paper Title	Traveler-Involved Traffic Crashes As A Negative Externality Of Tourism Industry
Abstract	Although it is well established that travelers have a higher risk of injury in traffic crashes compared to non-travelers, less is known about the magnitude of traffic crashes involving travelers and the negative externality of travelers' crashes (NETC) imposed on non-travelers. In this note, we rely on the U.S. Travel Association's definition of a traveler to conduct an empirical analysis focusing on the state of Tennessee; we define travelers as those who travel more than 50 miles from home or have a home-address outside of Tennessee state. We find that 19.2% (127,031 out of 694,276 from 2014-2016) of traffic crashes in Tennessee involve a traveler. The injury cost of non-traveler crashes due to a crash with a traveler (i.e., monetized value of NETC) exceeds $7.6 billion, or 12.3% of tourist expenditures between 2014-2016. Analyzing the net impact of travel (tourist expenditures minus NETC) at county level reveals that the NETC exceeds tourist expenditures in 19 of 97 counties (or 20%) in Tennessee. The results of this analysis reveal that an overlooked negative externality of tourism is traffic crashes involving travelers, which warrants further study and potentially policy remediation.

Authors	Numan Ahmad (Corresponding Author), University of Tennessee Ramin Arvin, University of Tennessee, Knoxville Asad J. Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02508
Paper Title	Exploring Pathways from Driving Errors and Violations to Crashes: The Role of Speed Volatility
Abstract	Transportation safety can be enhanced by applying safe systems approach to harness new forms of large-scale data. To enhance safety, this study explores how pre-crash data can be used to categorize various driving errors and violations and explore their contribution to speed volatility and crash outcomes. A rigorous path-analytic framework is applied analyzing subsample of Naturalistic Driving Study (NDS) data (N = 9,239). NDS data not only includes realworld information on pre-crash driving behavior and vehicle kinematics but also data on baselines, near-crashes, and crashes which can help quantify crash risk. We first classify human factors into six driving errors and violations using our previously developed systematic taxonomy of errors. Results indicate that human factors still prevail, contributing to 92.43% crashes. Next, tobit regression and ordered probit regression are used to model speed volatility and event outcomes. Results indicate that compared to no error, all six types of driving errors and violations are positively associated with both speed volatility and crash risk. While speed volatility shows significant association with crash risk indicating that all six types of driving errors and violations not only increase crash risk directly but also through speed volatility. For instance, recognition errors associate with 16% higher crash risk while indirect effect of recognition error through speed volatility was found to be about 3%, with total effects of 19%. From practical implication standpoint, implementing technology-based strategies such as cruise control, collision warning system, and dilemma-zone mitigation system can correct or lessen potentially dangerous driving errors and violations.

Authors	Qing Cai (Corresponding Author), University of Central Florida Mohamed Abdel-Aty, University of Central Florida Nada Mahmoud, University of Central Florida Ma'en Al-Omari, University of Central Florida Cheng Yuan, University of Central Florida Brenda Young, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02861
Paper Title	Exploring Effects of Speed Management Strategies on Drivers' Speeding Behavior on Urban and Suburban Arterials with Probe Speed Data
Abstract	Speeding is one of the major contributing factors to traffic fatalities. Various speed management strategies have been proposed to encourage drivers to select more appropriate speed on roads. This study attempts to collect road attributes related to speed management strategies such as road surface and lane narrowing on urban and suburban arterials and examine the effect of the collected road attributes on the speeding proportions. Probe speed data was used to calculate the speeding proportions. To overcome the variability of probe speed data caused by the signalized intersections, a method was suggested by developing a fractional split model to adjust the probe speed data. A Beta regression model was developed to analyze the speeding proportion. A grouped random modeling structure was adopted to realize the different effects of road attributes on speeding proportions of different road types. Besides, a fixed beta model was developed for the comparison. The results suggested the grouped random model could provide better performance over the counterpart and could realize the different effects of road features and other contributing factors on speeding of different roads. It is expected that the findings could help inform more appropriate road design in order to reduce speed limit violations on urban and suburban arterials.

