TRB Standing Committees

ANB10 – Transportation Safety Management

ANB20 – Safety Data, Analysis and Evaluation

ANB25 – Highway Safety Performance

Synthesis Report on Safety-Related Papers

presented at the 99th TRB Annual Meeting

Prepared by

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TRB Standing Committee ANB10 – Transportation Safety Management

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

Website: http://www.anb10.org, https://www.mytrb.org/OnlineDirectory/Committee/Details/1541

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TRB Standing Committee ANB20 – Safety Data, Analysis and Evaluation

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

Website: https://sites.google.com/site/trbanb20/, https://www.mytrb.org/OnlineDirectory/Committee/Details/1550

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Ezra Hauer, University of Toronto
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TRB Standing Committee ANB25 – Highway Safety Performance

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

Website: http://www.safetyperformance.org, https://www.mytrb.org/OnlineDirectory/Committee/Details/3844

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Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 99th Annual TRB meeting. With this aim, papers sponsored by the Committees ANB10 – Transportation Safety Management, ANB20 – Safety Data, Analysis and Evaluation, and ANB25 – Highway Safety Performance have been split into subthemes and the abstracts reproduced. For each subtheme, a brief comment on the methodological and application perspectives of the presented papers is reported. Further, some papers sponsored by other Interacting Committees which are within the scopes of ANB10[1], ANB20[2], and ANB25[3] have been identified and classified in order to promote better interaction between ANB10, ANB20, ANB25 and these other Committees. Indeed, highway safety is a worldwide major social challenge which requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

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

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

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

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

a) Crash Data and Data Analysis (105 papers);
b) Network Screening (14 papers);
c) Safety Performance Functions (84 papers);
d) Crash Severity Prediction (53 papers);
e) Crash Modification Factors (25 papers);
f) Surrogate Measures of Safety (25 papers); and
g) Transportation Safety Management (33 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 is concerned with the study of highway safety. This includes the collection, maintenance and use of crash records and related highway, driver, and vehicle data; the development of theories, analytical techniques, and evaluation methodologies for improving the understanding of highway safety; and the application of these theories, techniques and methods to identify driver, vehicle and/or roadway-based treatments that will enhance the safety of the transportation system.
[3] This Committee deals with the advancement, integration and institutionalization of quantitative highway safety information to support transportation decision-making at all levels. The function of this committee is to foster the continual development, validation and increased knowledge of science-based methods, procedures and measures that will increase the safety of the nation's highways and roadways.

Table 1 ANB 10, ANB20, and ANB25 Committee Meetings

Time	Title	Location
Tuesday, 1:30PM – 5:30PM	Safety Data, Analysis and Evaluation Committee, ANB20	Marriott Marquis, Salon 9 (M2)
Wednesday, 8:00AM – 12:00PM	Transportation Safety Management Committee, ANB10 https://sites.google.com/site/trbcommitteeanb10/news-events	Marriott Marquis, Shaw (M3)
Wednesday, 2:30PM – 6:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Salon 9 (M2)
Thursday, 8:00AM – 12:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Liberty Salon J (M4)

Table 2 ANB 10, ANB20, and ANB25 Subcommittee Meetings

Time	Title	Location
Tuesday, 8:00AM – 9:45AM	Bicycle and Pedestrian Safety Analysis, ANB20(4), Joint Subcommittee of ANB20, ANF10, ANF20, ANB25	Marriott Marquis, Independence Salon G (M4)
Wednesday, 10:15AM – 12:00PM	Surrogate Measures of Safety Subcommittee, ANB20(3)	Marriott Marquis, Salon 8 (M2)
Monday, 7:30PM – 9:30PM	Intersections, AHB65(1), Joint Subcommittee of AHB65, AFB10, AHB70, and ANB20	Marriott Marquis, Capitol (M4)
Wednesday, 8:00AM – 9:45AM	Future Directions in Safety Analysis, ANB20(1), Joint Subcommittee of ANB20, ANB25	Marriott Marquis, Salon 8 (M2)
Tuesday, 8:30AM – 9:45AM	Rural Road Safety Policy, Programming, and Implementation, ANB10(7), Joint Subcommittee of ANB10, AFB30, ANB20	Marriott Marquis, Salon 9 (M2)
Tuesday, 10:15AM – 12:00PM	School Transportation Subcommittee, ANB10(6)	Marriott Marquis, Howard University (M1)
Tuesday, 10:15AM – 12:00PM	Animal-Vehicle Collisions Subcommittee, ANB20(2), Joint Subcommittee of ANB20, ADC30	Marriott Marquis, Salon 16 (M2)
Monday, 8:00AM – 9:45AM	Traffic Speed and Safety - Cross-cutting Issues, ANB20(5), Joint Subcommittee of ANB20, AHB65, ANB10	Marriott Marquis, Supreme Court (M4)
Tuesday, 6:00PM – 7:30PM	Emergency Response, ABR30(1), Joint Subcommittee of ABR30, ANB10, ANB40, AHB10	Marriott Marquis, Liberty Salon O (M4)
Wednesday, 12:15PM – 2:15PM	Highway Safety Performance User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marriott Marquis, Salon 9 (M2)
Wednesday, 6:15PM – 7:15PM	Highway Safety Performance Policy and Legal Aspects Subcommittee, ANB25(1)	Marriott Marquis, Salon 13 (M2)
Wednesday, 7:30PM – 9:30PM	Highway Safety Performance Technical Issues Subcommittee, ANB25(8)	Marriott Marquis, Salon 12 (M2)

Table 3 ANB 10, ANB20, and ANB25 Workshops

Time	Title	Location
Sunday, 9:00AM - 12:00PM	(1004) Speed Management	CC, 152B
Sunday, 9:00AM - 12:00PM	(1033) The Nexus of Speed Management and Human Factors as a Focal Point of Safe Systems	CC, 101
Sunday, 9:00AM - 12:00PM	(1034) Surrogate Measures of Safety for Heterogeneous Traffic: Automation, Cyclists, and Pedestrians	CC, 102A
Sunday, 1:30PM - 4:30PM	(1073) Lessons Learned Using "Big Data" to Evaluate Geometric Effects	CC, Salon C
Sunday, 1:30PM - 4:30PM	(1076) Developing Local Road Safety Plans: Partnering with State DOTs, Municipal Planning Organizations, and Local Agencies	CC, 149
Sunday, 1:30PM - 4:30PM	(1077) Use of Safety Performance in Day-to-Day Transportation Decision Making	CC, 102B
Monday, 10:15AM - 12:00PM	(1188) Tools for Transforming Road Safety Practice to Safe Systems	CC, 103A
Thursday, 8:00AM - 12:00PM	(1783) Rural Transportation for Everyone: Policy and Practice in 2020	CC, 102B

Table 4 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 10:15AM – 12:00PM	(1188) Tools for Transforming Road Safety Practice to Safe Systems	CC, 103A
Monday, 10:15AM – 12:00PM	(1189) Doctoral Student Research in Transportation Safety—Hybrid Session	CC, Salon B
Monday, 1:30AM – 3:15PM	(1259) Taxis, Wealth, Speed, and Active Commuters: Informing Safety with Diverse Data Sources	CC, 103A
Monday, 3:45PM – 5:30PM	(1316) Safety Management in a World of Connected and Automated Vehicles—Hybrid Session	CC, Salon B
Wednesday, 10:15AM – 12:00PM	(1702) Moving Transportation Safety Research into Practice	CC, 150B
Wednesday, 10:15AM – 12:00PM	(1721) Highway Safety Performance Research	CC, 103A

Table 5 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 1:30PM – 3:15PM	(1284) Transportation Safety Management from Start to Finish	CC, Hall A
Monday, 3:45PM – 5:30PM	(1338) Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources	CC, Hall A
Monday, 3:45PM – 5:30PM	(1339) Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods	CC, Hall A
Monday, 3:45PM – 5:30PM	(1340) Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates	CC, Hall A
Monday, 6:00PM – 7:30PM	(1352) Emergency Responders	CC, Hall A
Monday, 6:00PM – 7:30PM	(1356) Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored	CC, Hall A
Monday, 6:00PM – 7:30PM	(1357) Intersection Safety in Focus	CC, Hall A
Monday, 6:00PM – 7:30PM	(1358) Focus on Pedestrian and Bicycle Safety	CC, Hall A
Wednesday, 8:00AM – 9:45AM	(1691) Highway Safety Performance Research	CC, Hall A

2 Crash Data and Data Analysis

Mohamad Banihashemi, CYFOR Technologies

Similar to the previous years, Crash Data and Data Anaysis contained many papers in wide variety of subjects in highway safety. Of over 230 papers submitted to the ANB10, ANB20, and ANB25 Committees for 2020 Annual Meeting, there are about **105 papers** that fit in this major category, with several sub-categories 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 33 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.

Hossain Shimu, T. (20-04761) have studied factors affecting crash reductions in 2008-2011. Taylor, B. et al. (20-05268) have questioned the use of the 85th percentile speed in safety evaluation. Peel, T. et al. (20-05708) have studied the relations between real-time weather data and crash likelihood. Jalayer, M. et al. (20-02123) have studied bridge-related crashes. Cai, Q. et al. (20-02940) present a method to balance the crash and non-crash data. Wang, J. et al. (20-03224) present a real-time crash prediction model for freeway workzones. Liu, T. et al. (20-03472) have used traffic trajectory data to evaluate crash risks. Fawcett, L. et al. (20-03883) have investigated alternative methods to the Empirical Bayes (EB) in dealing with Regression-to-the Mean (RTM). Jiang, F. et al. (20-00870) have used traffic data to detect crashes. Cai, X. et al. (20-02105) have evaluated the risk of crashes using vehicle onboard data. Bao, S. et al. (20-02682) have used car following to predict braking behavior. Raju, N. et al. (20-03089) have used trajectory data to identify rear-end crash risks. Yuan, J. et al. (20-03166) have used spatial-temporal LSTM data to predict real-time crash risks. Wang, K. et al. (20-03236) present a model to identify aggressive drivers. Ledezma-Navarro, B. et al. (20-03499) have used video trajectory data to study intersections. Azizi, L. et al. (20-04969) have used trajectory data to estimate freeway safety. Hu, M. et al. (20-00229) present a correlation analysis of traffic conflicts and driver behaviors. Clouter, M. S. et al. (20-005054) and J. S. Lopez Valderrama et al. (20-05723) have studied the safety effects of speed reduction.

Poster Session 1357, “Intersection Safety in Focus” presents several papers of this category related to intersections. These are papers submitted by J. Yuan et al. (20-01626), D. Yang et al. (20-01888), K. Ghosh et al. (20-04503), A. Ryan et al. (20-04710), M. Essa et al. (20-00438), and A. Deliali et al. (20-05955).

Poster Session 1691, “Highway Safety Performance Research” presents several papers of this category with models focusing on specific sections or characteristics of highway facilities.

Gayah, V et al. (20-00041) have focued on an alternative form of traffic volume. Pervez, A. et al. (20-00660) have studied expressways tunnels. Chen, Y. et al. (20-03150) have evaluated lane-unbalanced merging areas. Expressway crashes were studied by J. Tan et al. (20-03262) and the effect of high friction surface treatment was studied by C. Lyon et al. (20-04012). Xue, C. et al. (20-04521) and S. Duvvuri et al. (20-04902) have studied "Wrong-Way Driving" safety and D. Edere et al. (20-04778) have studied the relations between speed and crashes.

Pedestrians, Bicyclists and Scooters: This is the second largest sub-category with 20 papers presented in the Annual Meeting.

All of these papers are presented in the poster session 1358, "Focus on Pedestrian and Biycle Safety." Yue, L. et al. (20-01440), T. Fu et al. (20-01525), H. Golakiya et al. (20-03513), S. Geedipally et al. (20-04899), R. Apardian et al. (20-05107), R. Schneider et al. (20-02402), C. McCahill et al. (20-04507), H. Nasseredin et al. (20-05550), R. Schnieder (20-05733), D. Mukherjee et al. (20-05873) and R. Sanders et al. (20-06009) present papers related to pedestrians' safety.

Russo, B. et al. (20-05024), M. Saad Shaheed et al. (20-04215), N. Ferenchak et al. (20-05462), and S. Lavrenz et al. (20-05700) present papers related to bicyclists' safety. Torbik, D. et al. (20-04754), J. Lee et al. (20-3549), and A. Osama et al. (20-03773) have studied the combination of pedestrian and bicyclists' safety.

Das, S. et al. (20-02468) have used YouTube data to study pedestrian collisions with bikes and K. Fang et al. (20-05846) have studied the characteristics and circumstances of injuries related to scootes.

Data Manipulation, Emergency Medical Services (EMSs), and Secondary Crashes: There are 17 papers related to these subjects in the Annual Meeting. Poster Session 1352, "Emergency Responders" contains the majority of presentations related to EMSs.

Medcalf, S. et al. (20-03226), A. Hosseinzadeh et al. (20-03659), C. Xiong et al. (20-05675), V. Mishra et al. (20-03840), S. Jung et al. (20-03882) and B. Subedi et al. (20-04232) present their studies related to the EMSs. Wajid, S. et al. (20-04786) and J. Darko et al. (20-02283) have optimized "Ambulance" and "Unmanned Arial Vehicles" (UAVs) locations, respectively and T. Li et al. (20-05465) have developed a drone network for EMSs.

Dadvar, S. et al. (20-01983) have developed a tool to manipulate the HSIS data. Martin, M. (20-04603) presents a methodology to derive occupancy data. Yu, Z. et al. (20-00659) present their study on non-ID vehicles safety. Salum, J. et al. (20-05829) present their researches related to secondary crashes. Li, X. et al. (20-03622) have used Waze Data to improve crash data. Deng, L. et al. (20-02700) have used loop detector data to identify freeway secondary crashes. Ting Keung, J. M. (20-02239) present a framework for determining sample size for data used in conflict-based safety analysis and M. Lee et al. (20-02138) have studied the secondary crash risk factors

Connected and Automated Vehicle Safety: There are 10 papers presented in the Annual Meeting in this sub-category.

Feng, S. et al. (20-01530) have proposed a framework to evaluate the safety of the automated driving systems. Pan, A. et al. (20-03409) and H. Alambeig et al. (20-05062) have studied the highway safety under the condition of mix automated and human driven vehicles. Bin-Nun, A. et al. (20-05778) have used Heinrich's triangle to compare the safety of autonomous and human driving vehicles. Souleyrette, R. et al. (20-04468) have studied the effects of automated and comnnected vehicles on emergency response times. Li, Y. et al. (20-00665) have used trajectory data to compare connected and automated vehicles and human driven ones. Safety effects of adaptive cruise control systems were evaluated by R. Rahman et al. (20-01922). Lin, Q. et al. (20-02778) have proposed methodologies to evaluate the safety effect of automatic vehicle trajectory. Mousavi, S. M. et al. (20-04169) have used microsimulation to study the safety of autonomous driving in proximity of driveways and G. Yang et al. (20-05214) present the safety assessment of a connected vehicle pilot program.

Network and Macro-level Modeling, Systemic Safety, Hotspot Analysis, and Economic Analysis: There are 9 papers related to this sub-category.

Rahmani, R. et al. (20-03791) present a crash tree model to be used in systemic safety analysis. Herrera, M. (20-05787) offers a systemic approach to reduce left-turn crashes. Shen, S. et al. (20-01849) have studied the validity of Quasi-Induced Exposure (QIE) method assumptions. Parker, S. et al. (20-05109) present introduce tools developed by WI DOT to improve their safety analysis. Lu, J. et al. (20-2761) have identified hotspots using simulation. Wood, D. et al. (20-000506) have studied the association s between regional self-reported psychological assessments and crashes.

Himes, S. et al. (20-01426) present macro-level crash prediction models developed for Virginia. Yannis, G. et al. (20-01634) present a case study of an Economic Assessment in Greece and M. Wu et al. (20-03212) present the results of their study on the effect of Driver Feedback Sign (DFS).

Analysis of Spatial and Naturalistic Driving Data (including SHRP 2 Data): There are 16 papers related to this sub-category.

Zhou, Y. et al. (20-05352) and J. Stipancic et al. (20-01391) have used GPS data to study speeding and relations between traffic flow and crashes, respectively. Kong, X. et al (20-03307), P. Alrassy et al. (20-03476), and C. Chen et al. (20-04670) have used NDS and GPS data to study speeding and other driver behaviors. Iqbai, A. et al. (20-05894) have assessed the accuracy of crash locations. Savolainen, P. et al. (20-000906) have used NDS data to study reaction times and deceleration rates. Shirazi, M. et al. (20-02285) present simulation of temporal and spatial aggregation of safety datasets. Parsa, A. B. et al. (20-04120) present a model to detect crashes using real-time spatial data. Tang, H. et al. (20-04298) have used NDS

data to evaluate crash risk. Bamney, A. et al. (20-03977) have used NDS data to study the safety effect of distracted driving.

SHRP2 data are used in several researches. Ivan, J. et al. (20-05691), V. Venkatraman et al. (20-06087), A. Tarko et al. (20-01358), O. Osman et al. (20-04962), and M. Atiquzzaman et al. (20-05404) have used SHRP2 NDS data to study relations between speed, driver behavior, traffic conflicts, and vehicle kinematics, and crashes as well as the crash/near-crash situations relations..

Below, for each of the 105 papers involving crash data and data analysis, the following information is provided: authors, sponsporing committee, session numer, session title, paper number, paper title, and abstract.

Poster Session 1284

Authors	Seyedehsan Dadvar, Turner-Fairbank Highway Research Center, Federal Highway Administration Young-Jae Lee, Morgan State University Hyeon-Shic Shin, Morgan State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-01983
Paper Title	**Development and Application of Roadway Safety Data Integrator (RSDI) Tool for Highway Safety Information System (HSIS) Data**
Abstract	The Highway Safety Information System (HSIS) is a database that maintains crash data, roadway inventory, and traffic volume data for several US states. It is an excellent source of data to highway safety research and can be used to investigate many research questions. However, to prepare a roadway safety dataset based on the HSIS or any databases that store the data in multiple different subsets and follows linear referencing, the researchers should combine multiple datasets, merge or unmerge and remove certain inconsistent records, and finally clean the dataset. The HSIS staffs are usually accommodating and eager to help, but sometimes the nature of data needs is complicated and laborious. A tool named Roadway Safety Data Integrator (RSDI) was developed for combining, segmentation, and selection of homogeneous HSIS roadway segments and also crash assignment by desired crash fields (e.g., crash severity or type). This study utilized the RSDI to enhance the study on investigation of an alternative calibration method for the Highway Safety Manual (HSM). The results of a preliminary analysis based on sample data from Maryland were validated and complemented by statewide data from Illinois and Washington. The proposed calibration methodology incorporates multiple calibration factors for different components of the HSM predictive method rather than a single calibration factor, as recommended by the HSM that only calibrates at the aggregate level. In the proposed method, the application of calibration factors expressed in both weight and power function reflects better the local conditions while still ensuring calibration at the aggregate level.

Authors	Roozbeh Rahmani, University of Florida Nithin Agarwal, University of Florida Sivaramakrishnan Srinivasan, University of Florida Ilir Bejleri, University of Florida Xingjing Xu, University of Florida Jia Fang, University of Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-03791
Paper Title	**Cross-Comparison and Objective-Based Crash Tree Development and Analysis for Small Counties in Florida**
Abstract	The Federal Highway Administration (FHWA) developed the Systemic Safety Project Selection Tool that lists six steps to integrate existing safety management practices and safety analysis tools. The first step is to identify and understand the risk factors commonly associated with the focus crash types. Crash trees have been adopted by agencies to identify the focus facility types and crash types. For most organizations and departments of transportation (DOTs), the concept behind developing a crash tree is a stepwise elimination process where higher value in the crash tree is retained and the rest of the branch is eliminated. This paper demonstrates some of the challenges with the conclusions of this traditional approach and proposes an alternative structure using a cross-comparison framework that not only compares the raw counts from the crash data but also compares focus county's crash percentage and ranking to other similar counties or jurisdictions. This approach assists the decision-makers in understanding the intensity of overrepresentation. This study developed a tool that applied the cross-comparison crash tree approach for 27 small rural counties in Florida to determine the percentage and crash severity ranking. The results demonstrated the benefits of this approach by prioritizing the focus areas and the counties by normalizing the counts and the intensity of the overrepresentation.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04603
Paper Title	**Vehicle Occupants and Driver Behavior An Assessment of Vulnerable User Groups**
Abstract	The question of whether driver behavior, and speeding in particular, differs based on vehicle occupancy requires the use of large amounts of data—some of which may be difficult to accurately obtain. Traditional methods of obtaining information on driver behavior either lack passenger information altogether (i.e., insurance companies using telematics) or rely on rough estimates of passenger age and gender obtained from blurred photos (i.e., naturalistic driving studies like State Highway Research Program 2 (SHRP 2)). This research project represents a novel, data-driven approach to this topic. Household travel survey demographic information and global positioning system (GPS) traces were linked to HERE network speed limit to study the impact of vehicle occupancy on speeding. Survey responses from 11 study areas were cleaned, merged, and ultimately used in developing binomial logistic regression models. Of particular interest were the vulnerable user groups of teenagers, adults driving with children, and seniors. The models suggest that drivers speed less when there is a passenger in the vehicle, especially adults with a child passenger.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04761
Paper Title	**Investigating Factors that Contributed to the Large Reduction and Subsequent Increase in Roadway Fatalities in the United States between 2005 and 2016**
Abstract	The substantial decline in motor-vehicle fatal crashes over the period of 2008 to 2011 and a subsequent increase afterwards in the United States has been subjected to extensive research in the last few years. Following the perceptible reduction in traffic fatalities beginning in 2008, which concurred with a major recession, researchers focused on finding the relative influence of the recession on fatalities using statistical modeling. The Project 17-67 by the National Cooperative Highway Research Program (NCHRP) conducted an in-depth investigation, where the researchers developed two Poisson-gamma regression models, Model Controlling State (MCS) effect and Model Not Controlling State (MNCS) effect to analyze the factors associated with the decline in fatalities. This study sought to serve as an extension of the NCHRP Project 17-67 to provide a thorough investigation of the factors influencing fatalities during and after the 2008 recession using an updated dataset to 2016. The modeling results showed remarkable improvements, where both the MNCS and MCS models could reflect the fluctuations in fatalities over the focus period. The effect analysis revealed that the economic factors contribute as much as 84% to 86% in the reduction and subsequent increase in fatalities during and after the recession. The unemployment rate of 16 to 24 years old, median household income, and the price of gasoline were found to be the most statistically significant parameters in both the models. Changes in vehicle-miles traveled (VMT), government expenditure, and regulatory measures were not significant factors in affecting the number of fatalities over the analysis period.

Authors	Margaret Herrera, Maricopa Association of Governments
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05787
Paper Title	**Systemic Strategy to Mitigate Intersection Left-Turn Crashes A Regional Analysis Methodology**
Abstract	This paper presents a crash analysis methodology utilized by the Maricopa Association of Governments (MAG) to identify intersections with the best potential of benefitting from safety improvements related to creating positive offset. The Phoenix metropolitan planning area consists of 27 cities and towns and three (3) Native Nation communities with a population over five million. MAG has conducted over 70 Road Safety Assessments (RSAs) at intersections across the region. A detailed review of observations and recommendations of RSAs conducted where the left-turn crashes were overrepresented showed 26 percent of the observations related to the lack of sufficient sight distance noted as a potential causal factor. It is widely accepted that "a positive offset of left turn lanes" improves sight distance and would help mitigate this crash risk. Although a larger percentage of recommendations for mitigating left-turn crashes related to modifications to left-turn signal phasing, it was determined that the analysis should focus on the countermeasure related to sight visibility for a more meaningful screening and analysis to address a greater need in the MAG region. MAG identified a project to study a Systemic Strategy to Mitigate Intersection Left-Turn Crashes. The methodology outlined in this paper was used to screen all signalized intersections in the region. The study resulted in 1) a sample of intersections in the MAG region that would provide meaningful analysis of the left-turn crash problem as it relates to lack of sight visibility, and 2) a project assessment which included development of HSIP funding applications.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05268
Paper Title	**The Eighty-Five Percent Solution: A Historical Look at Crowdsourcing Speed Limits and the Question of Safety**
Abstract	The "85th percentile rule" is commonly used to set speed limits in jurisdictions across the U.S. Modern interpretations of the rule are that it satisfies key conditions needed for safe roadways: it sets speed limits deemed reasonable to the typical, prudent driver, reduces the problematic variance in travel speeds among vehicles, and allows law enforcement to focus on speeding outliers. Authoritative publications regularly assert that the rule came about because early driving surveys often found that drivers moving at or below the 85th percentile of a speeds on a given roadway were about one standard deviation above the mean speed for that roadway and were "in the low involvement group for traffic incidents" (Research Triangle Institute, 13). This conventional wisdom about the 85th percentile rule is increasingly called into question today by both safety advocates and promoters of more "complete" urban streets. Given this emerging debate, it's an opportune time to ask where this rule of driver-set speed limits came from and if the rule's developers' rationales still hold true today. While most observers trace the rule to safety research and a 1964 report, we find that it actually emerged decades earlier when "traffic service" was a preoccupation of the nascent traffic engineering profession during the first half of the 20th century, and likely a central motivation behind the development of the rule.