Authors	Md Hasibur Rahman (Corresponding Author), University of Central Florida Mohamed Abdel-Aty, University of Central Florida Mohamed H. Zaki, University of Central Florida Zubayer Islam, University of Central Florida Zubayer Islam, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-02905
Paper Title	EVALUATION OF THE IMPACT OF COMMUNICATION SYSTEM ON TRAFFIC SAFETY UNDER CONNECTED AND AUTOMATED VEHICLES ENVIRONMENT
Abstract	The operation of connected and automated vehicles (CAVs) depends on effective communication between vehicles and other roadway infrastructure. However, the impact of the communication network on road safety under the CAV environment is not thoroughly explored. Hence, the focus of this study is to evaluate the performance of various communication parameters and traffic conditions and their impacts on traffic safety in the CAV environment. This research considered Dedicated Short-Range Communications (DSRC) for vehicle ad-hoc network (VANET) and intelligent driver model (IDM) for driving behavior of CAV. For the safety evaluation, the crash risk was estimated based on the time-to-collision (TTC) value. A binary logistic regression model was developed for the safety assessment of different communication parameters and traffic conditions based on traffic conflicts. The simulation study was carried out on one of the major expressways (SR408) in Orlando, Florida. The results of the performance of different communication parameters indicated that queue size and transmission power have a significant effect on traffic safety. With the increase of queue size, crash risk was lower for a smaller number of packet drops. Higher transmission power creates more interference, which culminates in a higher number of traffic conflicts. From the transportation aspect, the study considered lane closure and different percentages of traffic flow scenarios. The results showed that lane closure increased the crash risk due to the higher number of communication collisions between packets. The crash risk was also higher with the increase in traffic flow.

Authors	Matthew Hui, University of California, Berkeley Jonathan Kupfer (Corresponding Author), University of California, Berkeley Offer Grembek, University of California, Berkeley
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03043
Paper Title	Traffic Safety During the COVID-19 Pandemic: A Study of How Incident-Based Traffic Safety Metrics Changed Over Time on State Highways in the San Francisco Bay Area and Los Angeles Regions
Abstract	This research examined the traffic safety impacts of the COVID-19 pandemic and shelter in place on California state highways from February to May 2020 in the San Francisco Bay Area (SFBA) and the Los Angeles (LA) regions. This paper used police dispatch data and highway loop data to observe the vehicle miles traveled (VMT), number of incidents, and incident risk daily and during the peak hours. VMT data were used to establish four unique time periods; 2019 data were used for comparison. Our analysis found that the relative reduction in incident risk (incidents per VMT) was less than the relative reduction in the number of incidents. We found that the reductions in VMT, number of incidents, and incident risk were not uniform across time of day between the morning peak period, evening peak period, and the daily average. We also found notable differences in trends between the two regions. These findings help us better understand how traffic safety metrics are changing in response to the COVID19 pandemic and illuminate questions for further research.

Authors	Jiguang Zhao (Corresponding Author), HNTB Corporation Rakesh Sharma, HNTB Corporation Yongfeng Ma, Southeast University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03046
Paper Title	Safety Benefits for Maintenance Activities on Rural Two-Lane Roads: An Empirical Bayesian Before-After Study
Abstract	Resurfacing, restoration and rehabilitation (3R) work is to preserve the serviceability of pavement surfaces with asphalt overlays and other interventions. The Missouri Department of Transportation deployed a combined 3R program of shoulder rumble stripes, shoulder widening and pavement resurfacing (RSR) to over 400 centerline miles of rural two-lane highway segments in Missouri. Crash modification factors (CMFs) for the RSR treatment were calculated using the empirical Bayesian (EB) before/after study method based on the roadway geometric, traffic and crash data collected. The calculated CMFs for the RSR treatment for almost all crash categories are below 1.000, with most CMFs significantly less than 1.000. In general the RSR treatment is effective at improving safety performance, particularly for fatal and injury crashes. CMFs of this study and that of previous studies were compared. The results of this study appear to be consistent with the aggregate results of the most comparable studies.

Authors	Fahmida Rahman (Corresponding Author), Kentucky Transportation Cabinet Xu Zhang, Kentucky Transportation Cabinet Mei Chen, Kentucky Transportation Center
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03068
Paper Title	Effect of Speed on Crash Prediction Model of Rural Two-Lane Highways
Abstract	Speed plays an important role in traffic safety. Previous works investigated speed's effect on the crashes of rural two-lane highways using estimated speed due to inadequate speed data. It implies a need to understand the effect using measured speed on these roads. This study filled this gap by utilizing ubiquitous probe speed data. Zero Inflated Negative Binomial model was adopted for accounting the excess zeros in crash dataset. Four speed measures, including average speed, the 85th percentile speed, difference in average speed and speed limit, and difference in 85 th percentile speed and speed limit, were evaluated. The average speed-based model was found to outperform other speed-based models as well as the traditional model. Later, to evaluate whether speed as a categorizer improves the overall model performance, separate prediction models were developed by dividing the dataset based on three-speed ranges: low, medium, and high speeds. Noticeably, speed becomes more significant for the crashes from low to high speed and is an obvious factor for the high-speed category. Compared to the traditional model, inclusion of speed reduced prediction error by 5% for the high-speed roads. Furthermore, for the medium-speed roads, using AADT as another categorizer resulted in further improvement over the model with speed categorizer only. Finally, the models developed for all three-speed ranges showed the lowest error in comparison to the no categorizer model. Since speed and AADT categorizer models enhance prediction accuracy, such an approach is recommended for developing crash prediction models for rural two-lane highways whenever possible.

Authors	Subasish Das (Corresponding Author), Texas A&M University Anandi Dutta, University of Texas, San Antonio Ioannis Tsapakis, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03150
Paper Title	Motorcycle Crash Causation Study: Exploratory Topic Models from Crash Narrative Reports
Abstract	The Motorcycle Crash Causation Study (MCCS) is a matched case-control study that contains a very wide list of crash contributing factors associated with motorcycle crash occurrences. It contains information such as motorcycle information, rider information, motorcycle information, and associated trip information. This study also provides crash narrative information that presents in-depth narrative discussion of the crash causation. Due to the plethora of information, it is critical to investigate MCCS related data. Some studies examined the structured information in MCCS datasets. There is no in-depth study that has examined the unstructured textual contents in the MCCS data. This study aims to mitigate this research gap by applying different natural language processing (NLP) tools (e.g., text mining, topic modeling). Fatal and non-fatal crash narratives are clustered separately to gain injury level specific insights. The findings of this study will contribute to the on-going studies on MCCS to better understand the crash causation mechanism associated with motorcycle crashes.

Authors	Nada Mahmoud, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai (Corresponding Author), University of Central Florida Brenda Young, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03294
Paper Title	Factors Contributing to Operating Speed on Different Context Classifications of Arterial Segments in Central Florida
Abstract	Operating speed is fundamental in many fields of transportation engineering including traffic safety, transportation planning, and geometric design. Hence, many studies explored the impact of different exogenous variables on the operating speed represented by the 85th percentile speed. This study contributes to the literature by evaluating and identifying the factors influencing operating speed considering context classification. The study focused on three contect classifications: C3R-Suburban Residential, C3C-Suburban Commercial, and C4-Urban General. Further, it identifies the potential speed calming measures that influence the operating speed for specific context classification categories. Hence, a Tobit model was proposed and developed using big data including traffic roadway characteristics, land use attributes, and sociodemographic information. Three years INRIX speed data were obtained for around 1800 roadway segments and to calculate the 85th percentile speed. The study propsed an approach to adjust the 85th percentile speed from INRIX data since traffic flow on arterials could be disrupted by signalized intersections. Afterwards, empirical analysis was conducted by developing three Tobit models: Generic, C3C/C3R, and C4 models using the adjusted 85th percentile speed. In conclusion, for the three developed models, several variables (e.g., inside shoulder type, inside shoulder width, speed limit, and number of signalized intersections per mile) were found to have significant influence on the 85th percentile speed. The analysis also indicated the potential speed management countermeasures that have significant impact on the 85th percentile speed.