Lectern Session 1316

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Lectern Session 1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-01530
Paper Title	**Safety Assessment of Highly Automated Driving Systems: A New Framework**
Abstract	Safety assessment is critical in the development and deployment of highly automated driving systems (ADS). In this paper, a new framework is proposed for closed-facility testing, which can quantitatively, accurately, and efficiently assess the safety of highly ADS in a cost-effective fashion. To this end, two major problems of closed-facility testing approach are resolved by two pillars of the framework. First, an augmented reality (AR) testing platform is constructed to augment the real ADS interacting with simulated background traffic. Second, a testing scenario library generation (TSLG) method is designed to systematically generate a set of critical scenarios for each operational design domain (ODD). Four research questions are identified as scenario description, metric design, library generation, and ADS evaluation. By the important sampling theory, generating a library is transformed as constructing an importance function. A new definition of criticality and critical scenario searching methods are proposed. The framework is implemented in the Mcity test facility at the University of Michigan. Field test results validate the accuracy and efficiency of the proposed framework. In the cut-in case study, the proposed framework can accelerate the safety assessment process by 9.87×10 4 times faster than the public-road testing approach.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Lectern Session 1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-03409
Paper Title	**An Analysis of the Efficiency and Safety of Signalized Intersections under Conditions of Autonomous Vehicle Mixed Flows**
Abstract	Field experiments of autonomous driving systems have already been started in several countries around the world. However, investigations on the performance of signalized intersections under the mixed flow condition of autonomous vehicle (AV) and human driven vehicle (HDV) is still very limited, especially in terms of considering the interaction between vehicles. This study aims at developing a methodology to evaluate the efficiency and safety performance of signalized intersections under the conditions of AV mixed flows. If AVs are set aggressively such as small critical gap acceptance thresholds, approach capacity of signalized intersections may increase. However, the aggressive driving maneuver and the misjudgment by human drivers to AV may lead to some potential safety risks. On the other hand, if AVs are set conservatively to ensure large safety margins, for example by setting large critical gap thresholds or a longer following headway, a significant drop in the capacity is expected while the safety improvements may not be insured since extra delays will be imposed on HDVs which may induce risky behaviors. This study finds that AV with either excessively aggressive or conservative settings will lead to waste of capacity or potential safety hazard.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Lectern Session 1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-05062
Paper Title	**Crash Themes in Automated Vehicles: A Topic Modeling Analysis of the California Department of Motor Vehicles Automated Vehicle Crash Database**
Abstract	Automated vehicle technology promises to reduce the societal impact of traffic crashes. Early investigations of this technology suggest that significant safety issues remain during control transfers between the automation and human drivers and automation interactions with the transportation system. In order to address these issues, it is critical to understand both the behavior of human drivers during these events and the environments where they occur. This article analyzes automated vehicle crash narratives from the California Department of Motor Vehicles automated vehicle crash database to identify safety concerns and gaps between crash types and current areas of focus in the current research. The database was analyzed using probabilistic topic modeling of open-ended crash narratives. Topic modeling analysis identified five themes in the database: driver-initiated transition crashes, sideswipe crashes during left-side overtakes, and rear-end collisions while the vehicle was stopped at an intersection, in a turn lane, and when the crash involved oncoming traffic. Many crashes represented by the driver-initiated transitions topic were also associated with the side-swipe collisions. A substantial portion of the side-swipe collisions also involved motorcycles. These findings highlight previously raised safety concerns with transitions of control and interactions between vehicles in automated mode and the transportation social network. In response to these findings, future empirical work should focus on driver-initiated transitions, overtakes, silent failures, complex traffic situations, and adverse driving environments. Beyond this future work, the topic modeling analysis method may be used as a tool to monitor emergent safety issues.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Lectern Session 1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-05778
Paper Title	**Heinrich's Triangle, Heavy-Tailed Distributions, and Autonomous Vehicle Safety**
Abstract	Road safety is a leading public health issue with over 1.35 million global road traffic fatalities in 2016. Automated Vehicles (AVs) may improve road safety. While considerable effort focuses on building AV systems according to strong engineering principles, measuring the safety of AV systems in the real world presents challenges. Severe crashes, while common in aggregate on public roads, occur at relatively low rates compared to the distance driven by a single driver. This paper examines the application of the Heinrich's triangle framework (HT) to human and autonomous driving. HT posits that severe incidents with injuries and fatalities share causal mechanisms with less severe incidents, near-misses, and even minor safety conflicts. This manuscript considers whether HT applies to human driving safety. We use several insurance claims data sets to examine whether there is a similar relationship between the frequency of milder and more severe crashes across the datasets. We offer evidence that human crash frequency-severity follows a heavy-tailed distribution, with the lognormal distribution generally providing a good fit. We further provide evidence that "leading indicators" such as near-crashes can help evaluate human driving safety. Finally, we discuss whether AVs may follow a similar crash frequency-severity distribution and whether examining rates of near-crashes or "safety envelope violations" could effectively evaluate AV safety using relatively small sample sizes We outline further research directions to evaluate this possibility.

Lectern Session 1259

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1259
Session Title	Taxis, Wealth, Speed, and Active Commuters: Informing Safety with Diverse Data Sources
Paper Number	20-05352
Paper Title	**Discrepancy Analysis of Four Cohorts of Taxi Speeding Recidivist Using GPS Trajectory Data**
Abstract	Despite the serious risk of speeding, driving groups such as taxi drivers are still inclined to commit repeated speeding violations during operations. However, the discrepancy of speeding among taxi recidivists are rarely discussed. The study attempts to explore the characteristics of speeding recidivism and evaluate the safety impact of different recidivists. GPS trajectory data are employed to identify the speeding violations, collected through the vehicular GPS device installed on taxis in Chengdu, China. According to the different speeding frequency and the percentage of high-range speeding (HSP), taxis are classified as four recidivist cohorts including low frequency-low HSP taxis (LLT), low frequency-high HSP taxis (LHT), high frequency-low HSP Taxis (HLT), and high frequency-high HSP taxis (HHT). The study utilizes ANOVA test and Power Model to explore the discrepancy of characteristics and safety performance among cohorts, respectively. The results find that speeding recidivism is a common phenomenon among the taxi drivers. All recidivists appear to commit the most speeding violations from 9pm to 12am and on the roadways with 20-40 km/h speed limit. In terms of the characteristics, LLT and LHT can be regarded as occasional and mild recidivist, while HLT and HHT seem to be the aggressive and risk-taking offenders. The safety evaluation suggests that the riskiest driving cohort is HHT. The elimination of those recidivists can reduce the frequency of injured crashes by at least 11.46%.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1259
Session Title	Taxis, Wealth, Speed, and Active Commuters: Informing Safety with Diverse Data Sources
Paper Number	20-05691
Paper Title	**Evaluation of Association between Observed Driving Speeds and the Occurrence of Crashes Using Naturalistic Driving Study Data**
Abstract	The SHRP2 Naturalistic Driving Study (NDS) data were used to investigate association between actual driving speeds before known crashes and at other times. Associations were evaluated for the same driver at a location where a crash occurred and similar locations where crashes did not occur, relative to the speeds of other drivers at those locations. It was found that an increase in the speed differential relative to other drivers at the same location between five and ten seconds before a crash occurred was significantly associated with a crash occurring. The quantile of the average speed over that five second period served as a better predictor than the quantile of the maximum speed. Crashes were also more associated with road locations classified as limited access highways. These findings are consistent across different drivers and types of road locations. The best performing model classified all of the crashes in the dataset perfectly, and only half of the cases classified as crashes were not. This suggests an ability to identify conditions that are 50 percent likely to result in a crash. The results could be used by road agencies to identify observed vehicle speed variations in real time that are likely to result in crashes, as well as by vehicle manufacturers to develop algorithms for identifying high crash risk conditions considering speeds of other vehicles in the vicinity.

Poster Session 1338

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-00659
Paper Title	**Speed Distribution and Safety Effects of License Plate Recognition: Analysis Combining Crash and Toll Record Data in Hunan Province, China**
Abstract	With the Chinese motor expressway network rapidly expanding, the amount of speed-related crashes has become an alarming phenomenon. Private vehicles that cannot be identified by enforcement cameras pose a threat to highway safety, specifically on expressways where it is problematic to initiate human enforcement. The purposes of this study are to investigate the speed characteristics of vehicles with no official identification (non–ID) on expressways and to compare key variables corresponding to the effects on casualties and injury severity. These variables will be analyzed for both non-ID vehicles and normal vehicles respectively. Data for expressway toll records and crash statistics from the expressway network of Hunan Province, China, have been collected and analyzed. The Results highlighted: 1) The means and variance of non-ID vehicles average travel speed are both higher than their normal counterpart; 2) There are relatively higher speeding rates among non-ID vehicles than their counterpart; 3) The injury severity of non-ID vehicles involved in crashes is significantly higher than that of normal vehicles. Moreover, according to the results analysis of crash severity, drivers' improper driving conducts, namely, speeding and fatigue driving are the fundamental causes of disastrous crashes. Summer, senior drivers, invalid license and alcohol intake also have an adverse effect on expressway travel safety. Similarly, crash time (evening) negatively affects crash injury severity. Findings of this study prove that it is essential to enhance safety management for non-ID vehicles on the expressway network in China.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-01391
Paper Title	**Relating Traffic Flow to Crashes Using Massive GPS Data: Smartphones and Usage-Based Insurance Data Agree**
Abstract	Mobile sensors are a powerful data source with applications in several transportation fields. Though cost of collection, transmission, and storage has practically limited studies on driving data and safety, this can be overcome through Usage Based Insurance (UBI). UBI programs track drivers to adjust their premiums based on driver-level surrogate safety measures (SSMs) related to exposure and driving style. Link-level SSMs (volume, speed, or density) could further improve discount calibration. This study quantifies relationships between traffic flow SSMs and historical crashes and includes the validation of previous results (using smartphone-collected data from Quebec City, Canada) and the comparison of three Canadian cities (using UBI data from Quebec City, Montreal, and Ottawa). Extracted SSMs were compared to large volumes of historical crash data using Spearman's Rank Correlation Coefficient and pairwise Kolmogorov-Smirnov tests to determine relationships with crash frequency and severity respectively. Results from the UBI data generally matched those from the previous study. With respect to crash frequency, observed correlations mirrored previous results in direction (congestion and speed variation are positively associated with crashes while mean speed is negatively associated with crashes) while correlation strength was slightly higher. Comparing cities, congestion appears to be a much weaker determinant of crashes in Montreal. Considering crash severity, the previously observed relationships were mostly validated: higher levels of speed variation are attributed to more severe crashes. The significant relationships between link-level SSMs and historical crashes clearly demonstrate the benefit for insurers, municipalities, and other agencies in predicting the likelihood and severity of crashes.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-01849
Paper Title	**Assessing the Validity of the Representativeness Assumption among Not-at-fault Driver via National Representative Field Observation Survey**
Abstract	The quasi-induced exposure (QIE) method has been widely used to estimate relative crash exposure. A key assumption of the QIE method states that not-at-fault drivers in clean two-vehicle crashes reflect the presence of the general driver population at the time of crash. This study, in contrast to previous studies who have utilized the remaining not-at-fault drivers excluding the first one in three-or-more vehicle crashes as the reference group, used direct field observation data to test the validity of the assumption for not-at-fault drivers in a United States (US) nationally representative crash database. Using the General Estimating System (GES) crash data and the National Occupant Protection Use Survey (NOPUS), distributions of driver gender, age, vehicle type, and time of crash among not-at-fault drivers in clean two-vehicle crashes (D2) and two-or-more-vehicle crashes (D_all) were compared to the driver population obtained from NOPUS. The results showed that with respect to gender and vehicle type, D2 and D_all were similar to the estimated driver population. Disaggregation of crashes by time suggested that similarities existed between D2, D_all, and NOPUS driver populations. Additionally, age distributions for all driver populations were marginally similar. Overall, not-at-fault drivers (regardless of D2 or D_all) in crash databases with all crashes ranging from no injury to fatal injury reflect the general driver population at the time of crash. Our study improves the credibility of the application of the QIE method in future traffic safety research using crash databases of all crashes with all severities.

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Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03307
Paper Title	**Understanding Speeding Behavior from Naturalistic Driving Data: Applying Classification Based Association Mining**
Abstract	Speeding is considered as one of the most significant contributing factors to severe traffic crashes. Understanding the associations between trip/driving/roadways features and speeding behavior is crucial for both researchers and practitioners. This research utilized GPS-based naturalistic driving data collected by the Safety Pilot Model Deployment (SPMD) program and roadway features from a road inventory dataset - Highway Performance Monitoring System (HPMS), provided by the Department of Transportation of the United States, to investigate the hidden rules that associated trip/driving/roadway features with speeding behavior. A classification-based association (CBA) algorithm was adopted to explore the hidden rules from two perspectives of speeding: speeding duration and speeding pattern. Results indicate that longer trips, driving during peak hours, tailgating other vehicles, being delayed in traffic before a speeding event, driving on roadways with a median or driving on higher functional class roadway are highly associated with relatively longer speeding events. In terms of speeding pattern, driving during peak hours, and tailgating other vehicles are two items showing repeatedly in the high speeding pattern cases. Moreover, higher functional class of roadway, presence or absence of median, and speed loss before a speeding event show high association with speeding events. The findings can help practitioners understand the composite effect of these factors more comprehensively and provide corresponding countermeasures to mitigate negative consequences wherever possible. These can also help in calibrating driver behavior parameters for transportation related simulation tools.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03476
Paper Title	**Driver Behavior Indices Derived from Large GPS Vehicle Fleet Telematics Data as Surrogate Safety Measures in a Metropolitan City**
Abstract	This study evaluates the relationship between driver behavior indices derived from large GPS vehicle fleet telematics data against collision frequency normalized with exposure, across the New York City road network. The key contributions are: (i) when studying the causality between hard braking and acceleration and collision, normalization by traffic volume is considered. (ii) The study adopts a data-fusion technique in which driver behavior data (maximum speed, hard braking and acceleration) are GPS-geolocated but extracted from the vehicle's engine through on-board diagnostic port and accelerometer data, instead of being calculated from GPS measurements that are prone to error in an urban canyon as the one in New York City. (iii) The temporal coverage of the driver behavior indices and the collision data overlap. Finally, (iv) there has been no similar comprehensive study of driver behavior relationship to large quantities of crash data in an urban setting and at a network scale such as the New York City road network. Several key findings are reported in this paper: (i) when normalizing crash frequencies on intersections with exposure, using a traffic model generated by DataKind, hot regions almost remain the same. (ii) the safety effects of hard braking and acceleration varied by traffic volume and speeding: strong correlation is found between hard acceleration and hard braking with collision rates, on high speeding high traffic volume intersections. (iii) hard acceleration is found to be a stronger risk indicator than hard braking. (iv) Higher travel times (i.e. lower mean speed values) may be linked to crashes.

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Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-04670
Paper Title	**Determination of Risky Driving Behavior Criteria using GPS data**
Abstract	The occurrence of road accidents is closely associated with driving behaviors. Drivers who always take risky behaviors are thought to be more easily involved in a road crash. To reduce drivers' crash probabilities, a practical method is to inform drivers about risky driving behaviors, i.e., the criteria of risky driving behaviors, and then urge them to drive in a safe way. However, the thresholds used to identify risky behaviors varied in previous studies, and these values might puzzle drivers and set obstacles to practical application for the improvement of safe driving. This paper aims to determine the criteria for risky driving behaviors using a genetic algorithm based on Beijing taxis' GPS data. To achieve this goal, a subobjective, the evaluation of drivers' driving safety levels, is first studied as the standard label by introducing the concept of information entropy. Then, a framework of driving event-based driving safety evaluation is established, in which thresholds used to identify risky driving events are pending parameters. Finally, a genetic algorithm is used to search for the optimal values of the pending parameters, and the best fitted values are regarded as the criteria for risky driving behaviors. This study provides GPS data-based risky driving behavior criteria that can be used in practice for the improvement of safe driving.

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Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-05404
Paper Title	**Predicting Crash/Near-crash Situations Resulted from Distracted Driving Using SHRP 2 Naturalistic Driving Study Data**
Abstract	Distracted driving is a serious traffic safety issue. Although many researchers have addressed this issue and developed distracted driving detection algorithms, previous studies mainly focused on identifying and quantifying the effects of driver distraction compared to baseline driving using driving simulator experiments. Unlike those studies, this paper used naturalistic driving data to perform a comparative analysis between three possible driving scenarios: 1) baseline (i.e., non-distracted) driving; 2) distracted driving without crash/near-crash situations; and 3) distracted driving with crash/near-crash situations. The data used to achieve the research goals was obtained from the Naturalistic Engagement in Secondary Task (NEST) dataset, which resulted from the SHRP 2 Naturalistic Driving Study. This study found that the standard deviations of pedal gas position, speed, longitudinal and vertical acceleration, pitch rate, and yaw rate are significantly different before a crash/near-crash situation resulted from distracted driving compared to both baseline driving and distracted driving without crash. Finally, several models were developed using a random forests algorithm to predict the potential crash/near-crash situations based on the driving performance data. The developed models were associated with an accuracy ranging from approximately 87% to 90%. These models can be a foreground for developing an in-vehicle system that can predict crash/near-crash situations resulting from distracted driving and give warnings to the drivers when a hazardous situation is detected. It can also be used to develop an automated distraction detection and mitigation system that automatically takes corrective measures when a hazardous situation is detected.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-05708
Paper Title	**Using Real-Time Weather Data to Assess Crash Likelihood on Snow Fence-Affected Mountainous Freeway Segments**
Abstract	Adverse winter weather conditions complicate and inhibit rural freeway travel in the state of Wyoming. The problems and hazard created by blowing and drifting snow, as well as additional adverse winter weather conditions, can create many complications for state or local transportation agencies. Adverse winter weather conditions can create numerous unsafe situations by affecting various factors such as vehicle performance, roadway surface, visibility, and driver behavior and performance. Snow fences have historically been utilized as a mean to reduce the effects caused by blowing and drifting snow, with regard to the traveled way. In this paper, a 19-mile segment of Interstate 80 located in Southeastern Wyoming, characterized by a high coverage of snow fences, was investigated in order to develop a crash model utilizing winter weather conditions as well as snow fence presence along rural mountainous freeway routes. In order to compare winter weather conditions during crash events and non-crash events, matched case control was utilized at a 2 to 1 ratio. Crashes from 2003 to 2011, which occurred during the winter weather season, were utilized in the analysis, and the corresponding winter weather conditions at the time of crash were applied. This study aims to provide a usable model in crash probability prediction based on numerous winter weather conditions and help researchers and practitioners to understand the singular and combined effects of winter weather conditions and snow fences on crash probability.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-05894
Paper Title	**Assessment of Crash Location Accuracy in Electronic Crash Reporting Systems**
Abstract	Over the last several years, traffic fatality rates in South Carolina have been consistently ranked amongst the highest in the country. Furthermore, South Carolina incurs over two billion dollars in economic loss annually due to roadway traffic crashes. The South Carolina Department of Transportation (SCDOT), in collaboration with the South Carolina Department of Public Safety (SCDPS), has undertaken a series of initiatives in an effort to reduce the number of vehicle crashes, especially injury and fatal crashes that occur every year in South Carolina. One of these initiatives is the deployment of a crash reporting system that uses map-based geocoding that has greatly improved the quality of crash location data. This paper provides an assessment of improvements in crash geocoding accuracy in South Carolina and how this improved accuracy can benefit safety analysis. Case studies are used in this assessment to demonstrate some of the many benefits of having spatially accurate crash data. A survey of state highway agencies is presented that indicates that there are disparate crash reporting systems used across the country from a crash geocoding standpoint. Our survey indicates that not only does the geocoded accuracy of crash locations vary by state, the accuracy can even vary by jurisdiction within each state. Our assessment shows that poorly geocoded crash data can bias certain types of safety analysis and that many states can enhance safety analysis by improving their crash report geocoding methods.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-06087
Paper Title	**Initial Validation of the Driver Behavior Questionnaire Using SHRP2 Questionnaire Data**
Abstract	Driving safety is a product of driver attitude, demographic, and situational factors. Our objective in this paper is to present an initial validation of the DBQ with respect to another self-reported questionnaires and crash-relevant measures that were concurrently collected in the SHRP 2 study. As an outcome of this analysis, we are interested in the ability of the DBQ to uncover driver sub-populations for targeted study and development of behavioral interventions. A factor analysis with a polychoric correlation matrix was performed and a two-factor solution was extracted. The associations between the factor score-based sub-samples and the other measures are in the expected direction. This paper presents a first step towards validating the DBQ with the SHRP 2 data.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-00906
Paper Title	**Investigation of Reaction Times and Deceleration Rates during Crash and Near-crash Events using Naturalistic Driving Data**
Abstract	Given the prevalence of driver error as a primary contributing factor in traffic crashes, research is warranted to better understand how drivers behave over the course of crash and near-crash events. The data resulting from the second Strategic Highway Research Program Naturalistic Driving Study provide a unique opportunity to investigate behavioral metrics such as reaction times and deceleration rates leading up to these safety-critical events. As a part of this study, driver performance during crash and near-crash events on freeways were examined. The average reaction times and deceleration rates in these events were 1.51 sec. and 9.53 ft/s2 (0.30 g), respectively, while the associated 85th percentile values were 2.60 sec. and 14.27 ft/s2 (0.44 g). Reaction times were found to vary by gender, as well as whether the driver was distracted at the time of the event. The reaction time also varied considerably based upon whether the event involve a rear-end conflict, a sideswipe conflict, or an unexpected object in the roadway. Deceleration rates were largely consistent across drivers and were not shown to vary by whether the driver was distracted. Interestingly, deceleration rates tended to be higher when initial vehicle speeds were lower. Ultimately, this study provides insights of interest to highway design, in addition to improving understanding of the impacts of distraction on driver performance.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03622
Paper Title	**Rethinking Highway Safety Analysis by Leveraging Crowdsourced Waze Data**
Abstract	Identification of traffic crash hot spots is of great importance for improving roadway safety. Traditionally, police crash reports (PCR) have been used as the primary source of crash data in safety studies. However, using PCR as the sole source of information has several drawbacks. For example, some crashes, which do not cause extensive property damage, are mostly underreported. Underreporting of crashes can significantly influence the effectiveness of data-driven safety analysis and prevent safety analysts from reaching statistically meaningful results. Crowdsourced traffic incident data such as Waze can add a new dimension to the traditional safety analysis by providing real-time crash and traffic incident data. However, using these data sources also have some challenges. One of the major problems is data redundancy; because many people may report the same event. In this paper, the authors explore the potential of using crowdsourced Waze incident reports (WIRs) to identify high-risk road segments. The researchers first propose a new methodology to eliminate redundant WIRs. Then, the researchers use WIRs and PCRs from an I-35 corridor in North Texas to conduct the safety analysis. Results demonstrated that WIRs and PCRs are spatially correlated; however, their temporal distributions are significantly different. WIRs have a broader coverage with 60.24 percent of road segments in the study site receiving more WIRs than PCRs. Moreover, by combining WIRs with PCRs, more high-risk road segments can be identified (14 miles) compared to the results generated from PCRs (8 miles).

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-05109
Paper Title	**Data and System Architecture Improvements for Statewide Crash Mapping and Analysis**
Abstract	Crash data analysis and visualization is an important way to improve transportation safety. The Traffic Operations and Safety (TOPS) Laboratory at the University of Wisconsin-Madison, in partnership with the Wisconsin Department of Transportation (WisDOT), has developed several safety tools on its WisTransPortal system to query and analyze Wisconsin crash data. This paper describes a new and comprehensive Crash Mapping and Analysis (CMAA) component of the WisTransPortal for performing map-based visualization and analysis. The primary features of the CMAA system are: 1. daily automated mapping of crash locations from police reported locations (over 95% of all crashes are mapped); 2. an open, service-based framework for data sharing based on ESRI geo-processing services; 3. the integration with the WisTransPortal crash data model. This paper presents the advanced CMAA through two major changes: the framework design and the derivation of crash locations. With the detailed explanation and comparison between the previous method and the new CMAA, the open framework combined with updated crash data source has provided a better resource and environment for development and analysis. The improvements have been validated through two case applications: the CMAA web map and an ArcGIS Online (AGO) web application. These two applications demonstrate how the new framework offers a common service for application development based on a single source of crash data.

Poster Session 1339

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-02123
Paper Title	**A Penalized-Likelihood Approach to Characterizing Bridge-Related Crashes in New Jersey**
Abstract	A roadway departure crash is one in which a vehicle crosses an edge line, a centerline, or otherwise leaves the traveled way. These crashes that involve run-off-road and cross-median/centerline head-on collisions tend to be more severe than other crash types. According to the NHTSA Fatality Analysis Reporting System database, a total of 7,833 people perished in crashes involving fixed roadside objects in 2017, accounting for 21 percent of the total number of fatalities in the United States. Several studies have reported that rural bridge-related crashes result in more fatalities due to their being mostly the fixed-object crash type. As such, further in-depth investigation of this type of crash is necessary. Due to the lack of a comprehensive database that includes bridge-related crashes and bridge characteristics, identifying the key factors contributing to this type of crash is a challenging task that is addressed in this paper. We gathered and compiled five years of crash data from the New Jersey crash database and the characteristics of bridges from the Long-Term Bridge Performance portal. A Firth's penalized-likelihood logistic regression model was developed to examine the influence of explanatory variables on crash severity. This model is an appropriate tool for controlling the influence of all the confounding variables on the probability of bridge-related crashes while considering the rareness of the event. Based on the obtained odds ratio, the various effects of the identified variables are discussed and recommendations made regarding countermeasures policymakers can establish to reduce the number of these crashes in New Jersey.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-02285
Paper Title	**A Simulation Analysis to Study the Temporal and Spatial Aggregations of Safety Datasets with Excess Zero Observations**
Abstract	Crash data are often characterized with numerous zero observations. Sometimes, the number of zero observations in the compiled dataset is directly correlated with the selected spatial and/or temporal scales. By adjusting the time and spatial scales, the number of zero responses observed in the dataset can increase or decrease. Finding a balance in aggregation is a critical task in data preparation. On the one hand, using the disaggregated data may result in having excessive zero observations, in which the traditionally used negative binomial model may not be adequate for the safety analysis. On the other hand, too much aggregation may result in loss of information. This paper documents a simulation study that aimed at determining the criteria for deciding when data aggregation is needed. The simulation study explores the information loss due to aggregation as a function of the precision or accuracy in the estimation of model coefficients. The simulation results indicate that the reduction in variability, i.e., coefficient of variation, of the independent variables upon aggregation, is an important criterion to decide on the aggregation level.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-02761
Paper Title	**Comparison of Pattern Recognition-Based Hotspot Identification Methods Based on Simulation**
Abstract	This research aims to compare different pattern recognition methodologies for prioritizing hotspots in the absence of volume information and accompanying safety performance functions. In particular, we analyze tests for pattern identification proposed in the traffic safety literature that use binomial and beta-binomial distributions respectively. Using simulated data, we compare the performance of these methods in evaluating both underlying patterns as well as the overall safety performance. We simulate spot crashes and crash types using a Poisson-Gamma and Dirichlet-Multinomial distributions respectively. We also controlled for the overdispersion parameter in the Dirichlet Multinomial distribution to simulate low, medium and high overdispersion scenarios. Two types of ground truth in the simulation study are defined: a true p-value for identifying true crash patterns and a True Poisson Mean (TPM) for ranking sites. The result shows that 75-percentile proportion is a good threshold proportion for Beta-Binomial test and that this test achieves higher precision and recall than Binomial test in medium and high overdispersion cases. Both tests have similar correlation with TPM. The correlation between TPM and Empirical Bayes (EB)-adjusted crash frequency using Method of Moments is also calculated as a baseline. Two pattern recognition-based methods perform slightly worse than EB adjustment.