Authors	Chiara Silvestri Dobrovolny, Texas A&M Transportation Institute Husain Aldahlki (Corresponding Author), Texas A&M University, College Station Roger Bligh, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03356
Paper Title	Best Practices for Guidelines for Inspection, Repair, and Use of Portable Concrete Barriers in Roadside Safety
Abstract	The Manual for Assessing Safety Hardware (MASH) implementation agreement allows state transportation agencies to continue the use of portable concrete barriers (PCBs) manufactured on or before December 31, 2019, and successfully tested to National Cooperative Highway Research Program Report 350 or the 2009 edition of MASH, throughout their normal service life. PCBs can incur damage while in transit, in storage, or due to vehicular impact. Often, PCBs can experience damage such as broken or bent connections, cracks, concrete spalling, and more. The American Traffic Safety Services Association developed a basic qualitative guidance for evaluation criteria of such barriers. A few departments of transportation (DOTs) have developed their own guidelines for inspection of PCB segments or evaluation criteria for the acceptability of PCBs. Since no federal guidance has yet been developed to determine life expectancy or acceptability for PCBs, agencies are left to determine whether to repair or replace segments without adequate information, which could lead to unsafe barriers on the National Highway System. There is a need to develop a comprehensive review of best practices of Agencies guidelines which address replacement or repair of PCB segments based on the type and extent of barrier damage. A survey was conducted to complement a throughout literature review of identified guidelines to provide those DOTs in needs with proposed guidelines for inspection, evaluation and repair of PCB segments. This paper summarizes relevant survey findings and proposes future research work to validate developed guidelines for inspection, evaluation, and repair of PCBs.

Authors	FAHMID HOSSAIN (Corresponding Author), University of Utah Juan Medina, University of Utah
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03366
Paper Title	VERIFICATION OF USRAP RISK ASSESSMENTS FOR RUN-OFF AND HEAD-ON CRASHES USING FIELD DATA
Abstract	The United States Road Assessment Program (usRAP) provides a systemic approach to estimate the risk of severe injury and fatal crashes along roadway segments based on expected safety performance of roadway and roadside characteristics, together with a general estimation of traffic volume. Detailed crash data is not needed for safety assessments, providing advantages over more traditional crash-driven approaches. However, experiences with usRAP are limited in the U.S., and to date, the program has a growing but limited number of participating states. Verification of the adequacy of usRAP assessments is therefore of significant value, not only to identify strengths and limitations of the methodology within the U.S. context, but also to potentially expand the set of tools available to agencies. This paper presents a verification of usRAP risk assessments for run-off road and head-on crashes using over 7,000 miles of coded segments and five years of crash data collected in Utah. Comparisons between risk estimations from usRAP and actual crash rates provided insights on expected and observed effects of roadside objects and their distances from the traveled lanes, type of median present, as well as horizontal curves. A spatial correlation test also confirmed the agreement between usRAP risk assessments and crash data, providing additional promising indications of the suitability of this systemic methodology for safety applications.

Authors	Yingying Pei, Tongji University Xuesong Wang (Corresponding Author), Tongji University Mingjie Feng, Tongji University Zhixing Zhu, Traffic Police Headquarters of Jiangsu Province Fang Liu, Traffic Police Department of Suzhou City Zhongyang Qie, Traffic Police Department of Suzhou City Paul P. Jovanis, Pennsylvania State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03435
Paper Title	Macro-Level Safety Analysis of Crashes and Violations: Influencing Factors and Crash Hotspots
Abstract	Regional traffic safety has been a public concern for many metropolitan areas, and it is urgent to turn this situation around by using an appropriate traffic safety analysis and crash hotspot identification method. Existing studies mainly focus on the effects of engineering-related indicators on regional crashes and violations, neglecting the traffic police enforcement-related factors. Meanwhile, the relationship between crashes and violations is insufficiently recognized. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, and collected socio-economic indicators, road features, land use intensity, facility data, and police enforcement information as independent variables. A Bayesian bivariate negative binomial spatial conditional autoregressive (BNB-CAR) model was developed to capture the association between crashes and violations, as well as their contributing factors. Results showed that (1) there existed a significantly correlated effect between crashes and violations; (2) engineering-related indicators had similar effects on crashes and violations, while some police enforcement-related factors were dual-effective. Based on the model results, this study used the potential for safety improvement (PSI) method to identify the hazardous areas of the 115 towns in Suzhou. It was observed that (1) the spatial distribution of crashes indicated the spatial correlations among the towns; (2) the fringe areas suffered higher crash risks than the downtown areas. Several engineering and enforcement countermeasures were provided for urban planning departments and traffic police to enhance their work effectiveness. Additionally, decision makers and administrators will benefit from this study to improve daily traffic safety management.

Authors	Branislav Dimitrijevic, New Jersey Institute of Technology Sina Darban Khales, New Jersey Institute of Technology Roksana Asadi (Corresponding Author), New Jersey Institute of Technology Joyoung Lee, New Jersey Institute of Technology Kitae Kim, New Jersey Institute of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-03591
Paper Title	Segment-Level Crash Risk Analysis for New Jersey Highways Using Advanced Data Modeling
Abstract	Highway crashes are the most significant challenge to the goal of providing a safe and efficient highway transportation system. They result in significant societal toll reflected in numerous fatalities, personal injuries, property damage, and traffic congestion. To that end, much attention has been given to developing models to study and predict crash occurrence. More recently advancements have been made in developing proactive crash risk models, aiming to assess crash risks in the short term, and inform traffic management strategies to prevent and mitigate the negative effects of crashes. This study developed and tested several models for segment-level crash risk considering the data available to most transportation agencies in real-time on a regional network scale. The data included roadway geometry characteristics, traffic flow characteristics, and weather condition data. The models included Bayesian Logistics Regression (BLR), Decision Tree (DT), Random Forest (RF), Gradient Boosting Machine (GBM), K-Nearest Neighbor (KNN), and Gaussian Naïve Bayes (GNB). The models were trained and tested using a dataset containing records of 10,155 crashes that occurred on two interstate highways in New Jersey over two years. It was found that for the given dataset the models provided limited predictive value.

Authors	Asad J. Khattak, University of Tennessee Numan Ahmad, University of Tennessee Behram Wali, University of Tennessee
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-04104
Paper Title	Heterogeneity in Naturalistic Driving Errors, Violations, and Crash Risk in Diverse Environmental Context
Abstract	Driving errors and violations are identified as contributing factors in most crash events. Different types of driving errors and violations may vary across diverse roadway environments. Due to unique nature of several types of driving errors and violations, crash risk associated with each type of these driving errors and violations can be different. To empirically explore errors and violations in diverse built environments, this study harnesses unique and highly detailed pre-crash sensor data collected in SHRP2 Naturalistic Driving Study (NDS), containing 673 crashes, 1,331 near-crashes and 7,589 baselines (no-event). First, we apply our previously proposed systematic taxonomy of driving errors and violations to bring all types of human crash-contributing factors into systematic framework, and then compute crash risk associated with different driving errors and roadway environment. Based on percentage of crashes per percentage of baselines in a specific locality, interstates and rural and semi-rural settings may pose lower risks. Contrarily, urban, business/industrial, and school locations seem to have higher percentage of crashes per percentage of baselines indicating higher crash risk. Human errors and violations contributed to 93% of crashes. Recognition and decision errors occurred more frequently (each contributing to ~39% of crashes) in business or industrial land use environments (but not in dense urban localities). Distribution of driving errors and violations across different roadway environments can aid in implementation of place-based countermeasures with implications for connected and automated vehicle development, e.g., by understanding complex and unusual (fringe case) situations for safety, testing of connected and automated vehicles can be enhanced.