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Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-02940
Paper Title	**Applying a Deep Learning Method to Balance Data for Real-Time Crash Prediction on Expressways**
Abstract	The traffic data of crash and non-crash cases are extremely imbalanced for any real-time crash prediction methods. Most of studies used under-sampling methods to balance the data, which may not capture the heterogeneity of full non-crash data. This study aims to suggest a new over-sampling method called deep convolution generative adversarial network (DCGAN) model to balance crashes and non-crashes. With fully understanding the traffic data of crashes, the DCGAN model could generate more data related crashes to balance the dataset. All non-crash data could be used for developing the prediction models. To capture the correlations between different variables, the data are augmented to 2-D matrix as the input for the DCGAN model. The suggested model is evaluated based on data from expressways and compared to two counterparts: (1) synthetic minority over-sampling technique (SMOTE); (2) random under-sampling technique. The results suggest that the DCGAN could provide better understanding of the crash data characteristics by generating data with better fit of the real data distribution. Three models are developed based on the data provided by the DCGAN over-sampling, SMOTE over-sampling, and random under-sampling methods. Compared to the other two models, the DCGAN-based model could provide more insights by identifying more significant variables which could help guide traffic management strategies. Furthermore, the DCGAN-based model could provide the best prediction performance for test data. With the prediction model developed based on the balanced data by DCGAN, it is expected that more crashes could predicted and prevented with more appropriate proactive traffic safety management strategies.

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Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03224
Paper Title	**Crash Prediction for Freeway Work Zones in Real Time: A Comparison between Conventional Neural Network and Binary Logistic Regression Model**
Abstract	Safety of drivers in freeway work zones has been a problem. Real-time crash prediction helps prevent crashes before they happen. This paper looks at real-time crash prediction in freeway work zones by using machine learning approaches. Both the Convolutional Neural Network and the Binary Logistic Regression model are introduced. For training and testing the models, crash data and traffic data from several freeways in D7 zone, Los Angeles, California, were used. Crash data were collected from California Highway Patrol Incident System, and traffic data were obtained from the Caltrans Performance Measurement System. Data processing and matching were conducted. Both the two models were trained and tested. Results show that the Convolutional Neural Network performed slightly better over the Binary Logistic Regression model in predicting crashes with a global accuracy of 69.9%. Despite this, the main merit of the Binary Logistic Regression model is that it is able estimate the impact of affecting variables on the probability of crashes and can help identify the factors related to risks in work zones. Machine learning approaches applied in this study perform well in crash prediction. In general, machine learning techniques and reliable real-time crash prediction applications can be promising in help drivers and transportation engineers take timely responses to potential crashes on freeways.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03472
Paper Title	**Using Empirical Traffic Trajectory Data for Crash Risk Evaluation under Three-Phase Traffic Theory Framework**
Abstract	This paper employed traffic conflict techniques to evaluate the crash risk in different traffic phases defined by three-phase theory. The analysis was based on empirical trajectory data extracted from two freeways, one is Interstate 80 in California, USA, the other is Yingtian Expressway in Jiangsu, China. First, the traffic phases were identified based on values of traffic flow variables and their correlations. Then, two advanced crash risk indexes based on time-to-collision were conducted to estimate the safety performance in each traffic phase. The effect of various traffic flow variables (e.g. flow rate, average speed) on crash risk were explored based on speed-density plane, speed-flow plane and flow-density plane. Three regression models were developed to quantify the effect of traffic flow variable and traffic phases. The results indicated significant disparity of safety performance among different traffic phases. High density and low speed were associated with high crash risk. In addition, the model only integrating different traffic phases had better fitness (R2=0.726) than that only integrating macroscopic traffic parameters (R2=0.545), and a better performance could be achieved when integrating both of them (R2=0.757).This study directly establishes the relationship between macroscopic traffic flow phase and microscopic traffic safety performance. The study also proposes a safety perspective that can be added to the three-phase traffic theory.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03883
Paper Title	**Sensitivity to Prior Specification when Evaluating Road Safety Countermeasures**
Abstract	Since the work of Ezra Hauer in the 1980s, the empirical Bayes (EB) framework for evaluating road safety countermeasures in before-and-after studies has emerged as a 'gold standard' tool for separating genuine treatment effect from other confounding effects such as regression-to-the-mean (RTM). The usual Poisson-Gamma formulation within this framework has the advantage of mathematical convenience – its conjugacy providing plug-in formulae for the expected (counterfactual) accident count in the after period, had no treatment been applied. The advent of simulation-based procedures for Bayesian inference in the early 1990s has meant that in most application areas (e.g. environmental and biological sciences, finance, social sciences) Markov chain Monte Carlo (MCMC) methods are now commonplace, enabling the exploration of non-conjugate model formulations with ease. However, despite several articles in the road safety literature proposing Fully Bayesian (FB) methods in transport safety, the use of such methods in practice still seems rather rare. The primary aim of this paper, then, is to investigate alternative model specifications to those used under a standard EB formulation as applied in before-and-after evaluation studies. Simple post-hoc diagnostics can be used to compare these different specifications, and results can be presented based on the 'best-fitting' specification – which may not be that assumed within an EB framework. We demonstrate the sensitivity of estimated RTM effects through a data example on mobile safety cameras in the UK. The FB methods presented are available for use by practitioners in a user-friendly software tool developed by the authors.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-04120
Paper Title	**Applying Deep Learning to Detect Traffic Accidents in Real Time Using Spatiotemporal Sequential Data**
Abstract	Accident detection is a vital part of traffic safety. Many road users suffer from traffic accidents, as well as their consequences such as delay, congestion, air pollution, and so on. In this study, we utilize two advanced deep learning techniques, Long Short-Term Memory (LSTM) and Gated Recurrent Units (GRUs), to detect traffic accidents in Chicago. These two techniques are selected because they are known to perform well with sequential data (i.e., time series). The full dataset consists of 241 accident and 6,038 non-accident cases selected from Chicago expressway, and it includes traffic spatiotemporal data, weather condition data, and congestion status data. Moreover, because the dataset is imbalanced (i.e., the dataset contains many more non-accident cases than accident cases), Synthetic Minority Over-sampling Technique (SMOTE) is employed. Overall, the two models perform significantly well, both with an Area Under Curve (AUC) of 0.85. Nonetheless, the GRU model is observed to perform slightly better than LSTM model with respect to detection rate. The performance of both models is similar in terms of false alarm rate.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-04298
Paper Title	**Driver Relative Risk Evaluation Based on Data Envelopment Analysis**
Abstract	Evaluating driver's driving risk is an important way to make people understand their driving behavior and is the basis for improving their driving performance. In order to evaluate the driver's driving risk more objectively, this paper proposes a driver relative risk evaluation method using the idea of benchmarking analysis. Based on the naturalistic driving data describing the driving state of the vehicle, various basic dangerous driving behaviors of a driver are determined. A clustering analysis is used to classify driving behaviors with different risk levels. Based on the technique of data envelopment analysis, we establish a driver risk evaluation model that comprehensively considers the crash risk brought by various dangerous driving behaviors. By solving the risk index and weight of various dangerous driving behaviors, the risk index score and ranking of drivers are obtained. Finally, based on the fixed relative risk index of various dangerous driving behaviors provided by the historical literature, the driver's comprehensive risk score and ranking consistent with historical research consensus are obtained. By comparing the results of the two models, we find that the model proposed in this paper emphasizes the contribution of high-risk driving behaviors to the total driving risk to some extent. Since the final iteration results of the two models are relatively close and the overall trend is the same, this model has certain rationality.

Poster Session 1340

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-00870
Paper Title	**Long Short-Term Memory Networks-Based Framework for Traffic Crash Detection with Traffic Data**
Abstract	Traffic crash detection explores the interconnected relationship between traffic data and crash risk. It can prevent potential traffic accidents and improve freeway safety. However, some limitations exist in current studies: First, datasets in most studies were simulated or very old, which cannot represent practical traffic patterns; second, few studies applied deep learning methods for crash detection, which had significant performance in other traffic domains. To address the above limitations, this study proposes a deep learning method of long short-term memory (LSTM) networks for crash detection with traffic data on freeways. A dropout technique is adopted to reduce overfitting and improve prediction performance in small datasets. The framework is implemented on datasets extracted from I880-N and I805-N in California, America. 6 LSTM models are constructed for real-time crash detection and validated to have satisfactory prediction performance, with the highest crash accuracy of 68.75% and highest comprehensive indicator of 72.33%. The results also indicate that dropout technique can improve prediction performance, increasing crash accuracy from 59.38% to 68.75%. The detection models established on one freeway can be transferred to another similar freeway, with the highest crash accuracy of 61.29%. Based on the comparisons of LSTM model and other machine learning methods, LSTM model has validated to have better prediction performance than SVM and ANN, especially on the criteria of crash accuracy and comprehensive indicator.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-01358
Paper Title	**Estimating the Expected Number of Crashes with Traffic Conflicts Observed in Naturalistic Driving Studies**
Abstract	Although the frequency and severity of crashes are direct measures of road safety, crash data are typically of low quality and they require long time to collect for conclusive analyses. Surrogates of crashes that allow a quick and accurate estimation of safety have been an active topic for years. Among multiple alternatives, traffic conflicts are most promising. This paper is aimed to demonstrate the validity of the recently proposed Lomax-based method of applying traffic conflicts to evaluate traffic safety. The data collected in the recent naturalistic driving study, the Strategic Highway Research Program 2 (SHRP2) were used in the validation task. The rear-end crashes recorded during the SHRP2 program and detected corresponding rear-end traffic interactions were analyzed for three category of drivers: young male, mature male, and mature female. These three categories of drives have distinctively different proneness to involvement in crashes. Out of all rear-end traffic conflicts, 1.7 % of them was used to estimate the crash frequencies and rates for each type of drivers by applying the Lomax distribution within the counterfactual approach. Then, the conflict-based crash rate estimates were compared to the crash rates of the studied types of drivers calculated from all the rear-end crashes observed in the SHRP2 study period. The conflict-based rate estimates followed well the crash-based rates and the existing knowledge about the safety performance of the studied drivers. The results confirmed the over-representation of young male drivers in crashes. It was also confirmed that mature male drivers are involved in rear-end crashes more frequently than mature female drivers. The results demonstrate both the validity of the Lomax-based analysis of traffic conflicts and the benefit of reducing the data-collection time by factor 60.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-02105
Paper Title	**Road Traffic Safety Risk Estimation Method Based on Vehicle Onboard Diagnostic Data**
Abstract	Currently, research on road traffic safety is mostly focused on traffic safety evaluations based on statistical indices for accidents. There is still a need for in-depth investigation on preaccident identification of safety risks. In this study, the correlations between high-incidence locations for aberrant driving behaviors and locations of road traffic accidents are analyzed based on vehicle OBD data. A road traffic safety risk estimation index system with road safety entropy as the primary index and rapid acceleration frequency, rapid deceleration frequency, rapid turning frequency, speeding frequency and high-speed neutral coasting frequency as secondary indices is established. A road safety entropy calculation method is proposed based on an improved entropy weight method. This method involves three aspects, namely, optimization of the base of the logarithm, processing of zero-value secondary indices and piecewise calculation of the weight of each index. Additionally, a safety risk level determination method based on two-step clustering (density and k-means clustering) is also proposed, which prevents isolated data points from affecting safety risk classification. A risk classification threshold calculation method is formulated based on k-mean clustering. The results show that high-incidence locations for aberrant driving behaviors are consistent with the locations of traffic accidents. The proposed methods are validated through a case study on four roads in Chongqing with a total length of approximately 3 8 km. The results show that the road traffic safety trends characterized by road safety entropy and traffic accidents are consistent.

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Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-02682
Paper Title	**Real-time Prediction of Hard-Braking Behavior when Following: A Hybrid SVM-Based Method**
Abstract	Car-following models are an important tool in understanding and predicting the behavior of the following vehicle with respect to the lead vehicle behaviors under different scenarios. These models are critical in the current automated vehicle technology designs for simulation and testing purposes. However, there is a lack of literature in the area of real-time car-following behavior prediction algorithms, especially for those behavior of safety concerns such as hard-braking. The objective of this research is to fill in the research gap by developing models to predict real-time hard-braking behavior when following other vehicles on highways hard-braking. Naturalistic driving study data was used with a total of 245 hard-braking events extracted and used in the models. A hybrid SVM-based method including two modules were proposed in this paper, support vector machine classifier (SVM) and support vector regression (SVR). This method uses hard-braking SVM classifier to predict vehicle next time point acceleration or deceleration values. Input variables in the model include acceleration or deceleration values up to current time point, velocity, following distance and relative velocity to the lead vehicle. Results showed this hybrid method is better than each single machine learning method. The prediction accuracy is 98.7% for normal driving only data, 85.1% for hard-braking time points only data, and 98.2% for mixed data with both normal driving and hard braking events. The mean absolute deviation of the prediction is 0.297 and mean squared predictor error is 0.349 . The proposed method in this study provides a promising way to model and predict car-following behavior.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-02700
Paper Title	**A Deep Learning Approach for Freeway Secondary Crash Prediction Using High-resolution Loop Detector Data**
Abstract	The primary objective of the study is to investigate how the deep learning approach contributes to freeway secondary crash (SC) prediction using real-time traffic flow data. The crash and traffic data were collected on the I-5 freeway for five years from 2010 to 2014 in California, United States. The secondary crashed were first identified by a method based on speed contour plot. The long short-term memory neural networks (LSTM NNs) were then developed to predict the probability of secondary crashes with the real-time traffic flow conditions for 5-min time intervals. The statistical model, artificial intelligence model and recently developed machine learning method were selected as benchmark methods to compare with the LSTM NNs. The comparative analyses suggest that, in general, the LSTM NNs outperform the benchmark methods in terms of a higher prediction accuracy rate. It also has an outstanding performance in recall rate, which is 33.45% and 11.6% higher compared with the Logistic Regression model and the Support Vector Machine model. The deep learning methods perform better than the conventional statistical method. All these results indicate that the LSTM NN model is a better choice for freeway SC prediction. Moreover, it can be concluded that the occurrence of SC is highly associated with the temporal features of the primary crash (PC). The developed LSTM NNs can be integrated into an intelligent traffic control system to develop proactive real-time traffic control strategies to prevent the occurrences of secondary crashes on freeways.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-03089
Paper Title	**Empirical Approach for Identifying Potential Rear-End Collisions Using Trajectory Data**
Abstract	This paper proposes a novel approach for examining rear-end collisions between successive vehicles in a traffic stream. In this approach, a new safety measure of the attentiveness of the follower driver is proposed, referred to herein as instantaneous heeding time (IHT), which reflects the heeding nature of the subject follower with respect to its leader. A safety framework that integrates the IHT with the distance gap and the instantaneous follower's speed is presented. The applicability of the framework is demonstrated using a mixed-traffic trajectory database (developed in this study) and the homogeneous traffic database of the next generation simulation (NGSIM) project developed in the United States (U.S.). Five study sections in India and two study sections in the U.S. are analyzed for three traffic-flow levels. For mixed traffic, the results show that the presence of motorized two-wheelers (MTW) has degraded road safety due to the unrestrained lateral crisscross movements. Due to the presence of MTW, mixed-traffic stream operates in a disorderly fashion, thereby increasing the probability of rear-end collisions with other vehicle classes. Further, the importance of implementing cautioning measures for drivers, that reduce the probability of collisions, is clearly demonstrated. In addition, the NGSIM application results confirmed the applicability of the proposed framework to both mixed and homogeneous traffic conditions. In practice, the proposed framework can be used in real-time to monitor driver's aggressive instincts.

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Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-03166
Paper Title	**Corridor-Level Real-Time Crash Risk Prediction Using Spatial-Temporal LSTM**
Abstract	Adjacent signalized intersections and road segments along an arterial corridor usually share similar traffic flows and signal control configurations, which might result in a high spatial correlation in the real-time crash risk. Also, crash occurrences might be influenced by the traffic conditions along its trajectory, i.e., the traffic conditions of the upstream segments during preceding time intervals, which turns to be a typical spatial-temporal problem. However, previous real-time safety studies mainly focused on a single type of road entity while ignoring the spatial correlation between adjacent road entities. This study aims to predict the corridor-level real-time crash risk by using convolutional Long Short-Term Memory (ConvLSTM) to incorporate both spatial and temporal dependencies. A 10-mile arterial corridor in Central Florida was selected as a case study to prove the feasibility and strength of the ConvLSTM in real-time crash risk prediction. Various predictors, including traffic, signal timing, shockwave, and weather characteristics, were prepared based on the high-resolution event-based Automated Traffic Signal Performance Measures (ATSPM) data and weather data. In addition, two baseline models, i.e., LSTM and CNN-LSTM, were also developed. Evaluation results showed that the ConvLSTM performs better than the baseline models in most of the cases, especially for the intersection crash risk prediction. Findings in this study could be integrated into the Real-Time Crash Risk Prediction System to provide more accurate and reliable predictions.

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Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-03236
Paper Title	**Identification of Aggressive Driver using Collision Surrogate and Imbalanced Class Boosting Algorithms**
Abstract	Machine learning algorithms are wildly applied in the recognition of risky driving behavior and dangerous drivers. Since the proportion of risky behavior or drivers in real traffic is very low, common machine learning algorithms prone to better recognize normal sample rather than risky sample, which is our real interest. This paper aims to use imbalanced class boosting algorithms to identify driver's driving style (normal vs. aggressive) using vehicle trajectory data, including speed, gap and acceleration. First, a surrogate measurement of collision risk is proposed to calculate vehicle's crash risk based on how driver response in car-following process. Then, the driver's driving style is determined by his average crash risk. Using the determined driving style information and vehicle trajectory data, we can train a classification model to identify aggressive drivers. Among all imbalanced class boosting algorithms we test, SMOTEBoost achieves the best performance. This paper uses Montanino and Punzo' reconstructed NGSIM dataset for aggressive driver identification and focuses on 299 leader-follower vehicle pairs on I-80 HOV lane that was not interrupted by lane-changing. This paper also finds that in a car-following process, the driving styles of the leading and following drivers are independent.

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Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-03499
Paper Title	**Does Stop-Signs Improve Safety For All Road Users? A Before-After Study On Stop-Controlled Intersections Using Video Trajectory And Surrogate Methods**
Abstract	The conversion of minor-approach-only stop (MAS) intersections to all-way-stops (AWS) intersections are a common safety countermeasure in North America in residential areas. Although there is a positive perception by the general population of the installation of stop-signs in residential areas, there is little research that has looked at the impact of AWS on road safety and road users behaviour. This paper aims at investigating the safety effect of converting MAS to AWS intersections using an observational before and after approach and alternative surrogate measures of safety (SMoS). More specifically, the impact of AWS conversion is investigated using multiple indicators including vehicle and bicycle speed measures, vehicle-pedestrian and vehicle-cyclist conflicts as well as yielding rates. To determine the effect of stop signs, a multilevel regression approach is adopted in order to control for built environment, traffic exposure and intersection geometry factors. In this study, a unique sample of 40 treated intersections is used from which data was collected before and after the implementation of AWS. Using automated video processing and computer vision software, 248 hours of video were processed and corrected; more than 62,000 (32,208 before and 30,127 after treatment) road users' trajectories were obtained from 110 approaches. Results show that the implementation of AWS has a statistically significant effect on the speed reduction of vehicles and cyclist. However, it is observed a small variation after the AWS implementation on the post-encroachment time (PET) values. The DV analysis shows that there is a better performance from the behavioural aspect, having more yielding compliances after the treatment. Future work would investigate the poor fit of the PET and evaluate cyclist behaviour deeply.

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Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-04962
Paper Title	**Crash Prediction Based on Vehicle Kinematics Profile Similarity**
Abstract	This study introduces a crash prediction model based on vehicle kinematics profile similarity (VKPS). A support vector machine (SVM) model was developed to predict crashes using the SHRP2 NDS vehicle kinematics data (speed, longitudinal acceleration, lateral acceleration, yaw rate, and pedal position). The study builds on the Osman et al.'s study (1) that any safety critical events are preceded by turbulence in the vehicle kinematics that leads to those events. Building on that hypothesis, which was proved to be true in Osman et al.'s study, the study herein applies a Gaussian function to the vehicle kinematics data to identify similarities between vehicle kinematics time series profiles and help detect crash-related turbulence in vehicle kinematics. To develop the SVM prediction model, the data was split into 80% for training and 20% for testing. To identify the optimal turbulence horizon (the time period during which crash related changes in vehicle kinematics take place) and prediction horizon (the time period before the occurrence of a crash), a sensitivity analysis was performed. The results showed that the crashes can be predicted with an outstanding accuracy 1-second before the crashes take place. This indicates that the vehicle kinematics turbulence increase significantly shortly before the crash occurrence. The results also showed that the best model performance (overall accuracy =99%) is achieved for a 6-seconds turbulence horizon, indicating that the VKPS approach can help early detect crash-related turbulences in vehicle kinematics. This performance is promising for crash avoidance systems in the emerging autonomous vehicle technology.

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Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-04969
Paper Title	**Estimation of Freeway Traffic Safety Utilizing Disturbance Metrics Based on Trajectory Data**
Abstract	There have been limited efforts to investigate the potential of using detailed trajectory data obtained from connected vehicles and/or other sensors in deriving metrics for use in real-time assessment of traffic safety and the activation of management strategies based on this assessment. This study investigates utilizing disturbance metrics for this purpose. The utilized disturbance metrics are the number of oscillations and a measure of disturbance durations in terms of the time exposed time to collisions index (TETIndex). TET has been widely used as a safety surrogate measure, however, to the best of authors knowledge, there is no study on the identification of its thresholds to justify activating plans to mitigate unsafe conditions in real-time operations. Since the TETIndex estimation requires the location and speed of both the leading and following vehicles and therefore cannot be measured accurately with low sample sizes of vehicle trajectories, this study derived regression model to estimate it based on speed parameters. The developed model was tested using real-world trajectory data from two locations that were not used in the development of the model. It was found that the TETIndex can be estimated based on speed parameters with an error of around 15%-20%. The study also found that the investigated disturbance metrics and associated models are significantly related to crash occurrence and thus can be used in the activation of transportation management strategies to reduce the probability of unsafe traffic and ease traffic disturbances that have adverse impact on traffic safety.

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Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-00229
Paper Title	**Correlation Analysis of Traffic Conflicts and Driving Behaviors at Interchange Diverging Areas**
Abstract	Driving Behaviors (e.g., lane-changing, acceleration/deceleration) might be the most possible reasons for traffic conflicts at freeway interchange diverging areas. This study aims to investigate the correlation between traffic conflicts and driving behaviors which include vehicle acceleration/deceleration and lane changing characters at diverging area based on Chinese cases. Principal component analysis was used to make a dimension reduction of the parameters which would influence traffic conflicts. The Bayesian network was used to construct a correlation model between relevant parameters and traffic conflicts at diverging area. Results showed that there is a significant correlation between the lane-changing position and the traffic conflicts, which were located within 600m from the beginning of the diverging area and the first 60m of the deceleration area. A representative correlation was found exist between acceleration/deceleration and the traffic conflict. Vehicle acceleration/deceleration and lane changing behaviors are the main factors affect traffic conflicts. The research could provide useful advices for driver training programs to reduce casualties and also put forward a basis for the active prevention of traffic crashes.

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Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-00665
Paper Title	**Longitudinal Safety Evaluation of Regular Vehicle and Connected and Automated Vehicle (CAV) via In-Depth Analysis of Trajectory Data**
Abstract	With the advancement of traffic video surveillance and data collection, micro-level trajectory data has become available for traffic safety analysis. Surrogate safety measures could be applied to establish the relationship between trajectories and conflicts, but it is difficult to verify the validity of the relationship due to the deficiency of pre-crash data in practice. This study investigated the related issues by in-depth analysis of vehicle trajectory data. Taking the time-to-collision (TTC) index as an example, this study proposed an indirect method to analyze the TTC values based on the well-known Heinrich's pyramid. Further, potentially dangerous durations and three types of critical durations were developed for revealing inherent impacts of micro-level driving behaviors on safety. Finally, the proposed methods were employed for the adaptive cruise control (ACC) and connected and automated vehicle (CAV) systems for safety evaluations. Results indicate the utilization of critical durations provides more information for longitudinal risks. For manually driven vehicles (denoted as regular vehicles, RVs), type 3 duration has the highest risks due to the combined effect. The CAV system is safer than ACC as the CAV has the smaller time delay but with the larger TTC distribution. The CAV system will not cause risks by accelerating actively. The initial critical duration type of RVs, the mean and standard deviation of leading vehicle speeds have significantly impacts on longitudinal safety for ACC and CAV systems. Results of this study could provide useful information for the safety improvement of advanced vehicle systems in the future.

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Session Number	Poster Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-02239
Paper Title	**A Comprehensive Framework for Determining the Optimal Sample Size for Conflict-based Traffic Safety Analysis**
Abstract	Conflict-based traffic safety analysis is a burgeoning field but many studies have failed to determine the optimal sample size before conducting their study. Power analysis is a well-established statistical tool used in many different scientific fields, is generalizable to many studies, and can be used to determine an appropriate sample size. The power analysis exploits the significance criterion (α), power (1-β), and effect size (ES) such that the sample size is large enough to protect investigators from Type I and Type II errors to conventional thresholds of 95% and 80%, respectively. This paper proposes a comprehensive framework for road safety researchers and practitioners based on power analysis to determine the minimum sample size required for a conflict analysis study. Three case studies are investigated to illustrate how power analysis can be conducted for different types of conflict analysis study specifications, using the corresponding statistical tests. The minimum sample size is also the optimal sample size because it minimizes the observation period while maintaining acceptable protection from Type I and Type II errors. The proposed framework was found to be valuable in the planning of a current conflict-based safety study and is recommended to be used in future conflict-based traffic safety analyses.

Poster Session 1352

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-03226
Paper Title	**Requirements Gathering Through Focus Groups for a Real-Time Emergency Communication System for Hazmat Incidents (REaCH)**
Abstract	During HAZMAT emergencies, first responders are the first to reach the incident site. Over the years, there has been an increase in the number of first responder deaths and heat related illness (HRI). HRI are most often studied in outdoor workers and wild land firefighters but occur in a variety of workers across the US. Surveillance programs reported approximately 28,000 HRI hospitalizations between 2001 and 2010. The progression from heat exhaustion to heat stroke can occur rapidly so first responders need warning systems to alert them to the impending health hazards of heat stress. This study works with HAZMAT first responders in Nebraska to explore and assess the current status of responder safety in the state and begins with the first responder focus group requirements gathering process. A consensus building process was used for the focus group sessions and yielded thematic areas of health and safety concern. Responder safety was named the most common area of concern and solutions to individual risks were proposed by focus group participants from a local HAZMAT response team. The results of this focus group serve to inform researchers of priorities to consider in the development of responder health monitoring systems and to continue with research in wearable technology for real time health monitoring. Early intervention when monitored responders demonstrate signs of distress ultimately saves lives.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-03659
Paper Title	**A Framework to Link Crashes to Emergency Medical Service Runs and Trauma Admissions for Improved Highway Safety Monitoring and Crash Outcome Assessment**
Abstract	In this research, crash data collected by Kentucky State Police was linked to Emergency Medical Service (EMS) runs from Louisville Metro Government's Computer-Aided Dispatch system and injury data from University of Louisville Hospital's Trauma Registry. An approach was developed to match EMS runs to crashes through time, location, and other indicators present in both datasets. Types of matches between EMS and Crashes were classified to explain the possible reasons behind the match or lack of match occurring. According to the outcome of the matching process, 71.8% of EMS runs matched with crash data and 69.3% of trauma registry data matched with EMS and crash data. Matches were validated through a manual investigation of the individual data points. After implementing the matches, the linked datasets were examined to 1) quantify the average EMS response time for injury compared to non-injury crashes, 2) investigate the difference between reported crash times and the time emergency services was called, and 3) compare police-reported injury crash classifications to diagnoses recorded in the trauma registry.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-04786
Paper Title	**Ambulance Location Optimization Incorporating O-D Travel Time Variability: A Case Study of Delhi**
Abstract	With a fragmented emergency medical services (EMS) system with no response standards in India, it becomes difficult for an emergency medical service system to cope up with the performance and timeliness goals. The uncertainty in the congestion on a city level also adds up to the problem. The main aim of this paper is to evaluate the current emergency service system (CATS) in Delhi and optimize it for performance under both uncongested and congested conditions. Static ambulance location problems with deterministic travel times cannot maintain coverage standards in congested traffic conditions. A modified version of the double standard model which incorporates travel time variability across the day is proposed and evaluated. Travel time variability is modeled using the Gaussian mixture model (GMM) that provides multiple traffic states, each corresponding to a traffic condition. A mixed integer problem has been formulated with scenario dependent travel times. Results show that it is necessary to include time-dependent variations into the model due to overestimation of coverage by the deterministic model. The optimized ambulance system performs better during congested conditions than the current system during uncongested conditions.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-02283
Paper Title	**DRONETIM: Dynamic Routing of Unmanned-aerial and Emergency Team Incident Management**
Abstract	There has been a lack of focus on optimally allocating the information of Unmanned Aerial vehicles (UAVs) to emergency response vehicles (ERVs) for a quicker response to the incident site to save lives, reduce secondary incident occurrences, and reduce delays to the road users. UAVs can be coordinated with ERVs, but without an automated framework, it is challenging to adopt to the revision of FAA rules that already have been announced to accommodate more advanced operations. To maximize the efficiency in distribution of limited resources for management of traffic incidents, this study develops a new generation of research in UAV-guided ERV with is a task that has generated significant interest among practitioners and researchers. The information that is acquired by the UAVs through its assignment is utilized by the ERVs to support in the execution of their arrivals at incident locations. UAV assigned tasks include checking the status of road shoulder, confirming shockwave, and updating the severity of crash resulting from the incident. If the task is assigned to a UAV, respective information is used by ERV to manage its speed and minimize its response time to its destination or to effectively manage the task at incident location. To assess how this approach can help improve the overall utility of the system, we compared our developed model to the Nearest Neighbor assignment. In a benchmark with numerous scenarios, the developed model performed better by maximizing the total utility of the system in a simulated environment than previous models.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-05675
Paper Title	**Integrating Transportation Data with Emergency Medical Service Records to Improve Triage Decision of High-Risk Trauma Patients**
Abstract	Nowadays, a leading cause of mortality and morbidity of elderly is vehicle crash. Given the vulnerability of the senior victims in crashes, the decisions of emergency vehicle services as well as triage to shock trauma centers become extremely crucial for this cohort to receive timely transport service and proper trauma care. However, many who could be saved by shock trauma centers are either not transported via emergency medical services (EMS) or treated by non-trauma hospitals. This paper explores possible ways to improve the EMS and trauma triage decision processes. First of all, transportation-related data sources, such as traffic volumes and time-dependent vehicle speeds, have been integrated with EMS and hospital records, offering measurements of exposure to crash risks. The critical transportation information is typically missing from the field triage process but becomes readily available in real-time to support decision-making. Then the integrated data has been employed to construct machine learning models with the new predictors. Predictions of EMS transport and triage to shock trauma centers have been analyzed using a Maryland dataset with records of over 55,000 elderly patients. Compared to benchmark models without transportation information as predictors, the models trained with integrated data exhibit superior prediction accuracy.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-05465
Paper Title	**Development of A Drone Network for Traffic Incident Response**
Abstract	This paper presents a general procedure to develop a drone network for traffic incident response. It uses Massachusetts as a case study to illustrate the proposed procedure and the recommended drone network design based on historical traffic incidents. The procedure consists of two major tasks: (1) identifying traffic incidents suitable for drone applications, and (2) determining the drone network parameters subject to various constraints (e.g., budget). The parameters include the number and locations of drone stations needed. A heuristic algorithm is developed for Task (2) to minimize the number of stations needed while meeting the desired incident coverage and other constraints. It was found that the number of stations needed increases with the desired coverage but decreases with the station coverage radius. Additionally, the marginal cost of increasing coverage grows as the coverage becomes large, and the marginal benefits of increasing station coverage radius decreases as the radius grows. The data suggests that the incident frequency (or likelihood) varies significantly across drone stations, and a small number of key stations covers a majority of the incidents. These key stations are likely to experience a high demand of requests in peak periods and would benefit from having a fleet of multiple drones. In addition to covering traffic incidents, the developed procedure and drone networks also provide satisfying coverage to areas affected by major hurricanes and flooding, serving multiple purposes and generating additional substantial benefits.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-05829
Paper Title	**Do Road Rangers Help in Preventing Secondary Crashes?**
Abstract	Many transportation agencies are utilizing freeway service patrols to quickly respond to traffic incidents. Their goal is to minimize incident duration and increase safety at incident scenes. One such service, the Florida's Road Rangers, respond to incidents and offer highway assistance services to motorists on Florida highways. While much work has been done in identifying the benefits stemming from the delay savings, fuel savings and emissions reduction, little has been done to identify the potential impact of Road Rangers in lowering the likelihood of secondary crashes (SCs). This study sought to evaluate the safety performance of the Road Rangers program. Since SCs are often rare, the study applied a complimentary log-log model. The analysis was based on incident data related to 6,088 incidents on freeways in Jacksonville, Florida. Of the factors analyzed, traffic volume, incident impact duration, moderate/severe crashes, weekdays, peak periods, percentage of lane closure, and shoulder blockage were found to significantly increase the likelihood of SCs. While vehicle speed and lighting condition showed little contribution (not significant at 95%) to SC likelihood, Road Rangers were associated with relatively lower probabilities of SC occurrence. Based on the reduction in the average incident duration, the results suggest that the Road Rangers reduce SC risk by 20.9%. Based on increased safety at incident scenes, Road Rangers reduce SC probability by 17.9%. These results provide researchers and practitioners with an effective means for conducting the economic appraisal of the Road Rangers program.

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Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-03840
Paper Title	**Capacity Building of Emergency Medical Services (EMS) in Low and Middle Income Countries (LMIC) using Taxi-EMS Systems: Case Study Delhi, India**
Abstract	World Health Organization recommends provision of 1 ambulance for every 50,000 people to fulfil demand for transporting patients to definitive care facilities in Low and Middle Income Countries (LMICs). Governments' consistent attempt to build capacity of emergency medical services (EMS) in LMICs has been financially demanding. This study is an attempt to assess the feasibility of capacity building of existing EMS in Delhi, India by using taxis as an alternative mode of transport for emergency transportation of the road traffic victims to enable improvement in response time for road traffic crashes where time criticality is deemed important. Performance of the proposed system is evaluated based on response time, coverage and distance. The system models the performance and quantifies the taxi - ambulance configuration for achieving EMS performance within international standards.

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Sponsoring Committees	Standing Committee on Emergency Evacuations (ABR30) Joint Subcommittee on Emergency Response of ABR30, ANB10, ANB40, and AHB10 (ABR30(1)) Standing Committee on Regional Transportation Systems Management and Operations (AHB10) Standing Committee on Traffic Law Enforcement (ANB40) Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-03882
Paper Title	**Impacts of Augmenting Heliports with School Playgrounds on Air Medical Transport Time**
Abstract	Air ambulance is an effective means of providing rapid medical access to remote areas. In spite of being initiated in 2011, the air medical transport service in South Korea and its infrastructure are in the infant stage. One of the hurdles to expanding service coverage is the limited heliports for air ambulance's landing. This study aims to quantitatively assess the impacts of adding school playgrounds as sub heliports to reduce air medical transport time. To achieve this goal, existing air medical transport infrastructure and traffic crash injury data recorded by hospitals were collected and used to establish the relationship between transport time and injury severity levels. Air medical transport times with and without the augment of school playgrounds were then estimated, respectively. Finally, air medical service coverage maps were created to illustrate the effectiveness of fatal injury reduction based on the locations of school playgrounds and estimated air medical transport times. The findings show significant impact of using school playgrounds on reducing air medical transport time, an encouraging sign that school playgrounds can be a potentially cost-effective heliport alternative. This research is the first data-driven study that assessed air medical transport infrastructure augment and enhancement in South Korea, and provided quantitative support for expanding air medical capacity with existing infrastructure. This study will contribute to the emergency medical services (EMS) decision-making in South Korea and other countries.

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Sponsoring Committees	Standing Committee on Emergency Evacuations (ABR30) Joint Subcommittee on Emergency Response of ABR30, ANB10, ANB40, and AHB10 (ABR30(1)) Standing Committee on Regional Transportation Systems Management and Operations (AHB10) Standing Committee on Traffic Law Enforcement (ANB40) Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-04232
Paper Title	**Connected Vehicle Technology to Protect the Safety of Highway Patrol Troopers: Training Framework and Lessons Learned from the Wyoming Connected Vehicle Pilot**
Abstract	The Wyoming Highway Patrol (WHP) investigates more than 7,000 vehicle crashes yearly, often as first-hand responders. They often drive at high speeds through difficult road/weather conditions, and under enormous secondary workloads leading to an increased risk of crash. Connected Vehicle (CV) technology can communicate timely road and Traveler Information Messages (TIMs) to troopers, which could significantly reduce the frequency and/or the severity of these crashes. The majority of the troopers however, might not be familiar with driving a connected vehicle. This paper develops a 'WHP-specific' training program on safe interaction with the technology and an in-depth assessment of how these new technologies are perceived by the troopers. The training program contains an E-training module and a hands-on driving simulator training module. The E-training presents concept of various CV warnings and notifications, including Forward Collision Warning (FCW), Spot Weather Impact Warnings (SWIW), Work Zone Warnings (WZW) and other TIMs. Two scenarios were developed to familiarize troopers to simulated driving, two single-alert scenarios to help them master the two most important warnings (FCW and Variable Speed Limit) and two multiple-alert scenarios to train the troopers to drive in a comprehensive connected environment. A quiz section in the E-training module and a comprehensive pre and post-training questionnaire surveys were performed to evaluate the effectiveness of the developed CV training program. According to the participants from the WHP, the driving simulator provided impressively realistic real-life-like scenarios for the troopers to practice the CV warnings they learned during the E-training.

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Sponsoring Committees	Standing Committee on Emergency Evacuations (ABR30) Joint Subcommittee on Emergency Response of ABR30, ANB10, ANB40, and AHB10 (ABR30(1)) Standing Committee on Regional Transportation Systems Management and Operations (AHB10) Standing Committee on Traffic Law Enforcement (ANB40) Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	Poster Session 1352
Session Title	Emergency Responders
Paper Number	20-04468
Paper Title	**Connected and Autonomous Vehicles Effects on Emergency Response Times**
Abstract	Studies have shown that mortality rates are directly correlated with emergency response times. Cardiac arrest events, trauma, and stroke are among the most time dependent emergencies. Response time, in turn is greatly affected by traffic and requirements to stop at intersections. New technology promises more efficient flow at these locations. In particular, connected and autonomous vehicles (CAV) can contribute to reductions in response times and resulting reductions in mortality. The purpose of this paper is to provide a framework and a tool for analysis of these improvements and subsequent reductions. Application of the framework for Lexington, Kentucky estimates a potential three-minute decrease in response time with a commensurate reduction of 189 to 296 fatalities, annually.

Poster Session 1356

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-00506
Paper Title	**Associations between Regional Variation in Self-Reported Psychological Characteristics and Automobile Fatality Rates**
Abstract	We explore the association between variation in self-rated psychological and behavioral characteristics and rates of fatal automobile crashes across small geographic areas. To examine this, estimates of ZIP-code-level automobile fatality rates were linked to a separate dataset comprising 2.8 million responses to the Big Five Inventory (BFI; John & Srivastava, 1999). To control for an area's wealth and population density, associations were estimated at the slightly larger level of US Census ZIP Code Tabulation Areas (ZCTAs). Relationships were estimated using an intraclass adjustment method, where the estimated correlation between individual scores and ZCTA-level fatality rates was divided by the square root of the estimated within-ZCTA intraclass correlation. Further, the ZCTA-level correlation was estimated separately for each US state to examine the consistency of associations. Rates of fatal crash involvement tended to be higher in areas where respondents were more likely to describe themselves as being depressed, moody, and quarrelsome. Some relationships were less intuitive: for instance, rates of fatal crash involvement tended to be higher in areas where respondents described themselves as more helpful and as less easily distracted. We discuss implications for understanding how psychological attributes relate to fatal crashes at both the geographic and individual levels of analysis.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-01922
Paper Title	**Towards Reducing the Number of Crashes during Hurricane Evacuation: Assessing the Potential Safety Impact of Adaptive Cruise Control Systems**
Abstract	Ensuring safer mobility for the evacuees during a hurricane evacuation has always been a major concern for traffic managers. That concern has grown further, particularly after hurricane Irma which forced 6.5 millions of Floridians to evacuate, causing significant congestion and a high number of traffic crashes. Though several strategies have been deployed to manage the heavy traffic demand during a hurricane evacuation, current approaches seem to have less impact on traffic safety. During Irma's evacuation about 221 crashes occurred from September 6 to September 9, 2017, before the landfall day. During the evacuation period, traffic stream follows oscillatory speed, which can potentially contribute to rear-end crashes. Moreover, a rear-end collision in stop and go traffic largely depends on driver perception. In a situation where people are forced to evacuate to a safer place, perception related errors are inevitable. In such conditions, advanced driving assistance system or vehicle automation can play a vital role. In this study, we assess the safety impact of Adaptive Cruise Control (ACC) systems during an evacuation. We develop a microscopic simulation model in SUMO for a segment in the Interstate highway 75 (I-75) and calibrate it using real-world traffic data collected from the evacuation period of hurricane Irma. To evaluate the safety impact ACC systems, we adopt two surrogate measures: time to collision (TTC) and deceleration rate to avoid a collision (DRAC). Our experiment results show that, during evacuation, about 49% of traffic collisions can be reduced at a 25% market penetration of ACC equipped vehicles.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-02778
Paper Title	**Lane Change Risk Modeling and Vehicle Trajectory Optimization at Highway Diversion Area**
Abstract	Recent technological advancements have facilitated the implementation of vehicle automated control based on connected and automated vehicles (CAV) to prevent crashes on the road. In addition, trajectory-level vehicle controls are receiving substantial attention as sensors, wireless communications, and control systems are rapidly advancing. This study proposes a novel vehicle trajectory control strategy to minimize inter-vehicle crash risks in automated driving environments. The proposed methodology consists of the following three components: a risk estimation module, a risk map construction module, and a vehicle trajectory optimization module. The essence of the proposed strategy is to adjust the subject vehicle trajectory based on an analysis of the crash risk among a subject vehicle and the surrounding vehicles. Crash risks are quantified by a fault tree analysis (FTA) method to integrate the crash occurrence potential and crash severity at every time step. A crash risk map is then constructed by projecting the integrated risk of the subject vehicle into a two-dimensional space composed of relative lateral and longitudinal position. Next, the vehicle trajectory is continuously controlled to reach the target position using risk map analysis to prevent a crash. The proposed methodology was achieved an approximate 56% and 79% reduction rate of the crash potential in the lane-changing trajectory optimization and in the lane-changing starting point optimization, respectively. It is expected that the outcome of this study will be valuable for supporting the development of vehicle trajectory control systems for preventing crashes in automated driving environments.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-03977
Paper Title	**Differences in Crash/Near-Crash Risk by Types of Distraction: A Comparison of Trends between Freeways and Two-Lane Highways using Naturalistic Driving Data**
Abstract	Distracted driving is among the leading causes of motor vehicle crashes in the United States, though the magnitude of this problem is difficult to quantify given limitations of police-reported crash data. This study leveraged data from the second Strategic Highway Research Program Naturalistic Driving Study in order to gain important insights into the risks posed by driver distraction on both freeways and two-lane highways. More than 50 types of secondary tasks were aggregated into ten distraction type categories and mixed effects logistic regression models were estimated to discern how the risks of near-crash events varied by distraction type while controlling for the effects of driver, roadway, and traffic characteristics. In general, the types of distractions that created the most pronounced risks were those that introduced a combination of cognitive, visual, and manual distractions. For example, drivers who used cell phones were subject to higher risks and these risks tended to be most pronounced when both visual and manual distractions were involved. Likewise, risks tended to be highest when drivers reached for other objects inside the vehicle, engaged in personal hygiene-related activities, or focused on activities occurring outside of the driving environment. While the same factors tended to increase near-crash risk on both types of facilities, the impacts of several factors tended to be more pronounced on two-lane highways where interaction with other vehicles occurred more frequently. From a policy standpoint, the results of this study provide further motivation for more aggressive legislation and enforcement of distracted driving.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-05054
Paper Title	**The Effect of Speed Reductions on Collisions: a Controlled Before-and-After Study in Quebec, Canada**
Abstract	Speed is known to be a risk factor in collision and injury severity. Speed limit reductions are also known to decrease road risks where they are introduced. Despite several research in the 1980s and 90s, recent studies on the impact of speed limit reductions on collisions are limited. The objective of this paper is to evaluate the effect of speed limit reductions on collisions in Quebec, Canada using a controlled before-and-after methodology. We built a database (n= 3,457) including road segments with speed limit reductions (between 2006 and 2013), and control segments. Data on three years preceeding and three years following speed limit changes were compiled for 20,437 segment-years. The number of killed or seriously injured (KSI) three years prior and after change was used to model the effect of the speed reduction on segments with initial speeds of 70, 80 and 90km/h and speed reductions of 10 and 20 to 40 km/h. Using a zero inflated negative binomial regression and logistic regressions (at least one KSI vs none), controlling for decreasing KSI trend, traffic counts and segment length, we found a clear downward trend of KSI on all road segments, and a higher decrease where initial speed (90 km/h) and speed reduction (20-40 km/h) were higher. Also, segments with sharp turns or including intersections were more likely and divided two-lane roads were less likely to increase KSI. Our results adds to the literature on the impact of speed reduction, helping transportation managers to adopt evidence-based best practices.

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Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-05723
Paper Title	**Effect of Reducing and Enforcing Speed Limits in Selected Arterial Roads in Bogota**
Abstract	In Bogota, the speed limit in five corridors with highest concentration of traffic crashes victims in the city was reduced from 60 to 50 km/h. For understanding the impacts of managing speeds, speed records for 3 different periods (November to February) between 2017 and 2019 were examined, as well as the evolution of road crashes with injuries and the number of fatalities. The average speed reduction in the corridors with speed management was 1.48 km/h during daytime and 3.04 km/h during nighttime. In arterial corridors without speed management, the average speed reduction was 0.7 km/h during daytime and 2.2 km/h during nighttime. Nevertheless, the speed management measure resulted in a reduction of 16.6% in the number of fatalities and an increase of 10.5% in the number of crashes with injuries. The number of crashes with injuries did not decrease as expected, but the severity of the crashes decreased and the type of incidents with injuries changed. The average count of runover crashes was also reduced by 10%. Notorious changes in the geographical distribution of crashes with injuries and fatalities along the corridors with speed management indicate the need to implement stricter enforcement measures to increase speed management effectiveness of during nighttime.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-02138
Paper Title	**A Comprehensive Examination of Highway Secondary Crash Risk Factors**
Abstract	Secondary crashes (SC) are typically defined as vehicle crashes that occur due to the repercussive effects of an earlier incident. The occurrence frequencies of SC on highways are important performance measurement for Traffic Incident Management programs in the US. Currently, our understanding on the risk factors contributing to SCs is insufficient. In this paper, we describe an effort of synthesizing the effects of highway SC risk factors by comprehensively examining and assessing results from existing studies. We first analyzed and categorized the risk factors identified from various studies. We then performed a vote-count analysis of the factors to assess the effects and relative significance of different factors. The results of the vote-count analysis show that factors related to characteristics of the primary incidents and traffic conditions at the crash sites were more significant factors to SC than highway infrastructure and environmental factors. Duration of the primary incidents themselves as well as duration for their clearance were consistently found significant for leading to SCs. Heavy traffic flows leading to congestions and queues trailing behind the PIs were more likely to cause SCs than high speed.