Authors	Shefa Arabia Shioma, University of Toledo Ahmad Ilderim Tokey (Corresponding Author), University of Toledo Muhammad Salaha Uddin, University of Toledo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1304
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	21-04448
Paper Title	Assessing the Effectiveness of Built Environment-based Safety Measures by Urban and Rural Area for Reducing the Non-motorist Crashes
Abstract	Built environment (BE)-based safety measures are usually implemented for reducing the non-motorist crashes in urban and rural area. However, their usefulness differing the urban and rural area were not widely explored in literature. Therefore, this study was explored the effectiveness of built environment-based safety measures in urban and rural settings. The study used four years' (2015-2018) non-motorist (pedestrian and bi-cyclist) crash data of Florida and examined the effect of built-environment based safety measures such as sidewalk, distance from the road, bike lane, barrier, land use mix. In this study urban and rural area were classified by applying the multivariate clustering method. The study used the negative binomial and geographically weighted Poisson regression (GWPR) for understanding the effects of BE factors assuming their spatial heterogeneity. The study finds that building the sidewalk only, and existence of intersection expose the people to crash incidents in urban areas while traffic volume works for increasing non-motorist crashes in the rural areas. The analysis also reveals that combinedly sidewalk and barrier can reduce the risks of non-motorist crashes. Signalized intersection also reduces the effect of high traffic volume on the frequency of crashes. Higher percentage of commercial Land uses (LU) in high mixed LU are helpful for ensuring the safety of pedestrian and cyclists. This study findings will be supporting for implementing the BE based safety measures considering their combined effectiveness as well as the urban and rural characteristics of the area.

9 Interacting Committees

Other **twenty-four Committees** sponsored several papers which are within the scopes of ACS10 and ACS20. Names and scopes of these Committees are reported below.

ACH10, 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.

ACH20, 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.

ACH60, Vehicle User Education, Training, and Licensing
The Committee is concerned with research and development activities designed to optimize the education, training, and licensing of motor vehicle drivers, riders, and operators throughout the lifespan. The committee maintains a special focus on the behavior, safety, and well-being of high-risk groups, including younger drivers, older drivers, and motorcyclists. We also work to ensure the adoption of automated vehicle technologies is incorporated within education and training across all age groups and high-risk groups.

ACP10, Regional Transportation Systems Management and Operations
This committee is concerned with regional transportation systems management to maximize transportation system performance in metropolitan areas, including coordinated and integrated decision-making approaches to operations and the harmonization of operations with planning, construction, preservation, and maintenance of transportation facilities.

ACP15, 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.

ACP25, Traffic Signal Systems

This committee is concerned with provision of the safe and efficient movement of people and goods on surface streets through the use of traffic management systems. The scope includes system design, implementation, operations, and maintenance; development of traffic operations centers; development of traffic management strategies; integration and operational evaluation of surface street systems with freeway, traveler information, and transit systems; and incorporation of surface street systems into Intelligent Transportation Systems (ITS).

ACP40, Highway Capacity and Quality of Service

This committee is concerned with relationships among those physical and non-physical factors which are found to affect capacity, traffic flow, comfort, convenience, and safety; measurement techniques for obtaining data for these factors; and acceptable standards of service in terms of measurable characteristics.

ACP55, Traffic Control Devices

The committee is concerned with all aspects of traffic control devices, including materials, installation, operational characteristics, maintenance, service life, human factors, and the effects of such devices on road safety and traffic operations. Applicable devices of interest to this committee include traffic signs, pavement markings/markers, delineators, channelizing devices, traffic signals, and work zone treatments, including barricades.