Poster Session 1357

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-01626
Paper Title	**Cycle-by-Cycle Crash Risk Analysis at Signalized Intersections by Considering Shockwave Characteristics**
Abstract	In the context of pro-active traffic management, real-time crash risk evaluation is one of the most important components. Signalized intersections are well-known high-risk locations because of the variety of traffic movements, modes, and their interactions. Unlike access-controlled freeways, the traffic flow at signalized intersections presents cyclical characteristics, which are temporally interrupted by signal timing. Therefore, the data preparation for real-time crash risk prediction at signalized intersections should be based on the signal cycle rather than a predefined fixed time interval (i.e., 5 minutes). In this research, the actual signal cycles where crashes have occurred were identified based on high-resolution event-based data (i.e., Automated Traffic Signal Performance Measures (ATSPM)). Meanwhile, all the real-time cycle-level data were calculated, including traffic volume, signal timing, headway and occupancy, traffic variation between upstream and downstream detectors, shockwave characteristics, and weather data. In this study, two approaches of under sampling strategies (i.e., matched case-control and random sampling) were utilized to develop conditional logistic and binary logistic models, respectively. Model results indicated that the binary logistic model based on the random undersampled dataset performs much better than the conditional logistic model based on the matched case-control dataset. It is revealed that higher cycle volume, overall average flow ratio across lanes, arrivals on yellow ratio, traffic volatility across approach sections, as well as longer cycle length and lower green ratio could significantly increase the crash likelihood at signalized intersections. Moreover, longer queue length, bigger shockwave, and higher absolute queuing shockwave speed tend to increase the crash likelihood.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-01888
Paper Title	**Comparison of State-of-the-art Observational Before-After Analysis Methods in Traffic Safety: A Case Study of the Red-light-running Program in New Jersey**
Abstract	Empirical Bayes (EB) and full Full Bayes (FB) methods are widely used for before-after safety evaluation because they can appropriately estimate the “should-be” crash occurrence in the after period should treatment not implemented. A new before-after method stemmed from the survival analysis was proposed in a recent study by Xie et al. (1), and this method shows its merits when sufficient data from reference sites is unavailable and temporal heterogeneity needs to be captured. On the other hand, two methods originated from the Neyman-Rubin causal framework in statistics, namely propensity score matching (PSM) and the difference-in-difference (DID) is gaining increasing attention in traffic safety research. In this study, we compared all aforementioned methods in terms of their treatment effect estimation after being unified within the Neyman-Rubin causal framework. Multiplicative average treatment effect on the treated was used as the target estimand. The deactivation of the red-light-running (RLR) program in New Jersey was used as the case study to compare treatment effects estimates from different methods. All the methods except the PSM can yield similar crash modification factors (CMFs) that are less than one. It indicates that deactivating RLR counterintuitively led to crash reduction, which may result from the carryover effect of the RLR program. The contradicting outcomes of the PSM was probably due to the overlap and balance assumption violation of the PSM method. The use of the PSM method

should be adopted with caution since PSM method may actually increase the bias in treatment effect estimates.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-04503
Paper Title	**Vulnerability Assessment of Urban Intersections apropos of Incident Impact on Road Network and Identification of Critical Intersections: A Case Study of Kolkata City**
Abstract	One of the major challenges in a transportation network management programme is responding to traffic incidents at or near intersections. For incident modelling purpose, it is important to assess the vulnerability of intersections within a network where traffic management would become extremely difficult and complicated during an incident. This paper presents a methodology to identify the critical intersections in an urban road network and the methodology is demonstrated with reference to Kolkata metro city, India. Some key factors governing the vulnerability of intersections are identified and expert opinion survey is conducted to assess the location-specific relevance of those factors for both peak and off-peak hour conditions using fuzzy analysis. On a parallel approach, a micro-simulation model for the study network is developed and different incident scenarios are evaluated on the basis of incident impact. Then a multiple linear regression model is developed by using the key factors as independent variables and the incident impact as obtained from the micro-simulation model as the dependent variable. The weightages of the factors estimated from the regression model and the intersection-specific scores of the factors obtained from the expert opinion analysis are then combined to determine overall scores for the intersections. The intersections are ranked in order based on the overall scores and this ranking is then validated by comparing it with the micro-simulation results which shows that the approach can be used for field-implementation. The proposed approach can also be expanded to a larger network and transferred to other cities with similar characteristics.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-04710
Paper Title	**Evaluating Crash Type Likelihood at Various Traffic Control Devices: A Multinomial Logistic Regression Approach Using HSIS Data**
Abstract	Widespread acceptance of analytical methods outlined in the Highway Safety Manual, including Crash Modification Factors (CMFs), have been developed to measure the safety effectiveness of a particular treatment or design element. Often, these CMFs are developed to target specific crash types, with the goal of reducing that crash type with a specific treatment. Implementing these countermeasures at specified locations can help mitigate preventable crashes. However, a lack of research has been completed analyzing the likelihood of each crash type occurring at various traffic control devices on a large, multi-year scale across the United States. Without this information, the increased need for specific CMFs to be developed cannot yet be fully realized. Certain crash types are often associated with higher severity, which should be targeted in future research. To align with the goal of reducing crashes and reaching zero fatalities, this study provides insight into the relationship between various crash types and traffic control devices on a macro scale for all roadway types. A multinomial logistic regression model and relative risk ratios were utilized in the analysis of Highway Safety Information System (HSIS) data obtained from over 1.8 million crashes occurring in the states of North Carolina and Ohio from 2010 to 2015. The results of this analysis provide both an improved understanding and necessary foundational element for future modeling of the relationships between crash types, and in relation, crash severity, that occur at specific traffic control devices.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-00438
Paper Title	**A Comparison between SSAM and Real-Time Safety Models in Predicting Field-Measured Conflicts at Signalized Intersections**
Abstract	Traffic simulation models are frequently being used to evaluate safety of signalized intersections, especially when testing unconventional designs or investigating effects of emerging technologies such as connected and autonomous vehicles. In this approach, vehicle trajectories extracted from traffic simulation are usually analyzed using the Surrogate Safety Assessment Model (SSAM) to estimate the number and severity of traffic conflicts. However, recent research showed that evaluating safety using SSAM is associated with several limitations. First, a rigorous calibration procedure must be applied to the simulation model to obtain reliable conflict results. Second, simulation models, in many cases, do not accurately represent the actual driving behavior. Subsequently, they often fail to capture the actual mechanism generating near misses. This paper presents a new procedure, alternative to SSAM, for evaluating the safety of signalized intersections. The procedure combines simulated vehicle trajectories with real-time safety models to predict rear-end conflicts. The conflict prediction is based on dynamic traffic parameters, such as traffic volume and shock wave characteristics, repeatedly measured over a short time interval (a few seconds). To validate the proposed procedure, we investigated its performance in predicting traffic conflicts extracted from 54 hours of real-world video data at two signalized intersections in the City of Surrey, British Columbia. The predicted conflict results were compared with SSAM. Overall, the results showed that the proposed procedure outperforms SSAM in terms of the conflict prediction accuracy. Lastly, we presented a case study of using the proposed procedure in evaluating the safety impact of a recently-developed connected-vehicles application.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-05955
Paper Title	**Understanding the Safety Impact of Protected Intersections Design Elements-A Driving Simulation Approach**
Abstract	Protected intersections are used to facilitate safe crossings for bicyclists and pedestrians at intersections. As a relatively new treatment in North America, it is essential to understand how its design elements such as bicycle crossing pavement markings and intersection radii, enhance bicyclist safety. Moreover, an improved understanding of the impacts of the specific design elements may provide guidance regarding the flexibility to introduce partial protected intersections. A driving simulation experiment was developed to test the effectiveness of different design elements of protected intersections on driver speeds. Participants were exposed to different protected intersection designs, i.e., turning radii and pavement marking levels. Their speed as they were completing right turns was analyzed. A combination of design elements, participant demographics, or bicyclist presence at the intersection contributes to safe interactions between bicyclists and automobiles at a protected intersection. Specifically, intersection approaching and turning speeds were analyzed across the different scenarios and participant demographics. The results indicate that the presence of a bicyclist crossing a protected intersection significantly reduces speeds for drivers performing a right turn. Larger intersection radii were found to reduce turning speeds as they were accompanied by larger corner islands and bigger curb extensions. Bicycle crossing pavement markings influenced only approaching speeds prior to the actual turn since that is the location where they were the most visible. Age, gender, and bicycling history were observed to be affecting turning speeds, indicating that design elements alone cannot determine the safety effectiveness of a protected intersection.

Poster Session 1358

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-01440
Paper Title	**In-Depth Approach for Identifying Crash Causation Patterns and its Implications for the Development of Active Pedestrian Safety Systems**
Abstract	A crash causation pattern describes a crash's causes and the associations between these causes. Identifying the causation patterns behind pedestrian crashes is essential not only to understanding the crash mechanism, but also to enabling an effective design of active pedestrian safety systems (APSSs). Previous research and engineering practices lack an in-depth investigation on crash causation patterns that can be representative of typical pedestrian crash scenarios. Meanwhile, the implications of causation patterns on APSS designs remain unclear. In this study, the Driving Reliability and Error Analysis Method (DREAM) was applied to 142 pedestrian crashes to discern the common causation patterns. In total, six crash causation patterns were identified for five pedestrian pre-crash scenarios. The results showed that the causation pattern related to "missed observation due to non-obstruction/visibility-factor" was the most common causation among all crash cases, while the causation pattern related to "unexpected sudden change of pedestrian movement" was one of the most common causations specifically at the road segment. In addition, "reduced visibility condition" and "misjudgment of gaps" were two other critical causation patterns. This study further recommends the requirements for APSS designs in terms of crash causation patterns and pre-crash scenario types. Finally, six requirements for the sensor system, six requirements for the functional algorithm, and two requirements for the actuating elements, were proposed to improve the current design of APSSs. The findings from this study have significant implications for OEMs, practitioners and researchers.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-01525
Paper Title	**Impact of Right-turn Channelization on Pedestrian Safety at Signalized Intersections**
Abstract	Channelized right turns or slip lanes have been widely implemented as an effective countermeasure of reducing traffic delay and number of conflicts between vehicles at signalized intersections. However, few studies have investigated the impact of channelized right turns (in left-band driving countries) on pedestrian safety. Channelized right turns may increase the risks for the crossing pedestrians since it brings all pedestrian-vehicle interactions in a fully non-signalized environment. Besides, the increased radius at channelized right turns can lead to higher vehicle speeds. This paper investigates the impact of channelized right turns on pedestrian safety based on surrogate safety and behavior measures. For this purpose, video data were collected from twelve signalized intersections in Zunyi, China, involving three main types of right-turn lane designs: 1) non-channelized right-only lane, 2) non-channelized right-through lane, and 3) channelized right-turn lane. Different measures are used including interaction and behavior measures based on a recent-proposed Distance-Velocity model, PET measurements, speed measurements (average crossing speed during interactions and interaction-free speed), and observations of failures in interactions (retreats and evasive maneuvers). Results indicate that the design of channelized right-turn lane increases pedestrian risks from different dimensions of safety. The impact of the nighttime condition on pedestrian safety was also compared. Results show that drivers pay more attention to pedestrians at non-channelized right-turn locations by reducing their speeds at nighttime.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-02468
Paper Title	**Pedestrian Collisions with Bicyclist: Emotion Mining using YouTube Data**
Abstract	In recent years, many studies have been conducted on vehicle-pedestrian incidents and vehicle-bicyclist crashes. Surprisingly, only limited research has focused on the collision between pedestrians and cyclists, and the research about the tension between pedestrians and cyclists is even rarer. The absence of this kind of research is due to the nature of a limited number of crashes and the consequence of the crash usually is not as severe as automobile involved crashes. However, pedestrians and cyclists' crashes could lead to serious social crisis. The largest video sharing website, YouTube.com, stores many videos about pedestrians and cyclists' crashes. Content analysis and text mining on the comments related to the videos with a larger number of views can provide insight into potential interactions. The topmost viewed YouTube videos on 'pedestrian collision with bicyclist' have 60.9 million views and contain around 25,000 comments. The findings show that the emotion patterns of comments and replies differ. This study also provided word shift plots that show the trend of the emotion used in comments and replies. Additionally, the cooccurrence plots show the reason behind the use of negative emotions. The findings of this study will provide additional insights into the ongoing debate on 'pedestrian collisions with bicyclist' issues.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03513
Paper Title	**Pedestrian Safety Analysis at Urban Midblock Sections under Mixed Traffic Conditions Using Time to Collision as Surrogate Safety Measure**
Abstract	Pedestrians are the most vulnerable road users, and pedestrian safety has become a major concern of researches in recent years due to increasing number of fatalities on roads. Conflict analysis using surrogate safety measures are hence a useful technique to study pedestrian safety, as there are many issues with collision data. Moreover, it is a cost-effective technique as compared to the historical crash data analysis. The present paper deals with analyzing pedestrian safety at urban midblock crosswalk using Time to Collision (TTC) as a surrogate safety measure. The data for the present study has been collected from four different midblock pedestrian crossing locations in four different cities located in western parts of India using the video-graphic technique. The trajectory of pedestrians and vehicles are extracted for micro-level analysis of pedestrian-vehicle interactions. The trajectory data are further used for calculating TTC at regular time interval during the interaction of pedestrian and vehicles. Two different types of pedestrian road crossing behavior known as vehicle-pass-first and pedestrian-pass-first are identified, and the analysis of TTC has been done differently for each scenario. The variation of TTC based on gender and vehicle category is analyzed to evaluate the influence of such parameters on pedestrian safety. Generalized linear mixed models approach used for developing linear regression models for TTC based on the empirical data. The threshold values for TTC are used to define various safety level of pedestrians using a clustering approach.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-04754
Paper Title	**Traffic Safety Countermeasures: Considering Impacts on Pedestrian and Bicyclist Safety**
Abstract	The objective of this research was to develop a decision tool and user guide to help planners, designers, and safety engineers identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from traffic safety countermeasures during countermeasure selection. The decision tool and user guide will help state and local highway agencies make more informed decisions as part of their roadway safety management process and Highway Safety Improvement Program (HSIP). The decision tool was designed with two primary purposes: For a given classification of roadway or intersection configuration and traffic control type, the decision tool will help practitioners select a traffic safety countermeasure that addresses specific crash types or contributing factors, while also considering potential impacts on pedestrians and bicyclists; and If a designer or engineer has already identified an initial traffic safety countermeasure for potential implementation to address a specific safety concern, the decision tool can be used to identify alternative countermeasures that address the same safety concern; while also considering the potential impacts on pedestrians and bicyclists of the initial countermeasure and the alternative countermeasures. The decision tool was designed to address countermeasures covering most types of roadway segments and intersections. The decision tool was designed to be consistent with the Highway Safety Manual and the AASHTOWare Safety Analyst software. In total, 17 roadway-segment and 14 intersection countermeasures are included in the spreadsheet-based decision tool, implemented using Visual Basic for Applications within Microsoft Excel.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-04899
Paper Title	**Identifying High Risk Locations to Address Pedestrian Safety Issues**
Abstract	Many states have identified pedestrian safety as one of the emphasis areas in their Strategic Highway Safety Plans. Identifying the high-risk locations is typically the necessary first task that states consider for implementation of countermeasures. Given the rarity and randomness of pedestrian crashes, advanced tools such as Safety Performance Functions (SPFs) are needed in the hot-spot detection process. The Highway Safety Manual (HSM) includes SPFs for pedestrian crashes for four-legged and three-legged signalized intersections in the urban and suburban areas but they need to be calibrated for local conditions. The HSM does not include SPFs for the stop-controlled intersections. The objective of this study is to develop the safety performance functions (SPFs) for pedestrian crashes for both signalized and stop-controlled intersections. To accomplish the study objectives, data at all intersections in Dallas, Texas were collected. The variables that were found to be significant in influencing the pedestrian crashes at intersections are total intersection vehicular volume, ratio of minor to major street volume, pedestrian crossing volume, number of bus stops and the land use. The Empirical Bayes method that considers both the observed and the predicted crashes was used for estimating the expected crashes. A safety risk index was estimated as a ratio of expected crashes to predicted crashes. A risk index value of greater than 1.0 indicates the intersection is with high crash risk. In total, 18 signalized and 24 stop-controlled intersections on state highways in Dallas were identified as high-risk locations for pedestrian safety.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05024
Paper Title	**An Exploratory Parameter Sensitivity Analysis of Bicycle-Vehicle Conflicts Using the Surrogate Safety Assessment Model**
Abstract	The use of traffic microsimulation software has been an invaluable tool for analysis of operational performance at signalized intersections in recent decades. Microsimulation also offers opportunities to examine the safety performance of an intersection through analysis of surrogate measures of safety such as conflicts identified using post encroachment time (PET) or time to collision (TTC). The use of microsimulation and surrogate measures of safety provides a very promising avenue for analysis of the safety impacts of treatments aimed at improving bicyclist safety, particularly for new and/or developing treatments given the absence of police-reported crash data. However, the use of these tools for the analysis of bicycle-vehicle conflicts is lacking. To fill this gap, the following to objectives were addressed in this study: 1) perform a sensitivity analysis on the impacts of behavioral parameters in microsimulation on the frequency and severity of bicycle-vehicle conflict outputs from Surrogate Safety Assessment Model (SSAM) at a signalized intersection, and 2) perform a qualitative analysis on the ability of microsimulation to emulate realistic interactions between motor vehicles and bicycles. The results indicated that some behavioral parameters had no effect on conflict outputs, while some did have effects with varying consistency and magnitude. The qualitative analysis revealed instances of unrealistic interactions between bicycles and vehicles, and further refinement of these models is needed. Ultimately, this study adds to the literature by providing an exploratory step forward in fine-tuning the use of microsimulation/SSAM to analyze bicycle-vehicle conflicts.

Authors	Rebekka Apardian, University of Toledo Bhuiyan Alam, University of Toledo
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05107
Paper Title	**Pedestrian Fatal Crash Location Analysis in Ohio Using ESDA Techniques**
Abstract	Pedestrian safety is a top priority within the transportation planning community as cities promote sustainable transportation, alternative travel modes, and healthy lifestyles. If people feel unsafe while walking, they will choose other modes of transportation if they are able. In order to prioritize safety, it is important to know where pedestrian crashes are occurring and in what severity. Using spatial statistical methods including nearest neighbor index, Moran's I, local indicators of spatial analysis (LISA), and Getis-Ord G-statistic, this study seeks to analyze the pedestrian fatality locations within the state of Ohio over a ten-year period (2007-2016) to identify hot spots, cold spots, and spatial patterns across three different spatial scales: county, census tract, and traffic analysis zone. It seeks to understand the effects of aggregated data across these spatial scales on the outcome of the analysis and determine the most useful spatial scale at which to study pedestrian fatalities. The study concludes that spatial analyses at small scales are most informative. It goes on to recommend locations within Ohio for further analysis based on the resulting maps, including areas with outliers. As of this writing, there is no current statewide pedestrian fatality analysis for the state of Ohio.

Authors	Robert Schneider, University of Wisconsin, Milwaukee Rebecca Sanders, Arizona State University Frank Proulx, Toole Design
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-02402
Paper Title	**United States Fatal Pedestrian Crash Hot Spot Locations and Characteristics**
Abstract	US pedestrian fatalities are at their highest level in nearly three decades and account for an increasing share of total traffic fatalities (16%). Pedestrian safety must be improved to create a future transportation system that produces zero deaths. In this study, we screen the entire US roadway network to identify fatal pedestrian crash "hot spot" corridors: 1,000m-long sections of roadway where six or more fatal pedestrian crashes occurred during an eight-year period. We identified 34 hot spot corridors during 2001-2008 and 31 during 2009-2016. While only five corridors were hot spots during both analysis periods, the 60 unique hot spots have remarkably consistent characteristics. Nearly all (97%) are multilane roadways, with 70% requiring pedestrians to cross five or more lanes. More than three-quarters have speed limits of 30 mph or higher, and 62% have traffic volumes exceeding 25,000 vehicles per day. Nearly all had adjacent commercial land uses, and three-quarters were bordered by neighborhoods with lower-income households. Corridors with these characteristics have the potential to produce high numbers of pedestrian fatalities. These results support a systemic approach to improve pedestrian safety: agencies should identify other roadway corridors with similar characteristics throughout the US and take actions to reduce the risk of future pedestrian fatalities.

Authors	Jaeyoung Lee, Central South University Mohamed Abdel-Aty, University of Central Florida Qing Cai, University of Central Florida
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03549
Paper Title	**Investigation of Safety-in-numbers for Pedestrians and Bicyclists at a Macroscopic Level with Various Exposure Variables**
Abstract	Safety-in-numbers effect is a phenomenon that crash risks of road users decrease when their numbers increase. Although a number of previous studies have confirmed the safety-in-numbers effect at microscopic scales, few study investigated the safety-in-numbers effect at a macroscopic level (e.g., census tracts). In this study, the safety-in-numbers phenomenon is investigated at a greatly larger scale unit, metropolitan statistical area (MSA), which are usually composed of multiple counties. Various pedestrian and bicyclist exposure data were obtained from the National Household Travel Survey, i.e., trips, miles, and hours. The preliminary results show that the number of fatal crashes involving pedestrians and bicyclists are significantly larger where walking and bicycle activities are higher. A series of Bayesian Poisson lognormal models confirm the safety-in-effects with the different exposure variables at a large-scaled geographic level (i.e., MSA). The findings imply that regions' travel behavior and cultures to respect vulnerable road users play a key role in the level of pedestrian and bicyclist safety. In addition, the results reveal other important factors to vulnerable road user involved crashes, including but not limited to climate, demographic, socio-economic, and travel characteristics of the study regions.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03773
Paper Title	**Does Walkable and Bikeable Mean Safe for Walking and Cycling?**
Abstract	Walkability and bikeability indices are used to succinctly quantify how conducive an environment is to walking and cycling, often including factors related to comfort and perceived safety. The potential assumption that walkable and bikeable means safe for walking and cycling (i.e., the association with objective safety or crash risk) has not yet been examined. This study investigates the association between two widely-used measures (Walk Score and Bike Score) and pedestrian and cyclist crashes in Vancouver, Canada, to determine whether more walkable and bikeable areas of the city are also safer for walking and biking, after controlling for exposure. Multivariate Bayesian crash models with random and spatial effects are developed for pedestrian-motor vehicle and cyclist-motor vehicle crashes in 134 traffic analysis zones using 5 years of crash data with walking, cycling, and motor vehicle traffic volume controls for exposure. Results indicate that areas of the city with higher walkability and bikeability are associated with greater pedestrian and cyclist crash risk, respectively, even after controlling for exposure. While the clear answer is that neighborhood walkability and bikeability does not indicate safety for pedestrians and cyclists, questions remain as to whether they should, and if so, how they could be modified to better incorporate objective risk.

Authors	Mohammad Saad Shaheed, Maricopa Association of Governments Randy Dittberner, Lee Engineering
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-04215
Paper Title	**Regional Bicycle Safety Analysis in the Maricopa Region based on Crash Report Review**
Abstract	As it can be challenging to assess the potential causal factors associated with bicyclist crashes because many bicyclist crashes are underreported involving minor injury or taking place in driveway, this study conducted an extensive crash report review of crashes involving bicyclists on arterial roadway segments in the Maricopa region for three years period. The study gathered information from reviewing crash reports of crashes involving bicyclists to gain better understanding of bicyclist riding behavior including riders' locations and travel directions under the presence or absence of bicycle infrastructure on roadways, crash site characteristics, crash types, fault of the road users, roadway operational characteristics etc. The study revealed that the most common type of bicycle crash was when a motorist entered a street from a driveway and a bicyclist approached from the right riding against the traffic flow. The study also revealed that bicyclist riding in contraflow direction or against the traffic on sidewalk were involved in the most common bicycle crash type. One interesting finding from the study was that the travel direction of bicyclists in crashes were highly correlated to their riding location. The findings from this study can be used to better inform the local agencies and decision makers to improve bicycle safety through planning new or upgrading existing bicycle infrastructure, education, and enforcement.

Authors	Chris McCahill, University of Wisconsin, Madison Mark Bennett, Harvard University
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-04507
Paper Title	**Wisconsin Pedestrian Crashes, 2008-2017**
Abstract	Pedestrian fatalities have increased suddenly in Wisconsin. Some theories focus on a sudden rise in distracted behavior due to growing cell phone use and increased risk to pedestrians from the rising prevalence of larger vehicles. By combining a robust set of crash data spanning 10 years with detailed information from original crash reports, this study examines recent trends and factors contributing to crash likelihood and severity in the state. Two notable trends emerged: 1) the total number of crashes has stayed relatively consistent while some crashes are becoming more severe, and 2) pedestrian crash risk is growing mainly among older populations, while dropping considerably among children. Crash increases are also more common in existing or growing job centers. This study supports the idea that larger vehicles are a risk to pedestrians, but they do not explain the recent increase. There is no evidence that increased distraction has played a major role. The clearest opportunities to mitigate severe pedestrian crashes are on highways and other high-speed roads, particularly in urban areas. Crashes involving alcohol, dark conditions, and older pedestrians are also common and more likely to be severe or fatal. In addition to addressing these issues, there is a clear need for more detailed and consistent crash reporting.

Authors	Nicholas Ferenchak, University of New Mexico Wesley Marshall, University of Colorado, Denver
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05462
Paper Title	**Is Bicycling Getting Safer for Adults? Age-Specific Bicycle Fatality Rates from Four Exposure Metrics, 1985-2017**
Abstract	Decreasing bicycle fatality rates in the United States over the past several decades suggest improved bicycling safety. Researchers agree that bicycle fatality rates for children are decreasing but ambiguity remains in terms of adult bicycle fatality rates. Is bicycling getting safer for adult riders, and if so, are the safety benefits shared equally among commuters and recreational riders? The objective of this paper is to explore age and rider type differences with respect to the direction and magnitude of bicyclist fatality rates in the United States between 1985 and 2017. Using fatality data from the Fatality Analysis Reporting System (FARS) and exposure data from the National Household Travel Survey (NHTS), the American Community Survey (ACS), the U.S. Census, and the National Sporting Goods Association (NSGA) – a relatively novel approach to measuring exposure through a comprehensive national bicycling participation survey – we derived trends of age-specific bicyclist fatality rates and corresponding confidence intervals for children and adults. This is the first research to provide a longitudinal, age-specific examination of bicycle fatality rates using these four exposure metrics. Results suggest that overall declines in bicycle fatality rates have been primarily driven by a sharp decline in child bicyclist fatalities while adult bicycle fatality rates have generally trended upwards (especially for the general population) or remained stagnant (for commuters). This work adds to the understanding of bicyclist fatality rate trends and gives direction to future research regarding the importance of considering age and exposure sources when examining bicyclist safety.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05550
Paper Title	**Modeling Vehicle-Pedestrian Interactions Using a Non-Probabilistic Regression Approach**
Abstract	Understanding how vehicle drivers and pedestrians interact is key to identifying countermeasures to improve the safety of these interactions. Furthermore, there is a need to identify techniques that can be used to evaluate the effectiveness of safety countermeasures and traffic control devices without the need to wait for crash data. Using video, interactions between right-turning vehicles and conflicting pedestrians were documented by logging the timestamps associated with key vehicle positions during right turn maneuvers and corresponding key conflicting pedestrian positions. Interactions documented were purposely limited and narrow in scope to provide a controlled dataset. Logged timestamps enabled the calculation of values such as time to complete a right turn and time for a pedestrian to reach a critical conflict point when a vehicle initiated a right turn. A non-probabilistic regression model explaining the relationship between the calculated values was created. The model described the expected right turning behavior: when drivers perceive the possibility of pedestrian reaching a critical conflict point at the same time as them, they will modify their behavior even if not coming to a stop. The behavior is not a surprise and has been previously documented in the literature. The main contribution of this paper is demonstrating that by analyzing a narrow set of interactions, a clean and simple model that explains the interaction of right-turning vehicles and pedestrians can be developed using a non-probabilistic regression approach. An argument is made that the model parameters can be used to evaluate the effectiveness of traffic control devices.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05700
Paper Title	**Towards Vision Zero for Cyclists: New Insights & Methods for Assessing Bicycle Crash Severity**
Abstract	Cycling represents an increasingly common mode of travel in the United States, as well as an increasing share of fatal and serious injury crashes; transportation professionals are still working to understand how different types of riding behavior and roadway infrastructure can impact the number and severity of bicycle crashes, particularly in lower-density, suburban-type areas. A lack of consistent and comprehensive data to characterize cyclist behavior and crash contributing factors is part of this challenge; additionally, many crash severity models are constrained when it comes to interpreting specific influencing factors – these models often interpret such factors to either universally increase or decrease crash severity, with no ability to account for different levels of effect for a single variable. This study furthers the understanding of factors influencing bicycle crash severity, by examining five years of crash data, coded using FHWA's Pedestrian and Bicycle Crash Analysis Tool (PBCAT), from two counties in the State of Michigan. We apply an ordered probit model with random parameters to better account for the range of potential impacts, both positive and negative, that individual variables may have. Our model confirms existing research findings, such as the elevated risk of severe crashes outside of intersection areas, while also illustrating [through the random parameters specification] several cases where variables have a range of positive and negative effects on crash severity.