ACP60, Access Management

The committee will share the latest knowledge, expertise, and experience to facilitate leadership and partnerships to advance the state-of-the-practice in access management and its integration into established planning, policy, and design processes.

ACS30, Traffic Law Enforcement

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

ACS40, Occupant Protection

The Occupant Protection Committee monitors, synthesizes, encourages, and disseminates research activities related to the science of occupant protection, in all modes of transportation and around the world, to promote an evolving research agenda that addresses current and future occupant protection priorities. Occupant protection priorities include restraint system performance and efficiency to optimize protection, including biomechanical issues; economic impact to society; and behavioral measures to increase restraint use such as enforcement and education.

ACS60, 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.

AED30, Information Systems and Technology

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

AED60, 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.

AJE35, Research Innovation Implementation Management

The committee explores research and innovation processes and life cycles, from formulating needs through conduct of research and development efforts to technology transfer and implementation activities.

AJE40, Public Engagement and Communications

The committee focuses on the integration of tools, guidance, and best professional practices for engagement and communication with the public, stakeholders, and decision-makers during the planning, development, and delivery of transportation projects and policies, resulting in transportation decisions that reflect an understanding of current and emerging community, regional, statewide, and federal needs, values, and issues.

AJL70, Tort Liability and Risk Management

This committee will fill the need of the states for research, education, and training in the areas of tort liability and the administration of risk management. Its membership will be composed of attorneys, engineers, and administrators concerned with liability and risk management. Its members will provide useful insight and act as liaison, when requested, to other safety-conscious committees within TRB.

AKD10, Performance Effects of Geometric Design

This committee is concerned with all aspects of geometric design for components of the roadway system, with emphasis on research to inform geometric design policies, guidance and best practices. The Committee scope includes the development of frameworks, methods and tools to support performance-based geometric design approaches that speak to measurable performance outcomes such as road user safety and operational quality of service.

AKD30, Low-Volume Roads

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

AMR00, Transportation Systems Resilience Section

The Transportation Systems Resilience Section is part of Transportation Sustainability and Resilence Group. It consists of three committees that propose research, share research findings, sponsor special activities, and provide a forum for transportation professionals to discuss today's and tomorrow's transportation systems resilieince-related transportation issues. The chairs of each of these committees are members of the Transportation Systems Resilience Section Executive Board, who along with the section chair, provide general oversight of the activities within the Section.

AMR20, Disaster Response, Emergency Evacuations, and Business Continuity

This committee addresses issues related to managing and executing transportation, mobility, and logistical efforts associated with the preparation for, response to, and recovery from human-made and natural emergencies and disasters. Specific topics include emergency evacuations, the supply chains associated with disaster response, longer-term business and community continuity, and humanitarian relief. Each topic is considered in terms of technical, operational, and human dimensions and policies using analytical methods, innovative techniques, and decision-making processes to plan for, respond to and recover from emergency events.

AMR40, Systems, Enterprise, and Cyber Resilience

The Committee is concerned with identifying, replicating, and scaling the factors that contribute to a transportation system's resilience capacity. Organizational capabilities of interest include evidence-based analysis, decision-making processes that recognize the importance of resilience, funding strategies that support resilience-oriented investments, and staff who are trained in knowing what is necessary to improve system, enterprise, and cyber resilience.

AP050, Bus Transit Systems

The committee considers all factors relating to the operations, planning, and administration of bus transit systems, including the operations planning and development of bus rapid transit, including the forecasting of demand, financing, implementation, and systems analyses. Issues associated with guided, electric and battery-powered buses are also considered.

AT025, Urban Freight Transportation

The committee is concerned with the study and research of urban freight transportation topics and issues, including urban transportation system demand and economic relationships, right-of-way issues, pick-up and delivery needs, terminal transportation needs, institutional challenges, and new technology, with an emphasis on providing support to practitioners.