Authors	Robert Schneider, University of Wisconsin, Milwaukee
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05733
Paper Title	**Far from Zero: United States Pedestrian Fatality Trends, 1977 to 2016**
Abstract	After decreasing for three decades, US pedestrian fatalities increased by more than 40% between 2009 and 2016, hindering progress toward a future transportation system that produces zero deaths. While many researchers have investigated changes in the last decade, this study takes a long-term perspective and asks: what are the most common characteristics associated with US pedestrian fatalities, and how have these characteristics shifted over the last 40 years? It analyzes all 231,675 pedestrian fatalities recorded between 1977 and 2016 in the Fatality Analysis Reporting System database. Over 40 years, most pedestrian fatalities occurred in darkness (65%) and involved male pedestrians (70%) and male drivers (67%). They were commonly in roadway lanes (90%), away from intersections (80%), and involved vehicles traveling straight (83%). Most occurred on roadways with speed limits of 35 mph or higher (70%) and four or more lanes (50%). Trends were compared across eight five-year periods. Between the earliest and latest periods, there were significant decreases in the proportion of pedestrian fatalities among children younger than 15 (18% to 5%) and involving drivers who were drinking (15% to 8%). There were significant increases in pedestrian fatalities during darkness (63% to 73%), involving large vehicles (e.g., pickup trucks, vans, and SUVs) (22% to 44%), on roadways with speed limits higher than 35 mph (56 kmh) (60% to 76%), and on roadways with four or more lanes (41% to 58%). These findings underscore the need for fundamental transportation systems changes to ultimately eliminate pedestrian fatalities.

Authors	Kevin Fang, Sonoma State University
Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05846
Paper Title	**Characteristics and Circumstances of Injuries Related to the Use of Scooters and Other "Personal Transportation Devices" as Indicated by US National Emergency Room Data**
Abstract	Highlighted by the emergence of electric scooter systems, personal transportation devices (PTDs) and other forms of "micromobility" are a growing in presence in cities. Reaction to PTDs has been positive and negative, with concerns about safety a prominent concern. This paper explores PTDs and safety through an examination of injuries related to the use of PTDs reported to the National Electronic Injury Surveillance System (NEISS), which tracks emergency room (ER) visits. Review of the characteristics of injuries and the circumstances surrounding injury occurrences show similarities between PTDs and more traditional modes, namely bicycles and electric bicycles. While serious injuries are possible, ER visits related to PTD use typically do not generally result in further admission to a hospital. Strains, sprains, cuts, and bruises are most common. Head injuries and concussions occur, but in the range of what is seen with bicycles. Like bicyclists and pedestrians, PTD users are vulnerable to motor vehicles. Hospital admission rates rise sharply when motor vehicle collisions factor into PTD injuries. Specific PTDs that saw a lower proportion of injuries on streets, likely indicating less on-street and more off-street riding, tended to have fewer vehicle-related injuries and lower overall hospital admission rates. Such findings point to a benefit from and justification for better infrastructure such as protected bicycle lanes, which could also be utilized by PTD riders. Such infrastructure could also separate PTDs from pedestrians. NEISS data indicates PTD-pedestrian collisions occur, however injuries to bystanders represent a lower share of PTD-related injuries than motor vehicle-related injuries.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05873
Paper Title	**Pedestrian Safety Analysis of Urban Intersections in Kolkata, India Using a Combined Proactive and Reactive Approach**
Abstract	Assessment of pedestrian safety is often conducted in a reactive way by analyzing pedestrian crash data. However, in a developing country, the availability of reliable crash data is a major challenge. Therefore, without relying solely on reactive approach, it is essential to combine some methods that can proactively assess pedestrian safety. In this background, the present study proposed a methodology combining both reactive and proactive approach to assess pedestrian safety at urban intersections in Kolkata, India. The method developed in the present study utilizes a combination of the historical crash data analysis, the analysis of pedestrian-vehicular conflict (i.e., pedestrian-vehicular post-encroachment time), along with pedestrians' risk perception towards the built environment and traffic parameters, to identify potential risk-prone intersections in Kolkata. Based on the combined reactive and proactive assessments, there is evidence that the high traffic volume, pedestrian-vehicular interaction captured through pedestrian and vehicle volume ratio, the absence of police personnel, high approaching speed, the presence of commercial area, inadequate sight distance, the presence of slum population, and a high population density near the intersection significantly increase the risk of pedestrian crashes. Finally, using this combined proactive-reactive approach, the present study also identifies and ranks 25 high risk-prone intersections for pedestrians. This is a significant step towards scientific decision making and allowing use of information beyond historical crash records.

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Sponsoring Committees	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-06009
Paper Title	**Pedestrian Fatalities in Darkness: What Do We Know, and What Can Be Done?**
Abstract	Pedestrian fatalities in the U.S. steadily declined between the 1970s and 2010, when they began rising again, culminating in a 28-year high of 6,227 pedestrians killed in 2018. The vast majority of pedestrian fatalities occur in darkness and account for the most of the recent increase in pedestrian fatalities – an alarming trend that merits further investigation. This paper examines six years of data on pedestrian fatalities at the national level and pedestrian fatalities and severe injuries in California to better understand correlates specifically with regard to darkness. Logit models reveal that fatalities and combined KSI are significantly more likely on roadways with higher speeds and numbers of lanes, such as freeways and state highways. Pedestrians are significantly safer where traffic is slowed, such as at traffic control devices and intersections, and when crossing in marked crosswalks (at intersections). Alcohol usage by pedestrians or drivers significantly increases pedestrian fatality and severe injuries, as does a hit-and-run incident. Younger (under age 16) and older (over age 65) pedestrians are at less risk, but Black pedestrians are at increased risk in all models. Future research examining additional correlates, such as temporally-resolved pedestrian exposure data, finer-grained built environment variables, and the influence of mobile phone distraction, could help further illuminate the causes of – and potential solutions for – this complex yet solvable problem. Immediate solutions include roadway design and policies that slow drivers, particularly at night, additional roadway lighting, and adaptive lighting and detection technology for vehicles.

Poster Session 1691

Authors	Vikash Gayah, Pennsylvania State University Eric Donnell, Pennsylvania State University
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-00041
Paper Title	**Estimating Safety Performance Functions for Two-Lane Rural Roads Using an Alternative Functional Form for Traffic Volume**
Abstract	Statistical models of expected crash frequency are referred to as Safety Performance Functions (SPFs) in the first edition of the American Association of State Highway and Transportation Officials' Highway Safety Manual (HSM). The SPFs in the HSM specify expected annual crash frequencies as a function of various roadway and roadside features, with the most important predictor variable being traffic volume, which serves as a measure of vehicle exposure to crashes. Traffic volumes are typically measured using the average annual daily traffic and are incorporated into the SPFs using a natural logarithm transformation. This specification suggests that the relationship between expected crash frequency and traffic volume increases non-linearly with a constant elasticity over the range of observed values. While researchers concur that the relationship between expected crash frequencies and traffic volume is non-linear, further exploration of the functional form of this relationship may offer additional insights concerning the association between safety performance and vehicle exposure. This paper proposes an alternative functional form for the traffic volume variable in SPFs that allows for different elasticities between traffic volume and expected crash frequency within different traffic volume ranges, while preserving the same general non-linear relationship in existing HSM SPFs. The proposed functional form was applied to SPFs developed for two-lane rural roadways in Pennsylvania. Comparison with SPFs developed using the traditional functional form in the HSM suggests that this proposed functional form offers an improved fit and predictive performance, and thus might be considered for the development of future SPFs.

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Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-00660
Paper Title	**Revisiting Expressway Single Tunnel Crash Characteristics Analysis: A Six-Zone Analytic Approach**
Abstract	Considerable research has been conducted to investigate the tunnels' traffic safety. However, the entrance and exit parts of a tunnel are mostly considered symmetrical in previous studies, and the different lengths (long, medium, and short) of tunnels have also been studied aggregately. This study aims to investigate the characteristics of traffic crashes in expressway single tunnels by separately considering the entrance and exit of the tunnel as well as the different lengths of tunnels. A six-zone approach is proposed, and the data from 156 single tunnels in Hunan province, China, are applied for safety analysis. The crash rate, crash type, and contributing crash factors are compared between the conventional four-zone approach and the proposed method, and the three different lengths of tunnels are also compared for in-depth analysis.

Authors	George Yannis, National Technical University of Athens (NTUA) Anastasios Dragomanovits, National Technical University of Athens (NTUA) Julia Roussou, National Technical University of Athens (NTUA) Dimitrios Nikolaou, National Technical University of Athens (NTUA)
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-01634
Paper Title	**Economic Assessment of Road Infrastructure Safety Schemes in Greece Using Crash Prediction Methodology**
Abstract	The economic assessment of intervention projects at hazardous locations aims to maximize road safety benefits by exploiting the full potential of limited available funds for road safety. The study presents a case study for the economic assessment of road safety schemes in crash prone locations in rural highways in Viotia and Imathia sub-regions in Greece, using crash prediction models from the AASHTO Highway Safety Manual. The models were suitably adjusted, calibrated and adapted according to data availability, and were used, along with findings from road safety inspections of the locations under consideration, to estimate expected reductions in fatalities and casualties due to the implementation of specific road safety schemes. Road safety benefits were then translated into monetary terms, and, taking also into account construction and maintenance costs for each scheme, the economic rate of return (ERR) of the project was estimated. The economic rates of return were estimated at 27.1% for Viotia sub-region and 18.2% for Imathia sub-region, thus demonstrating the very high cost effectiveness of road safety intervention schemes in hazardous locations.

Authors	Ye Chen, Southeast University Meng Li, Southeast University Zhibin Li, Southeast University Yutin Luo, Southeast University
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-03150
Paper Title	**Safety Evaluation of Mandatory Lane Change Behaviors in Lane-Unbalanced Merging Area Using Vehicle Trajectory Data**
Abstract	Lane-unbalanced merging area is a common bottleneck which usually leads to traffic jam and increased crash risks. This paper aims at proposing an insight which combines the lane change decision behavior with traffic states to analyze the safety impact of mandatory lane change from the microscopic level. A total of 292 mandatory lane change trajectories were obtained from UAV videos on an urban expressway in Nanjing, China. Based on the vehicle trajectory data, the lane change duration and location were investigated, and the difference of mandatory lane change decision behavior under free flow state and congested state were considered. Then, an indirect lane change evaluation index was developed to estimate the overall crash risk between the merging vehicle and its neighboring vehicles. The findings suggest that the lane change duration and location are affected by the surrounding vehicles and traffic conditions. With respect to the congested state, the merging vehicles tend to have shorter lane change gap, longer lane change duration, and higher risk potential than the free flow state. The result demonstrates that the traffic state could significantly affect the safety of mandatory lane changes in the lane-unbalanced merging area. Findings of this study will be valuable for the safety evaluation and real-time crash risk prediction in lane-unbalanced merge area.

Authors	Jiyuan Tan, North China University of Technology Qianqian Qiu, North China University of Technology Shuofeng Wang, Tsinghua University Department of Psychology Na Xie, Central University of Finance and Economics Yuelong Su, AutoNavi Software Company Yujing Wang, AutoNavi Software Co Weiwei Guo, North China University of Technology Ke Zhang, North China University of Technology
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-03262
Paper Title	**Research on Characteristics and Prediction Methods of Expressway Accidents**
Abstract	With the construction of expressways and the increase in car ownership, the traffic safety problems of expressways have become increasingly severe. Based on the data of expressway accident data and vehicle mobile navigation trajectory data in a province, this paper firstly uses the statistical analysis method to study the characteristics of traffic accidents. Then it uses Wilcoxon signed rank test to quantitatively analyze the space-time characteristics of the road speed before and after traffic accidents; Then it uses the average speed of the upstream and downstream sections one hour before the traffic accident and five kilometers from the accident point to train the support vector data description (SVDD) model, and the corresponding hypersphere was obtained. Finally, the accuracy and feasibility of the accident prediction method proposed in this paper were verified by experiments. The research results will help the management department to predict expressway traffic safety, implement preventive measures in a targeted manner, and pre-regulate deployments, and issue early warning messages to reduce accident rates and mitigate accident hazards.

Authors	Craig Lyon, Persaud and Lyon Inc./Traffic Injury Research Foundation Bhagwant Persaud, Ryerson University David Merritt, The Transtec Group, Inc. Joseph Cheung, Federal Highway Administration (FHWA)
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-04012
Paper Title	**Safety Evaluation of High Friction Surface Treatments**
Abstract	The intent of the study was to provide high quality crash modification factors (CMFs) and benefit/cost (B/C) ratios for high friction surface treatments (HFSTs) and in so doing to recommend where and under what conditions to use them to effectively reduce roadway crashes. The state-of-the-art empirical Bayes before-after methodology was applied to evaluate the effects of HFST treatments on various crash types – total, injury, wet road, run-off-road, and head-on plus opposite direction sideswipe (for curves only) using data obtained from West Virginia (curve sites), Pennsylvania (curve sites), Kentucky (curve and ramp sites), and Arkansas (ramp sites). The results for curve sites indicate substantial and highly significant safety benefits (low CMFs) for each State and the 3 States combined. This is especially so for the primary crash types targeted by HFST programs: run-off-road, wet road, and head-on plus opposite direction side-swipe crashes. The results for ramp sites for the two States were inconsistent, except for wet weather crashes for which the benefits are quite large and highly significant). The benefits for all crashes and injury crashes are substantial for Kentucky while there are negligible effects for these crashes in Arkansas. A disaggregate analysis of the curve sites suggested that there appears to be a logical and consistent relationship between CMFs and three variables: friction improvement, traffic volume, and expected crash frequency before treatment. These variables were used in developing recommended crash modification functions.

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Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-04169
Paper Title	**Safety Performance of Autonomous Vehicles on an Urban Arterial in Proximity of a Driveway**
Abstract	Urban traffic network has been growing as an integral part of cities. Urban arterials, as the backbone of the urban traffic network, are characterized by closely spaces driveways and carry a high traffic volume per day. The literature consistently reported that there is a positive relationship between driveway density and crash rate. Therefore, managing driveways, which usually work as three-legged unsignalized intersections, located along urban arterials is crucial, especially under high traffic demand, to improve both safety and operation. However, due to the cost and space limitation, conventional methods are impractical and, therefore, new solutions should be implemented. Autonomous Vehicles (AVs), as a multidisciplinary technology, have been the focus as a replacement for human-driven vehicles to improve both traffic safety and operation. In this study, the effect of AVs on the safety of an urban arterial in the proximity of an unsignalized intersection was evaluated. A microsimulation model was used to develop an urban network with an unsignalized access point under various traffic congestion levels for both conventional vehicles and AVs. Afterward, the frequency and distribution of the conflicts for conventional vehicles and AVs were compared. The results indicated that AVs can enhance safety significantly compared to the conventional vehicles in proximity of an access point, especially under congested traffic situations. However, providing an exclusive lane on the arterial for the driveway vehicles to merge to the arterial promotes safety and operation of the network.

Authors	Chennan Xue, Auburn University Huaguo Zhou, Auburn University Dan Xu, Auburn Universi
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-04521
Paper Title	**Field Implementation of Directional Rumble Strips to Deter Wrong-Way Driving on Freeways**
Abstract	This paper presents the field implementation results of directional rumle strips (DRS), a low-cost traffic control device (TCD), designed to deter wrong-way driving (WWD) on freeways. Southbound off-ramps at Exits 208 and 284 on I-65 in Alabama were selected for implementation because they were ranked as high-risk locations by a network screening tool. Three patterns (D3, C, and E.1) were recommended for field implementation according to the previous test results. Pattern D3 was installed at the off-ramp terminal near the stop bar or yield line. Pattern C was implemented at the segment between the terminal and ramp curve. Pattern E.1 was placed on the tangent part before the ramp curve. WWD incidents and distances before-and-after the implementation were collected using cameras. Field driving tests were conducted to collect sound and vibration data at various speed categories for both right-way (RW) and WW directions. Before-and-after studies evaluated the effectiveness of DRS patterns in deterring WWD incidents. Sound and vibration analysis quantified the differences between RW and WW drivers' perceptions. Results showed that the number of WWD incidents and average driving distances significantly reduced after implementing all the DRS. The results also confirmed that WW drivers can perceive elevated sound and vibrations when passing the DRS. A general guideline was developed for implementing three different DRSs on freeway off-ramps to deter WWD.

Authors	Sarvani Duvvuri, University of North Carolina at Charlotte Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-04902
Paper Title	**Factors Influencing the Likelihood of Occurrence of a Wrong-Way Driving Crash and Injury Severity**
Abstract	Head-on and sideswipe collisions are the possible consequences of a driver traveling in the direction opposite to the mainline flow. Higher fatality rates associated with the wrong-way driving (WWD) crashes calls for an investigation of these crashes along with identification of their corresponding contributing factors. Crash data for the years 2012-15 for the State of North Carolina was gathered. The crashes resulting due to driving in the opposite direction were identified for the analysis and modeling. This research is two-fold. The former examines and identifies risk factors contributing to the occurrence of WWD crashes while the latter identifies the factors associated with various levels of injury severity. Binary logistic regression model and partial proportionality odds model were developed to examine and identify the crash risk factors, significant at a 95% confidence interval. The results indicate that driver-related characteristics, crash location characteristics, weather condition, driver impairment (DUI), time of the day, day of the week and the pavement characteristics are significantly associated with the likelihood of the occurrence of a WWD crash. Similarly, driver characteristics, weather condition, variables corresponding to the crash location, and temporal factors were found to have a significant effect on the injury severity of the crash. This research assists by identifying the characteristics of areas/locations prone to wrong-way entries. The results from the models help the agencies proactively plan and reduce the occurrence of WWD crashes and associated injury severity.

Authors	Scott Himes, VHB Vikash Gayah, Pennsylvania State University Jeffrey Gooch, VHB Stephen Read, Virginia Department of Transportation
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-01426
Paper Title	**Estimating Baseline Numbers for Safety Measure Target Setting in Virginia**
Abstract	The Federal Highway Administration established the Safety Performance Management program (Safety PM) to support the Highway Safety Improvement Program. The Safety PM Final Rule requires State Departments of Transportation (DOTs) to establish and report safety targets annually. The FHWA does not identify a specific methodology to use when establishing safety targets. Many State DOTs apply annual growth/decline factors to previous year safety measures. However, State DOTs also have flexibility to use a data-driven process. The Virginia Department of Transportation (VDOT) recently pursued the development of a more robust data-driven safety target setting methodology. This paper presents a methodology for establishing safety target baselines for several measures, including: 1) fatalities; 2) serious injuries; and, 3) non-motorized fatalities and serious injuries. Predictive models were developed for establishing a baseline for 2019 targets and were further refined for 2020 targets. The predictive models include macro-level inputs and were developed for monthly, VDOT district-level outcomes. Performance measure data from 2018 were withheld from models for validation purposes and 2018 through 2020 model inputs were forecasted based on recent data. As 2019 data become available, the models should incorporate newer data and new models should be developed for revised 2020 and beyond predictions, as necessary. Refined models should include additional data elements as predictors, include more years of data to increase sample size, and capture moments when unobserved annual factors (i.e., unobserved underlying macro-level trends) begin to change.

Authors	Mingjian Wu, University of Alberta Karim El-Basyouny, University of Alberta Tae J. Kwon, University of Alberta
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-03212
Paper Title	**Before-and-After Empirical Bayes Evaluation of Citywide Installation of Driver Feedback Signs**
Abstract	Speeding is a leading factor that contributes to approximately one-third of all fatal collisions. Over the past decades, various passive/active countermeasures have been adopted to improve drivers' compliance to posted speed limits in order to improve traffic safety. The Driver Feedback Sign (DFS) is considered a low-cost innovative intervention that is being widely used, in growing numbers, in urban cities to provide positive guidance for motorists. Despite their documented effectiveness in reducing speeds, limited literature exists on its impact on reducing collisions. This study addresses this gap by designing a before-and-after study using the Empirical Bayes method for a large sample of urban road segments. Safety performance functions and yearly calibration factors are developed to quantify the sole effectiveness of DFS using large-scale spatial data and a set of reference road segments within the city of Edmonton, Alberta, Canada. Likewise, the study followed a detailed economic analysis based on three collision costing criteria to investigate if DFS was indeed a cost-effective intervention. The results showed significant collision reductions that ranged from 32.5% to 44.9%, with the highest reductions observed for severe speed-related collisions. The results further attested that the benefit-cost ratios, combining severe and Property-Damage-Only collisions, ranged from 8.2 to 20.2 indicating that the DFS can be an extremely economical countermeasure. The findings from this study can provide transportation agencies in need of implementing cost-efficient countermeasures with a tool they need to design a long-term strategic deployment plan to ensure the safety of travelling public.

Authors	David Ederer, Georgia Institute of Technology (Georgia Tech) Michael Rodgers, Georgia Institute of Technology (Georgia Tech) Michael Hunter, Georgia Institute of Technology (Georgia Tech) Kari Watkins, Georgia Institute of Technology (Georgia Tech)
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-04778
Paper Title	**Probe-speed Based Safety Performance Metrics in Georgia: A Case Study**
Abstract	Speed is a primary risk factor for road crashes and injuries. Previous research has attempted to ascertain the relationship between individual vehicle speeds, aggregated speeds, and crash frequency on roadways. Although there is a large body of research linking vehicle speeds to safety outcomes, there is not a widely applied performance metric for safety based on regularly reported speeds. With the increasingly widespread availability of probe vehicle speed data, there is an opportunity to develop network level safety performance metrics. This analysis examines the relationship between percentile speeds and crashes on a large arterial in Metropolitan Atlanta. This study uses data from the National Performance Metric Research Database, the Georgia Electronic Accident Reporting System, and the Highway Performance Monitoring System. Negative binomial regression models were used to analyze the relationship between speed percentiles, and speed differences to crash frequency on roadway sections. Results suggest that differences in speed percentiles, a measure of speed dispersion, are related to the frequency of crashes. Based on the models, the difference in the 85th percentile and median speed is proposed as a performance metric. This difference is easily measured using NPMRDS probe vehicle speeds, and provides a practical performance metric for assessing safety on roadways.

Authors	Guangchuan Yang, Institute for Transportation Research and Education (ITRE) Mohamed Ahmed, Federal Highway Administration (FHWA) Eric Adomah, University of Wyoming
Sponsoring Committees	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-05214
Paper Title	**Analysis, Modeling, and Simulation Framework for Safety Performance Assessment of the Wyoming Connected Vehicle Pilot Deployment Program**
Abstract	The 402-mile of Interstate 80 in Wyoming was selected by the U.S. Department of Transportation to develop, test, and deploy a suite of Connected Vehicle (CV) applications (WYDOT CV Pilot). It is expected that after full deployment of the technology, the pilot will improve safety and mobility under adverse weather conditions by creating new ways to communicate road and travel information to both drivers and fleet managers. In this regard, this research developed an Analysis, Modeling, and Simulation framework to assess the safety performance of the WYDOT CV Pilot. A 23-mile representative I-80 corridor was selected for developing the microsimulation models. Traffic flow and driving behavior data under winter snowy weather condition were collected to calibrate the baseline microsimulation model. A driving simulator experiment was conducted to quantitatively investigate the impacts of CV technology on driving behavior; accordingly, the driving behavior data under CV environment were employed to properly update the calibrated CV microsimulation models. The safety effectiveness of the WYDOT CV Pilot were assessed for various demand levels and CV penetration rates. It was concluded that WYDOT CV applications increased drivers' situational awareness under adverse weather conditions, and thus, have the potential to reduce crash risks. The reductions in conflicts displayed a decreasing trend with the increase of CV penetration rates, although the reduction was not significant when CV penetration was lower than 10 percent. The maximum reduction in conflicts was 85 percent, when all trucks were equipped with CV technology.

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 **fourteen papers** related to network screening. The majority of the papers dealt with network screening in the context of pedestrian and bicycle crashes. 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. Both groups of studies are included in this review.

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

- Negative binomial regression models with different functional forms including logarithmic and customized functional forms (Kweon and Lim; paper 20-03261; Tao; paper 20-05628).
- Geographically and temporally weighted regression models compared with traditional poisson and NB regression models (Mohammadnazar et al.; paper 20-02544).
- Macro level models to predict crashes at the district level (Himes et al; paper 20-01426).
- Use of simulation to compare different network screening methods in the absence of volume and SPFs (Lu et al.; paper 20-02761).
- Multinomial logit and ordinal logistic models to identify hotspots (Acquaah et al.; paper 20-02263).
- Spatial methods including nearest neighbor index, Moran's I, local indicators of spatial analysis (LISA), and Getis-Ord G-statistic (Apardian and Alam; paper 20-05107).
- Kernal density estimation technique and understanding the spatio-temporal trend of collisions (Saha et al.; paper 20-05847).
- Three negative binomial model forms (with fixed parameters, with observed heterogeneity, and with both observed and unobserved heterogeneities) were examined (Guo et al.; paper 20-00388).
- Bayesian Poisson lognormal models (Lee et al.; paper 20-03549)
- Ordered probit model with random parameters (Lavrenz et al.; paper 20-05700).

- Historical crash data along with the analysis of conflicts (i.e., post-encroachment time), and risk perception (Mukherjee and Mitra; paper 20-05873).

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

- Multilane rural highway systems in Tennessee (Mohammadnazar et al.; paper 20-02544).
- District level for Fatalities, serious injuries, and non-motorized fatalities and serious injuries in Virginia (Himes et al; paper 20-01426).
- Stop and signalized intersections in Dallas, Texas, to identify hot spots for pedestrian crashes (Geedipally et al.; 20-04899).
- Hot spots for pedestrian fatality locations in Ohio across three different spatial scales: county, census tract, and traffic analysis zone (Apardian and Alam; paper 20-05107).
- Identify hot spots for crashes involving pedestrians, public transit, and unconventional modes, in Dhaka, Bangladesh (Saha et al.; 20-05847).
- Identification of pedestrian crash hot zone provides practitioners with prioritized neighborhoods (Guo et al.; 20-00388).
- Safety in numbers in a Metropolitan Statistical Area (MSA) (Lee et al.; 20-03549).
- Pedestrian and bicycle crashes in the trunk highway intersections of the Twin Cities metro area to identify problematic intersections (Tao; paper 20-05628).
- Pedestrian safety in two counties in Michigan (Lavrenz et al.; 20-05700).
- Pedestrian safety at urban intersections in Kolkata, India (Mukherjee and Mitra; 20-05873).

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

Authors	Young-Jun Kweon, National Highway Traffic Safety Administration (NHTSA) In-Kyu Lim, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-03261
Paper Title:	Development of Network Screening Safety Performance Functions for Roadway Departure Safety in Virginia
Abstract:	Roadway departure (RD) crash is recognized as one of eight emphasis areas in Virginia's 2017-2021 Strategic Highway Safety Plan, and the Virginia Department of Transportation (VDOT) has been using annual counts of RD crashes to identify locations for RD safety improvement. However, identifying locations based on crash counts is subject to bias and inaccuracy. The safety performance functions (SPFs) developed and deployed by VDOT for statewide network screening might be used for RD safety, but this could lead to undesirable outcomes in that those SPFs are intended for all crash types and RD safety issues are believed to be different from other crash types. This study was to develop RD SPFs that should be implemented for statewide network screening in Virginia using existing resources. A total of 93 RD SPFs were successfully developed with three functional forms: (1) SPFs with AADT in the logarithmic form, (2) SPFs with AADT in a customized functional form, and (3) SPFs with AADT and other predictors in customized functional forms. The study found that the RD SPFs vary in their functional forms across site types. The logarithmic form of AADT, regarded as a standard for an SPF, is deemed suitable in general for a typical range of AADT. However, that form could be severely deviated from the

underlying relationship. Therefore, a proper functional form of AADT for an RD SPF should be determined for each site type and by severity level separately whenever possible.

Authors	Amin Mohammadnazar, University of Tennessee, Knoxville Numan Ahmad, University of Tennessee Iman Mahdinia, University of Tennessee, Knoxville Asad Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-02544
Paper Title:	Application of Geographically and Temporally Weighted Regression Models for Estimating Safety Performance Functions of Multilane Rural Highways in Tennessee
Abstract:	Although the Highway Safety Manual (HSM) provides default SPFs, they recommend that states develop jurisdiction-specific SPFs using local crash data. Accordingly, crash and road inventory data were integrated for multi-lane rural highway segments in Tennessee covering 2013-2017. Besides developing SPFs similar to those contained in HSM, this study applied a new methodology that can capture variation in crashes both in space and over time. Specifically, Geographically and Temporally Weighted Regression (GTWR) models for localization of SPFs were developed. The new aspect is incorporating temporal aspects of crashes in the models as the impact of a specific variable on crash frequency may vary over time due to several reasons. Results indicate that negative binomial models have a better fit with the crash data than Poisson models and that GTWR models remarkably outperform the traditional regression models by capturing spatio-temporal heterogeneity. Moreover, a majority of parameter estimates vary substantially across space and over time. In other words, the association of contributing variables with the number of crashes can vary from one region and period of time to another. This fact weakens the idea of transferring default SPFs to other states and even applying a single localized SPF for all regions of a state. Enabled by growing computational power, the results emphasize the importance of accounting for spatial and temporal heterogeneity and developing highly localized SPFs. The methodology of this study can be used by researchers to follow the temporal trend and location of critical factors and identify sites for safety improvements.

Authors	Scott Himes, VHB Vikash Gayah, Pennsylvania State University Jeffrey Gooch, VHB Stephen Read, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-01426
Paper Title:	Estimating Baseline Numbers for Safety Measure Target Setting in Virginia
Abstract:	The Federal Highway Administration established the Safety Performance Management program (Safety PM) to support the Highway Safety Improvement Program. The Safety PM Final Rule requires State Departments of Transportation (DOTs) to establish and report safety targets annually. The FHWA does not identify a specific methodology to use when establishing safety targets. Many State DOTs apply annual growth/decline factors to previous year safety measures. However, State DOTs also have flexibility to use a data-driven process. The Virginia Department of Transportation (VDOT) recently pursued the development of a more robust data-driven safety target setting methodology. This paper presents a methodology for establishing safety target baselines for several measures, including: 1) fatalities; 2) serious injuries; and, 3) non-motorized fatalities and serious injuries. Predictive models were developed for establishing a baseline for 2019 targets and were further refined for 2020 targets. The predictive models include macro-level inputs and were developed for monthly, VDOT district-level outcomes. Performance measure data from 2018 were withheld from models for validation purposes and 2018 through 2020 model inputs were forecasted based on recent data. As 2019 data become available, the models should incorporate newer data and new models should be developed for revised 2020 and beyond predictions, as necessary. Refined models should include additional data elements as predictors, include more years of data to increase sample size, and capture moments when unobserved annual factors (i.e., unobserved underlying macro-level trends) begin to change.

Authors	Jiajian Lu, University of California, Berkeley Aditya Medury, University of California, Berkeley Offer Grembek, University of California, Berkeley
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-02761
Paper Title:	Comparison of Pattern Recognition-Based Hotspot Identification Methods Based on Simulation
Abstract:	This research aims to compare different pattern recognition methodologies for prioritizing hotspots in the absence of volume information and accompanying safety performance functions. In particular, we analyze tests for pattern identification proposed in the traffic safety literature that use binomial and beta-binomial distributions respectively. Using simulated data, we compare the performance of these methods in evaluating both underlying patterns as well as the overall safety performance. We simulate spot crashes and crash types using a Poisson-Gamma and Dirichlet-Multinomial distributions respectively. We also controlled for the overdispersion parameter in the Dirichlet Multinomial distribution to simulate low, medium and high overdispersion scenarios. Two types of ground truth in the simulation study are defined: a true p-value for identifying true crash patterns and a True Poisson Mean (TPM) for ranking sites. The result shows that 75-percentile proportion is a good threshold proportion for Beta-Binomial test and that this test achieves higher precision and recall than Binomial test in medium and high overdispersion cases. Both tests have similar correlation with TPM. The correlation between TPM and Empirical Bayes (EB)-adjusted crash frequency using Method of Moments is also calculated as a baseline. Two pattern recognition-based methods perform slightly worse than EB adjustment.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-02263
Paper Title:	Development of Multinomial and Ordinal Logistic Models for Bicyclist and Pedestrian Crashes across Divisions 13 and 14 of North Carolina
Abstract:	Pedestrians and bicyclists can be put in the category of vulnerable road users due to lack of traffic protection. The State of North Carolina Division of Highways 13 and 14 recorded 61.6% and 58.6% of pedestrian crashes respectively because of an absence of traffic controls between 2007 to 2016. In this study, exploratory analysis for pedestrian and bicyclist crashes in highway divisions 13 and 14 is performed to understand the trends in the environment variables of these crashes. Eleven locations in highway division 13 were identified to be hotspots for pedestrian and bicyclist crashes. Six locations in highway division 14 were also identified as hotspots for pedestrian and bicyclist crashes within the study period. Multinomial logit and ordinal logistic models were used to examine the contribution of several environmental key factors to the injury severity of bicyclists crashes. The multinomial logit model results identified motorist left turn – opposite direction crash type, intersections, weekdays, traffic control, clear weather and dry road condition as more likely to result to injuries relative to fatal and disabling injury crashes. The developed ordinal logistic regression model results revealed that bicyclists age group 30-39 who are involved in motorist left turn – opposite direction crashes where there are no control present on weekdays on dry roads are more likely to suffer fatal and disabling injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-04899
Paper Title:	Identifying High Risk Locations to Address Pedestrian Safety Issues
Abstract:	Many states have identified pedestrian safety as one of the emphasis areas in their Strategic Highway Safety Plans. Identifying the high-risk locations is typically the necessary first task that states consider for implementation of countermeasures. Given the rarity and randomness of pedestrian crashes, advanced tools such as Safety Performance Functions (SPFs) are needed in the hot-spot detection process. The Highway Safety Manual (HSM) includes SPFs for pedestrian crashes for four-legged and three-legged signalized intersections in the urban and suburban areas but they need to be calibrated for local conditions. The HSM does not include SPFs for the stop-controlled intersections. The objective of this study is to develop the safety performance functions (SPFs) for pedestrian crashes for both signalized and stop-controlled intersections. To accomplish the study objectives, data at all intersections in Dallas, Texas were collected. The variables that were found to be significant in influencing the pedestrian crashes at intersections are total intersection vehicular volume, ratio of minor to major street volume, pedestrian crossing volume, number of bus stops and the land use. The Empirical Bayes method that considers both the observed and the predicted crashes was used for estimating the expected crashes. A safety risk index was estimated as a ratio of expected crashes to predicted crashes. A risk index value of greater than 1.0 indicates the intersection is with high crash risk. In total, 18 signalized and 24 stop-controlled intersections on state highways in Dallas were identified as high-risk locations for pedestrian safety.

Authors	Rebekka Apardian, University of Toledo Bhuiyan Alam, University of Toledo
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05107
Paper Title:	Pedestrian Fatal Crash Location Analysis in Ohio Using ESDA Techniques
Abstract:	Pedestrian safety is a top priority within the transportation planning community as cities promote sustainable transportation, alternative travel modes, and healthy lifestyles. If people feel unsafe while walking, they will choose other modes of transportation if they are able. In order to prioritize safety, it is important to know where pedestrian crashes are occurring and in what severity. Using spatial statistical methods including nearest neighbor index, Moran's I, local indicators of spatial analysis (LISA), and Getis-Ord G-statistic, this study seeks to analyze the pedestrian fatality locations within the state of Ohio over a ten-year period (2007-2016) to identify hot spots, cold spots, and spatial patterns across three different spatial scales: county, census tract, and traffic analysis zone. It seeks to understand the effects of aggregated data across these spatial scales on the outcome of the analysis and determine the most useful spatial scale at which to study pedestrian fatalities. The study concludes that spatial analyses at small scales are most informative. It goes on to recommend locations within Ohio for further analysis based on the resulting maps, including areas with outliers. As of this writing, there is no current statewide pedestrian fatality analysis for the state of Ohio.

Authors	Bijoy Saha, The University of British Columbia Mahmudur Fatmi, University of British Columbia, Okanagan Md. Mizanur Rahman, Bangladesh University of Engineering and Technology
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05847
Paper Title:	Spatio-Temporal Analysis of Collision Frequency and Injury Severity Involving Unconventional Modes, Pedestrians, and Transit in Dhaka, Bangladesh
Abstract:	Road safety is a global concern; particularly, in developing countries due to the significantly high collision occurrences and subsequent deaths. The major reason for the road safety challenges is the limited understanding of the factors that are unique in the context of developing countries, such as the predominant use of unconventional modes. This study presents a spatial and temporal analysis of collision frequency and injury severity of crashes in Dhaka, Bangladesh. The focus is to understand the spatio-temporal trend of collisions involving pedestrians, public transit, and unconventional modes, which are the key collision factors in Dhaka. This research utilizes the police-reported collision record for Dhaka for the years 2011-2015. The temporal analysis suggests that fatalities and major injuries increased by >7% and >31% respectively in the 5-years. Public transit collisions increased from 43.9% to 60.9%. Fatalities among pedestrians and unconventional mode users are 76.6% and 29.8% respectively. The daily distribution suggests that a higher share of severe injuries involving pedestrians (16.6%) and unconventional modes (20.5%) occur on the Fridays and Thursdays respectively. The hourly distribution suggests that pedestrians are more vulnerable from 11:00 am - 12:00 pm on weekends. Unconventional mode users are vulnerable from 7:00 am-8:00 am on weekdays. Spatial analysis is performed adopting a Kernel density estimation technique. The results suggest that the major activity locations of Dhaka such as CBD, airport, business districts, and ferry terminals are collision prone areas. Interestingly, the density of public transit collisions is skewed around the major transit hubs of the city.

Authors	Rui Guo, University of Florida Zhiqiang Wu, University of South Florida Yu Zhang, University of South Florida Pei-Sung Lin, University of South Florida Zhenyu Wang, USF Center for Urban Transportation Research
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-00388
Paper Title:	Pedestrian Crashes, Demographics, and Land Uses: Insights from Integrated Geo-Location Data
Abstract:	This study investigates the effects of demographics and land uses on pedestrian crash frequency by integrating the contextual geo-location data. To address the issue of heterogeneity, three negative binomial models (with fixed parameters, with observed heterogeneity, and with both observed and unobserved heterogeneities) were examined. The best fit with the data was obtained by explicitly incorporating the observed and unobserved heterogeneity into the model. It highlights the need to accommodate both observed heterogeneity across neighborhood characteristics and unobserved heterogeneity in pedestrian crash frequency modeling. The marginal effect results imply that some land use types (e.g., discount department stores and fast-food restaurants) could be candidate locations for the education campaigns to improve pedestrian safety. The observed heterogeneity of the area indicator suggests that priority shall be given to more populated low-income areas for pedestrian safety, but attention is also needed for the higher-income areas with larger densities of bus stops and hotels. Moreover, three normally-distributed random parameters (proportion of older adults, proportion of lower-speed roads, and density of convenience stores in the area) were identified as having random effects on the probability of pedestrian crash occurrences. Finally, the identification of pedestrian crash hot zone provides practitioners with prioritized neighborhoods (e.g., a list of areas) for developing effective pedestrian safety countermeasures.

Authors	Robert Schneider, University of Wisconsin, Milwaukee Rebecca Sanders, Arizona State University Frank Proulx, Toole Design
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-02402
Paper Title:	United States Fatal Pedestrian Crash Hot Spot Locations and Characteristics
Abstract:	US pedestrian fatalities are at their highest level in nearly three decades and account for an increasing share of total traffic fatalities (16%). Pedestrian safety must be improved to create a future transportation system that produces zero deaths. In this study, we screen the entire US roadway network to identify fatal pedestrian crash "hot spot" corridors: 1,000m-long sections of roadway where six or more fatal pedestrian crashes occurred during an eight-year period. We identified 34 hot spot corridors during 2001-2008 and 31 during 2009-2016. While only five corridors were hot spots during both analysis periods, the 60 unique hot spots have remarkably consistent characteristics. Nearly all (97%) are multilane roadways, with 70% requiring pedestrians to cross five or more lanes. More than three-quarters have speed limits of 30 mph or higher, and 62% have traffic volumes exceeding 25,000 vehicles per day. Nearly all had adjacent commercial land uses, and three-quarters were bordered by neighborhoods with lower-income households. Corridors with these characteristics have the potential to produce high numbers of pedestrian fatalities. These results support a systemic approach to improve pedestrian safety: agencies should identify other roadway corridors with similar characteristics throughout the US and take actions to reduce the risk of future pedestrian fatalities.

Authors	Jaeyoung Lee, Central South University Mohamed Abdel-Aty, University of Central Florida Qing Cai, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03549
Paper Title:	Investigation of Safety-in-numbers for Pedestrians and Bicyclists at a Macroscopic Level with Various Exposure Variables
Abstract:	Safety-in-numbers effect is a phenomenon that crash risks of road users decrease when their numbers increase. Although a number of previous studies have confirmed the safety-in-numbers effect at microscopic scales, few study investigated the safety-in-numbers effect at a macroscopic level (e.g., census tracts). In this study, the safety-in-numbers phenomenon is investigated at a greatly larger scale unit, metropolitan statistical area (MSA), which are usually composed of multiple counties. Various pedestrian and bicyclist exposure data were obtained from the National Household Travel Survey, i.e., trips, miles, and hours. The preliminary results show that the number of fatal crashes involving pedestrians and bicyclists are significantly larger where walking and bicycle activities are higher. A series of Bayesian Poisson lognormal models confirm the safety-in-effects with the different exposure variables at a large-scaled geographic level (i.e., MSA). The findings imply that regions' travel behavior and cultures to respect vulnerable road users play a key role in the level of pedestrian and bicyclist safety. In addition, the results reveal other important factors to vulnerable road user involved crashes, including but not limited to climate, demographic, socio-economic, and travel characteristics of the study regions.

Authors	Tao Tao, University of Minnesota
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05628
Paper Title:	Exploring the Pedestrian and Bicycle Crash Risk in Highway Intersections: Systemic Approach Applied in the Twin Cities Metro Area
Abstract:	Pedestrians and bicyclists become more vulnerable to the increasing crash risk resulted from the growing auto-dependent development. The pedestrian and bicycle crashes in the highway intersections happened less frequently than those in local streets but could be more severe due to the faster speed of the vehicles, and thus, need more attention. Using the systemic approach, we explored the pedestrian and bicycle crashes in the trunk highway intersections of the Twin Cities metro area. We constructed new crash estimation models with the Negative Binomial Model and searched the high-risk intersections based on the combination of model prediction results and historical crash data. Based on the results, we identified the influential risk factors including vehicular AADT, population density, and traffic facility related and built environment variables. Those risk factors could help to find countermeasures to improve the safety of the highway intersections. The result of the identified high-risk intersections could support the planners or policymakers to prioritize the pedestrian and bicycle facilities planning or improvement projects.

Authors	Steven Lavrenz, Wayne State University Kerrick Hood, OHM Advisors Stephen Remias, Wayne State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05700
Paper Title:	Towards Vision Zero for Cyclists: New Insights & Methods for Assessing Bicycle Crash Severity
Abstract:	Cycling represents an increasingly common mode of travel in the United States, as well as an increasing share of fatal and serious injury crashes; transportation professionals are still working to understand how different types of riding behavior and roadway infrastructure can impact the number and severity of bicycle crashes, particularly in lower-density, suburban-type areas. A lack of consistent and comprehensive data to characterize cyclist behavior and crash contributing factors is part of this challenge; additionally, many crash severity models are constrained when it comes to interpreting specific influencing factors – these models often interpret such factors to either universally increase or decrease crash severity, with no ability to account for different levels of effect for a single variable. This study furthers the understanding of factors influencing bicycle crash severity, by examining five years of crash data, coded using FHWA's Pedestrian and Bicycle Crash Analysis Tool (PBCAT), from two counties in the State of Michigan. We apply an ordered probit model with random parameters to better account for the range of potential impacts, both positive and negative, that individual variables may have. Our model confirms existing research findings, such as the elevated risk of severe crashes outside of intersection areas, while also illustrating [through the random parameters specification] several cases where variables have a range of positive and negative effects on crash severity.

Authors	Dipanjan Mukherjee, Indian Institute of Technology Kharagpur Sudeshna Mitra, The World Bank
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05873
Paper Title:	Pedestrian Safety Analysis of Urban Intersections in Kolkata, India Using a Combined Proactive and Reactive Approach
Abstract:	Assessment of pedestrian safety is often conducted in a reactive way by analyzing pedestrian crash data. However, in a developing country, the availability of reliable crash data is a major challenge. Therefore, without relying solely on reactive approach, it is essential to combine some methods that can proactively assess pedestrian safety. In this background, the present study proposed a methodology combining both reactive and proactive approach to assess pedestrian safety at urban intersections in Kolkata, India. The method developed in the present study utilizes a combination of the historical crash data analysis, the analysis of pedestrian-vehicular conflict (i.e., pedestrian-vehicular post-encroachment time), along with pedestrians' risk perception towards the built environment and traffic parameters, to identify potential risk-prone intersections in Kolkata. Based on the combined reactive and proactive assessments, there is evidence that the high traffic volume, pedestrian-vehicular interaction captured through pedestrian and vehicle volume ratio, the absence of police personnel, high approaching speed, the presence of commercial area, inadequate sight distance, the presence of slum population, and a high population density near the intersection significantly increase the risk of pedestrian crashes. Finally, using this combined proactive-reactive approach, the present study also identifies and ranks 25 high risk-prone intersections for pedestrians. This is a significant step towards scientific decision making and allowing use of information beyond historical crash records.

4 Safety Performance Functions

Mohamed Abdel-Aty, Qing Cai and Jaeyoung Lee, University of Central Florida (UCF)

Safety performance functions (SPFs) are used to model crash frequencies as a function of the contributing factors, or to investigate effect of (or changing) a factor on crash frequency. The subcommittee identified **eighty-four papers**, which are classified based on the use of SPFs, type of roadway facilities, scope, methodology, and so on.

SPF transferability and local calibration are among the popular topics this year. Paper 20-01993 provides an equation to estimate the required sample size for the calibration purpose. Paper 20-04083 assessed the transferability of Highway Safety Manual (HSM) SPFs for urban and suburban arterials in Wyoming. In paper 20-03261 network-screening SPFs for Virginia were developed. Paper 20-02676 used TrAdaBoost.R2 algorithm, which is an instance-based transfer learning technique, to improve the transferability of the SPF models. Some papers (e.g., 20-00351 and 20-00467) evaluated the use of SPFs in crash prediction. Paper 20-04159 developed SPFs to evaluate the safety effects of using the all-electronic toll collection system.

Overall seven papers studied the safety performance at the macroscopic level (20-01110, 20-01355, 20-02317, 20-02893, 20-05284, 20-03276, and 20-05020). Other papers studied the safety performance at the mesoscopic level (20-02889) or network level (20-00235 and 20-01034).

Also, there are several common topics among the SPF papers. Several papers investigated the weather effect in the SPFs development (20-01221 and 20-02847), and found that the weather plays an important role in safety performance. Furthermore, many papers developed SPFs for different road elements such as arterials (20-01448 and 20-04363), expressways (20-01281 and 20-03662), freeways (20-00618 and 20-03909), rural highways (20-00041, 20-04893, 20-05079, 20-01448, 20-02544, 20-03205 and 20-00955), intersections and interchanges (20-00144, 20-00496, 20-00467, 20-02595, 20-03303, 20-04134, 20-05366, 20-05464 and 20-03859). In addition, two papers analyzed the safety effectiveness of alternative intersections such as median U-turn intersections (20-01603), restricted crossing U-turn intersections (20-01603), and displaced left-turn intersections (20-03379). Some papers developed SPFs considering the impact of connected and automated vehicles (CAVs) (20-00285 and 20-01070). Paper 20-00285 estimated the number of crashes which could be reduced by CAVs in six countries. Paper 20-01070 developed a system dynamic approach to quantify the long-term effects of automated vehicles.

Furthermore, several papers developed SPFs considering non traditional explanatory variables (i.e., wealth level, active traffic management, drivers' errors, and demographic factors) (20-

00268, 20-01893, 20-04054 and 20-04801). Other papers analyzed unconventional crash types (i.e., culvert related, wrong way driving, and e-bike related) (20-03980, 20-05220 and 20-05153). Considerable number of papers developed SPFs for non-motorized users (20-02263, 20-03424, 20-05172, 20-05619, 20-05847, 20-00388, 20-01934, 20-03549, and 20-05628).

Lastly, it is noteworthy to mention that many papers applied alternative methodologies for developing SPFs (20-00144, 20-02544, 20-03782, 20-04597, 20-05512, 20-05645). Paper 20-02544 developed geographically and temporally weighted regression models to estimate SPFs for multilane rural highways. Paper 20-03782 used the Poisson-Tweedie Distribution to develop a SPF. Paper 20-04597 included the demographic proportions for developing SPFs by using the Quasi-Induced-Exposure method. The same metod was applied in paper 20-00144 to investigate the contributing factors of the drivers' risk at interchanges. Paper 20-04840 used level of service as disaggregated data in lieu of AADT for developing SPFs for freeways. Paper 20-05512 used a linear Poisson autoregressive model to accommodate the dynamic characteristics for fatal crashes. Paper 20-05645 used a latent segmentation-based ordered logit model to address the ordinal nature of injury severity.

Below, for each of the eighty-four 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 their ID number.

Authors	Vikash Gayah, Pennsylvania State University Eric Donnell, Pennsylvania State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-00041
Paper Title	Estimating Safety Performance Functions for Two-Lane Rural Roads Using an Alternative Functional Form for Traffic Volume
Abstract	Statistical models of expected crash frequency are referred to as Safety Performance Functions (SPFs) in the first edition of the American Association of State Highway and Transportation Officials' Highway Safety Manual (HSM). The SPFs in the HSM specify expected annual crash frequencies as a function of various roadway and roadside features, with the most important predictor variable being traffic volume, which serves as a measure of vehicle exposure to crashes. Traffic volumes are typically measured using the average annual daily traffic and are incorporated into the SPFs using a natural logarithm transformation. This specification suggests that the relationship between expected crash frequency and traffic volume increases non-linearly with a constant elasticity over the range of observed values. While researchers concur that the relationship between expected crash frequencies and traffic volume is non-linear, further exploration of the functional form of this relationship may offer additional insights concerning the association between safety performance and vehicle exposure. This paper proposes an alternative functional form for the traffic volume variable in SPFs that allows for different elasticities between traffic volume and expected crash frequency within different traffic volume ranges, while preserving the same general non-linear relationship in existing HSM SPFs. The proposed functional form was applied to SPFs developed for two-lane rural roadways in Pennsylvania. Comparison with SPFs developed using the traditional functional form in the HSM suggests that this proposed functional form offers an improved fit and predictive performance, and thus might be considered for the development of future SPFs.

Authors	Xin Gu, Southeast University Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, Central South University Qiaojun Xiang, Southeast University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-00144
Paper Title	Investigation of Contributing Factors to Drivers' Risk of Crash Involvement at Interchanges Using Quasi-Induced Exposure and Logistic Regression Approach
Abstract	Interchanges on freeway and expressways have been considered more dangerous than other basic segments because of drivers' decision-making to stay or exit, weaving, variations in speeds, etc. In this study, we aim at contributing to the literature by using a quasi-induced exposure method and logistic regression modeling approach to identify contributing factors associated with the risk of causing an interchange crash. To this end, the 2014 traffic crash data, roadway and drivers' characteristics were collected from Florida. Subsequently, a logistic regression model was developed to examine the statistical effects of different factors on the at-fault involvement of drivers in crashes at interchanges. The modeling results indicate that drivers' age, gender, distraction, alcohol, and other factors have statistically significant effects. In addition, the finding suggests that drivers are more likely to cause crashes at cloverleaf and direct connection interchanges than at diamond interchanges. It is expected that the findings from this study would be helpful for establishing effective strategies to reduce traffic crashes at interchanges by targeted education, engineering, and enforcement.

Authors	Zili Li, University of Queensland Kara Kockelman, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)

Paper Number	20-00235
Paper Title	Modeling Animal-Vehicle Collision Counts Across Large Networks Using a Hierarchical Model with Dirichlet Process
Abstract	Animal-vehicle collisions (AVCs) are common around the world and result in considerable loss of animal and human life, as well as significant property damage and regular insurance claims. Understanding their occurrence in relation to various contributing factors and being able to identify locations of high risk are valuable to AVC prevention, yielding economic, social and environmental cost savings. However, many challenges exist in the study of AVC datasets. These include seasonality of animal activity, very low counts across most sections of extensive roadway networks, and computational burdens that come with discrete response analysis using large datasets. In this study, a hierarchical model with Dirichlet process is developed in order to overcome these challenges. By using the AVC data across over 100,000 segments of state-controlled highways of Texas, U.S., it is demonstrated that the model can tackles large datasets, with a preponderance of zeros and clear monthly seasonality in counts, while identifying high-risk locations (for application of design treatments, like separated animal crossings with fencing) and key explanatory factors like what & what?. . Furthermore, scenario evaluations based on segment-specific factors (such as changes in speed limit) can be done within the modelling framework, which provide useful information for policy making purposes.

Authors	Rebeka Yocum, Pennsylvania State University Vikash Gayah, Pennsylvania State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1259
Session Title	Taxis, Wealth, Speed, and Active Commuters: Informing Safety with Diverse Data Sources Monday 1:30 PM- 3:15 PM
Paper Number	20-00268
Paper Title	Determining the Effect of Wealth on Crash Frequency in Pennsylvania
Abstract	Current crash prediction models utilize roadway and traffic data as independent variables to describe crash frequency. Recent work has moved away from the traditional explanatory variables, instead introducing alcohol and gasoline prices and providing a fresh perspective on crash prediction. This paper aims introduce wealth into the crash modeling conversation by determining the effect of measure of wealth on crash frequency in Pennsylvania. 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. After estimating a negative binomial model representing total crashes and fatal and injury crashes in Pennsylvania counties, two interesting results are observed. First, the population of unemployed individuals is positively related to the observed crash frequency in that county. This relationship is observed when considering total crashes as well as fatal and injury crashes. Second, the population of people living in poverty is positively related to fatal and injury crash frequency in that county. The marginal effect of the population of people living in poverty on fatal and injury crashes is relatively small compared to that of the unemployment population. Regardless, the relationship between the wealth of a community and the crashes experienced by that community exists, and 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	Hao Zhong, Tongji University Ling Wang, Tongji University Mohamed Abdel-Aty, University of Central Florida Wanjing Ma, Tongji University Juneyoung Park, Department of Transportation and Regional Services
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-00285
Paper Title	Safety Benefit Analysis Of Connected and Automated Vehicle Technologies Based on Meta-analysis
Abstract	The connected and automated vehicle (CAV) technologies have made great progresses. It has been commonly accepted that CAV technologies would reduce human errors in driving and benefit traffic safety. However, the answer of how many crashes can be prevented because of CAV technologies has not reached a consistent conclusion. In order to quantitatively answer this question, this study used meta-

analysis to evaluate the safety effectiveness of eight common and important CV or AV technologies, and tested the safety effectiveness of these technologies for six countries. First, 73 studies about the safety impact of these technologies were filtered out from 826 CAV-related papers or reports. Second, in the meta-analysis, the random effect model was used to evaluate the safety effectiveness, and the funnel plots and trim-and-fill method were used to evaluate and adjust publication bias, so as to objectively evaluate the safety effectiveness of each technology. Then, according to the crash data of six countries, the comprehensive safety effectiveness and compilation of safety effectiveness of the above technologies were calculated. The results show that if these technologies were implemented in the six countries, the average number of crashes could be reduced by 2.79 million, among which the USA would reduce the most (40.53%). Additionally, different countries should develop different development strategies, e.g., USA should prioritize the development of the emergency action technologies. Overall, this study provides comprehensive and quantitative understating of the safety effectiveness and would contribute to government, vehicle companies, and agencies in deciding the development priority of CAV technologies.

Authors	Susan Paulus, Lakeside Engineers, LLC
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-00333
Paper Title	2017 Fatal Rollover Crashes in the United States
Abstract	Although rollover crashes account for 2.1 percent of all crashes in the United States, they result in nearly 35 percent of all fatalities (National Highway Traffic Safety Administration, n.d.). Rollover crashes can be categorized as tripped or untripped. Tripping occurs when a vehicle leaves the roadway and the tires dig into soft soil or the vehicle strikes an object. The high tripping force can cause a vehicle to rollover. Tripped rollover crashes occur in 95 percent of rollover crashes (National Highway Traffic Safety Administration, n.d.). This study analyzed fatal rollover crash data from the Fatality Analysis Reporting System (FARS) to determine trends and potential rollover crash causes. This research looked at environmental factors (weather, pavement condition, and lighting), roadway factors (facility type, number of lanes, and speed limit), crash factors (most harmful event, first event, and first action), and vehicle factors (model year, make, type) to examine fatal rollover crash trends. The data analysis implied fatal rollover crashes are likely on a decline since newer vehicles are less likely to be involved in fatal rollover crashes. Since model year 2009 there have been fewer fatal crashes involving vehicles rolling over. Over time the U.S. may age-out of fatal rollover crashes.

Authors	Jake Kononov, DiExSys, LLC James Williams, DiExSys Catherine Durso, DU
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1721
Session Title	Highway Safety Performance Research
Paper Number	20-00351
Paper Title	Diagnostics Revisited
Abstract	Diagnostic methods in the context of the Highway Safety Manual (HSM) aim to identify some abnormality or pattern in crash occurrence which may provide an important clue to an effective remedy. These methods are used to assess the nature of the safety problem and on its basis select a countermeasure for which there is a known crash modification factor. Two approaches are presently used to perform diagnostic examination: Test of Proportions and crash type-specific Safety Performance Functions (SPF). Test of Proportions uses empirical proportions (diagnostic norms) of crash types and crash attributes within congestion strata, total number of crashes, and the number of observed crashes of a specific type to compute cumulative probability of observed outcome. Crash type-specific SPFs are used to identify sites where observed frequency or severity of specific crash types is higher than expected. This paper examines the strengths of both methods by applying them to the same datasets and comparing results. The findings suggest that Test of Proportions works well in identifying locations with a single disproportionally frequent crash type. Crash type-specific SPFs can identify locations having multiple crash types with elevated frequency but will not identify locations having crash patterns susceptible to correction but not having

elevated counts. Findings also suggest that the degree of stratification in diagnostic norms influences the number of overlapping sites detected by both methods.

Authors	Rui Guo, University of Florida Zhiqiang Wu, University of South Florida Yu Zhang, University of South Florida Pei-Sung Lin, University of South Florida Zhenyu Wang, USF Center for Urban Transportation Research
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-00388
Paper Title	Pedestrian Crashes, Demographics, and Land Uses: Insights from Integrated Geo-Location Data
Abstract	This study investigates the effects of demographics and land uses on pedestrian crash frequency by integrating the contextual geo-location data. To address the issue of heterogeneity, three negative binomial models (with fixed parameters, with observed heterogeneity, and with both observed and unobserved heterogeneities) were examined. The best fit with the data was obtained by explicitly incorporating the observed and unobserved heterogeneity into the model. It highlights the need to accommodate both observed heterogeneity across neighborhood characteristics and unobserved heterogeneity in pedestrian crash frequency modeling. The marginal effect results imply that some land use types (e.g., discount department stores and fast-food restaurants) could be candidate locations for the education campaigns to improve pedestrian safety. The observed heterogeneity of the area indicator suggests that priority shall be given to more populated low-income areas for pedestrian safety, but attention is also needed for the higher-income areas with larger densities of bus stops and hotels. Moreover, three normally-distributed random parameters (proportion of older adults, proportion of lower-speed roads, and density of convenience stores in the area) were identified as having random effects on the probability of pedestrian crash occurrences. Finally, the identification of pedestrian crash hot zone provides practitioners with prioritized neighborhoods (e.g., a list of areas) for developing effective pedestrian safety countermeasures.

Authors	Jia Yang, Toyota Transportation Research Institute Peng Ren, China Academy of Transportation Sciences Ryosuke Ando, Toyota Transportation Research Institute
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-00392
Paper Title	Examining Drivers` Injury Severity of Two-Vehicle Crashes between Passenger Cars and Light Motor Trucks
Abstract	This study aims to investigate the important factors affecting the drivers` injury severity of two-vehicle crashes between passenger cars (PCRs) and light motor trucks (LMTRs). To consider the difference in crash pattern between elder drivers and non-elder drivers, 889 vehicle crash data for elder LMTR drivers and 4,690 vehicle crash data for non-elder LMTR drivers in Fukuoka Prefecture, Japan is used as the research sample. The injury severity of PCRs with LMTRs for elder drivers and that for non-elder drivers are modeled by two bivariate ordered probit models, respectively. Each ordered probit model in a bivariate ordered probit model is used to measure the injury severity of one driver, and the covariance measures the correlation of injury severity. The major findings suggest: 1) that weather condition, traffic condition, manner of collision have different effects for injury severity of LMTR drivers in two types of crashes; 2) that time of day and road level do not have any effects for injury severity of LMTR drivers in two types of crashes; 3) that the injury severity of two drivers involved in two types of crashes are negatively correlated, since two crash patterns i.e. no injury with minor injury and minor injury with no injury accounted for large ratios inside two types of crashes, which indicated that there is only one driver injured in most crashes of PCRs with LMTRs.

Authors	Kai Wang, University of Connecticut Tanmoy Bhowmik, University of Central Florida Shanshan Zhao, University of Connecticut Naveen Eluru, University of Central Florida Eric Jackson, University of Connecticut
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-00467
Paper Title	Assessment of Statistical Methodologies for Crash Prediction by Severity
Abstract	Predicting crash counts by severity plays a dominant role in identifying roadway sites that experience overrepresented crashes, or an increase in the potential for crashes with higher severity levels. The results of this process allow for the implementation of effective countermeasures to improve highway safety. This paper uses urban & suburban intersection data in Connecticut, along with two commonly used modeling approaches, to accommodate for the unobserved factors in predicting crash counts by severity level. Specifically, a Multivariate Poisson-Lognormal (MVPLN) model is used to estimate the crash counts by different severity levels simultaneously. A Joint Negative Binomial - Generalized Ordered Probit Fractional Split (NB-GOPFS) model is used to jointly estimate total crash counts and crash proportions by severity level. Furthermore, crash prediction models based on vehicle damage level are estimated using the two methodologies. These models can be used to supplement the injury severity in estimating crashes by severity when the sample mean of severe injury crashes is very low. The model estimation results highlight the presence of correlations of crash counts among severity levels, as well as the crash counts in total and crash proportions by different severity levels. A comparison of results indicates that injury severity and vehicle damage are highly consistent. This finding suggests that when crash data samples have challenges associated with the low observed sampling rates for severe injury crashes, vehicle damage can be appropriate as an alternative to injury severity in crash prediction by severity.

Authors	Khaled Hamad, University of Sharjah Abdulkarim Ismail, Freelancer
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-00496
Paper Title	Safety Evaluation of Directional Interchange with Semi-Direct Ramp Connections and Loops
Abstract	The purpose of this paper is to evaluate the safety of the Directional Interchange with Semi-Direct Ramp Connection with Loops (DI-SDRL). Towards this end, the FHWA's Interchange Safety Analysis Tool-Enhanced (ISATe) was utilized to predict the safety performance of this interchange under 30 different scenarios covering a wide range of traffic volumes. The performance of this interchange has been also compared to a conventional one, i.e. Directional with Loops Interchange (DLI) in terms of the percentage difference and using the paired t-Test. The results showed that DI-SDRL ramp segments witnessed higher number of crashes than the DLI by the average of 36% and 37% for fatality-injury (FI) and property-damage-only (PDO) crashes, respectively. The statistical t-test results showed that the differences between the two interchanges were statistically significant, except for the freeway segments. On the other hand, the differences reported by crash type were not as large as ramp segments. For example, the DI-SDRL reported higher number of multiple-vehicle crashes than the DLI by the average of 4% and 2% for FI and PDO severity levels, respectively. As for the total SV crashes, the DI-SDRL reported higher number of crashes that the DLI by average of 2% for both FI and PDO severity levels. Nevertheless, the statistical t-test indicated that the difference between the studied interchanges is statistically significant.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-00618
Paper Title	Investigation of Associations between Multiple Freeway Roadway Characteristics and Freight Safety Performance
Abstract	Since various freeway design features are simultaneously installed on roadways, it is important to assess their combined safety effects correctly. This study investigated associations between multiple roadway cross-section design features on freeways and traffic safety. In order to consider the interaction impact of multiple design features and nonlinearity of predictors concurrently, multivariate adaptive regression splines (MARS) models were developed for all types and freight vehicle crashes. In MARS models, a series of basis functions is applied to represent the space of predictors and the combined safety effectiveness of multiple design features can be interpreted by the interaction terms. The generalized linear regression models (GLMs) with negative binomial (NB) distribution were also evaluated for comparison purposes. The results determine that the MARS models show better model fitness than the NB models due to its strength to reflect the nonlinearity of crash predictors and interaction impacts among variables under different ranges. Various interaction impacts among parameters under different ranges based on knot values were found from the MARS models whereas two interaction terms were found in the NB models. The results also showed that the combined safety effects of multiple treatments from the NB models over-estimated the real combined safety effects when using the simple multiplication approach suggested by the HSM (Highway Safety Manual). Therefore, it can be recommended that the MARS is applied to evaluate the safety impacts of multiple treatments to consider both the interaction impacts among treatments and nonlinearity issue simultaneously.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-00951
Paper Title	Analysis and Modelling of Ramp Related Crashes in Tennessee
Abstract	The study analyzed ramp related crashes in Tennessee. The paper identified explanatory variables that were significant predictors of crash frequency and injury severity Using NB and MNL. The analysis showed that factors which tend to significantly increase ramp related crash frequency includes: rural and commercial land use areas, crashes that occur during morning, ramps with posted speed limits between 35 mph to 45 mph, and high traffic (AADT) locations. The study found that most of the ramp-related crashes (77.7%) are Property damage only compared to evident injury, incapacitating injuries or fatal. Crashes due to a vehicle hitting the guardrails are highly likely to result in PDO, the odds of sustaining evident injuries is 14% less likely compared to PDO/Base injury. With each crash due to an overturned vehicle, the odds of evident and fatal injuries will increase by 93% and 265% respectively. The study also indicates that crashes occurring during day time and on weekdays are less likely to result in fatal crashes and the odds of the severity being fatal/incapacitating injury will decrease by 30.2% for each crash occurring during the day and 17% in weekday. Rear end and angle collision compared to sideswipe collision will increase the odds of evident injury by 21.6% and 24.3% respectively. Also, rural and commercial land uses, high speed limits, AADT and DHV have shown to significantly increase crash frequency while low speed limit, residential land use and fewer number of lanes have shown to decrease crash frequency.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-00955
Paper Title	Rural Intersection-Related Crashes and Injury Severities in Tennessee
Abstract	This study focuses on intersections in a rural context within the State of Tennessee for a 5-year period (2011-2015). The importance of this paper lies in the fact that rural intersections and roads are seldom considered in transportation safety strategies as compared to urban roads and intersections. For a state such as Tennessee which is mostly rural, the study is highly essential. 5-year crash data were obtained from Tennessee Department of Transportations' (TDOT) database. A negative binomial (NB) model was used to determine the relationship between crash frequency and the investigated independent variables. Injury severity was categorized into four different levels and Multinomial Logit (MNL) model was used for the analysis. IBM SPSS Statistics software and MS Excel were utilized, and the resulting models were assessed. It was found that high AADT, absence of illumination, fringe & commercial, the high number of lanes and arterial roads were associated with an increase in crash frequency. But collector roads, low speeds, residential land uses, and presence of illumination were associated with low crash frequency. At rural intersections, the total number of vehicles involved, absence of intersection lighting, manner of collision such as head-on collisions showed higher severity. While rear-end crashes, harsh weather conditions, adequate lighting and crash due to collision with ditch showed lesser injury severity (PDO). Based on these findings, a recommendation can be proposed to lessen injury severity by installing adequate lighting for all the rural intersections in Tennessee and moderating speed limits to reduce crash frequency.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-01034
Paper Title	Integrated Regional Transportation Model (RTM)-Network-based Collision Prediction Model (NCPM) Framework
Abstract	Road safety is rarely considered in the transportation planning process. Instead, each effort is typically conducted individually. For decades, transportation planners have used Regional Transportation Models (RTMs) to analyse and evaluate future transportation policies, road and transit network expansion and design options, and land use scenarios. Examples of an RTM's outputs include future trips by transportation mode, transit ridership, and traffic patterns, volume, speed and congestion indices on road segments. Road safety is conventionally evaluated separately via statistical models that use estimated collision numbers based on historical collision data as dependent variables and that explore a variety of independent explanatory variables. Some explanatory variables are exposure variables that can be extracted from RTM models for base and future horizons, but most current Network-based Collision Prediction Models (NCPMs) are standalone models that do not interact with RTMs. The primary objective of this study is to advance transportation planning and road safety research by developing a NCPM that can be integrated with an RTM as a fifth step of the traditional four-step RTM modeling concept. The integrated RTM-NCPM framework provides estimates on both traffic demand and the number of collisions for base and future planning horizons. The City of Calgary's RTM model is used as a case study to test various scenarios and to examine the safety implications of changes in transportation policies related to fuel price, parking fees, transit fare, and transit frequency. The results of the scenario analysis clearly show the expected reduction in collision frequency at mid-blocks and intersections upon implementation of policies designed to shift travellers' mode choices from auto to transit. These collision-reduction policies include both incentives to encourage transit use and disincentives to discourage auto use. This study thus demonstrates how the integrated RTM-NCPM framework can help transportation planners and policy makers to incorporate a safety impact assessment as part of transportation planning process.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-01070
Paper Title	A System Dynamics Approach for Assessing the Impacts of Autonomous Vehicles on Collision Frequency
Abstract	Autonomous vehicle (AV) technology is expected to transform transportation systems, including traffic safety. This study develops a system dynamics (SD) approach to quantifying the long-term effects of AVs on collision frequency. First, the major variables that affect collision occurrence are used to develop an SD model that represents the existing transportation system where no AVs are present. We then extend the SD model to reflect the future introduction of AVs and to assess their impacts on road collisions. The SD models developed in this paper predict the expected number of property damage only (PDO) and fatal-injury (FI) collisions with different levels of market penetration rates by AVs. The developed model is used to examine the effectiveness of AVs in reducing the frequency of PDO and FI collisions based on the implementations of two different policies: incentives for using shared AVs and higher occupancy rates of shared AVs. The results suggest that traffic safety will significantly improve with a higher AV penetration rate, a higher passenger occupancy of shared AVs, and improved sensing and communication technologies. Applying the model shows its strong potential for providing a better understanding of the complex interactions between AVs and other variables that affect the occurrences of collisions. The model can be used to assess the efficacy of policies meant to guide the introduction of these emerging technologies to help to reduce accidents and save lives.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-01110
Paper Title	Multi-Scale Approaches to Cope with Scale Effect Issues in Macroscopic Safety Analysis
Abstract	Many macroscopic traffic safety analyses have been conducted with different geographic units. Since traffic crashes exhibit extreme spatial heterogeneity at different scales, the analyses using different spatial units are subjected to the modifiable areal unit problem (MAUP). Especially, a high-level of spatial aggregation of data could bring about the loss of detailed spatial information, also known as the scale effect. It might result in biased parameter estimates and incorrect inferences in macroscopic crash prediction models. In this study, we propose Bayesian multi-scale models that are capable of accounting for the scale effect due to the high-level spatial aggregation of crash data. The performances of proposed models were assessed, as compared to the conventional (independent) model, using the crash data of two geographical scales, i.e. block groups (lower level) and census tracts (higher level) in Hillsborough County of Florida. The results indicate that the proposed multi-scale models could address the scale effects and enhance the model performance at the highly aggregated spatial units such as census tracts.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-01221
Paper Title	The Joint Effect of Weather and Lighting Conditions on Injury Severities of Single-Vehicle Accidents
Abstract	This study seeks to identify and analyze variations in the effect of contributing factors on injury severities of single-vehicle accidents across various lighting and weather conditions. To that end, injury-severity data from single-vehicle, injury accidents occurred in Scotland, United Kingdom in 2016 and 2017 are statistically modeled. Upon the conduct of a likelihood ratio test, separate models of accident injury severities are estimated for various combinations of weather and lighting conditions taking also into account the presence and operation of roadside lighting infrastructure. To account for the possibility of unobserved regimes underpinning the injury-severity mechanism, the zero-inflated hierarchical ordered probit approach with correlated disturbances is employed. The approach also relaxes the fixed threshold restriction of the traditional ordered probability models and captures systematic unobserved variations between the underlying regimes. The model estimation results showed that a wide range of accident, vehicle, driver, trip and location characteristics have varying impact on injury severities when different weather and lighting conditions are jointly considered. Even though several factors are identified to have overall consistent effects on injury severities, the simultaneous impact of unfavorable weather and lighting conditions is found to introduce significant variations, especially in the effect of vehicle- and driver-specific characteristics. The findings of this study can be leveraged in vehicle-to-infrastructure or in-vehicle communication technologies that can assist drivers in their responses against hazardous environmental conditions.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-01281
Paper Title	Accuracy Assessment of Using Application Programming Interface in the Development of Safety Performance Function on Indian Expressway
Abstract	Data accessibility and quality form a critical element in the development of multivariate safety performance function. Over the past few years, access to new large-scale data resources through various map Application Programming Interfaces (APIs) have grown. However, limited understanding is available on the accuracy of the archived data present with these mapping platforms. Thus, the primary focus of the present study is to examine the scope of using the information available at mapping services in developing SPF. An Indian expressway is chosen to illustrate the methodology. The automatic bulk acquisition of link-based operating speed and road geometry is demonstrated using Google APIs and Google Earth. API derived link-based average travel speed, horizontal and vertical geometry is compared with actual data available for the study section. Encouraging accuracies indicate the scope of utilizing the expanding databases of the online map APIs in safety applications. Advantages and limitations of using the online-based information are further explored.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-01355
Paper Title	Hierarchical Analysis of Traffic Violations and Crashes: A Macroscopic Safety Analysis
Abstract	Traffic safety has been one of the most important topics in the transportation field. Most previous safety studies have focused on analyzing traffic crash data. Crash data has been analyzed to determine the level of traffic safety along with possible candidate contributory factors. Another way to examine the safety level is to analyze traffic violations. Traffic violation and crash data of five years (2013-2017) were collected from Montgomery County, Maryland. The numbers of non-crash violations and crashes during the five years are 954,428 and 22,563, respectively. (Approximately 42:1 ratio). Using traffic, commuter, roadway, industry, socio-economic, and demographic data collected from multiple sources, three different modeling frameworks are applied to explore violations and crashes. Each framework has two components: Bayesian Poisson lognormal models for violations and crashes. The first scenario has a hierarchical structure by using the expected number of violations from the first component as the exposure variable of the crash model. The second scenario's crash model uses the observed number of violations as the exposure. The third scenario's crash model uses the daily miles-traveled as the exposure. The first modeling scenario shows the best performance, in terms of deviance information criterion (DIC), it is followed by the second scenario, and the third scenario performs the worst. Subsequently, hot zone identification analysis was conducted, and revealed the areas with particular problems with respect to violations and crashes. It is expected that the proposed hierarchical approach will be a useful tool to investigate traffic safety with diverse perspectives.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-01409
Paper Title	A Before-After Evaluation of Left-turn Lane Extension: Considering Injury Severity and Collision Type
Abstract	Left-turn lanes are commonly used to provide space to accommodate vehicle deceleration and provide adequate storage of turning vehicles. The objective of this study is to evaluate the safety effectiveness of extending the length of left-turn lanes at signalized intersection approaches. Five years of collision data including injury severity and collision type from 3 treatment sites and 31 comparison sites in the City of Surrey, Canada were used in the study. A Full Bayesian (FB) before-after analysis was conducted for all collisions, severity levels, and collision types. Multivariate Poisson–lognormal linear intervention (PLNI) models were used. The treatment effectiveness index were calculated to quantitatively measure the effectiveness of the safety treatment. The FB before-after results showed that the treatment-related collisions were reduced by 57.4% following the implementation of extended left-turn lane. The reduction in injuries and fatalities (I+F) collisions (63.8%) was greater than that in property damage only (PDO) collisions (55.7%). The decrease in rear-end collisions (62.8%) was greater than that in sideswipe collisions (58.11%). The findings indicate a remarkable improvement in safety after the length extension of the left-turn lane.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-01448
Paper Title	Safety Performance Functions for Rural Arterial Roads in Egypt
Abstract	This paper presents the development of safety performance functions (SPFs) for total, fatal, injury, and damage only crashes for five rural arterial roads in Egypt using crash data between 2008 and 2011. Four segmentation methods were used for the SPFs development: (1) fixed section length of one kilometer (S1); (2) homogenous sections (S2); (3) variable sections with respect to presence of curvatures (S3); and (4) variable sections with respect to the presence of both curvatures and U-turns (S4). The generalized linear modeling (GLM) technique was used for SPFs development using stepwise procedure, with/without considering time-effect (year-to-year variation). The Akaike information criterion (AIC) along with the cumulative residual (CURE) plots were used to evaluate the prediction accuracy of the proposed models. The segmentation method was found to affect the prediction accuracy of the model. For all crash types, the developed SPFs using the segmentation method S1 and S3, with multiple variable crash model form, were found to produce the most accurate predictions compared to other SPFs using other segmentation methods. In addition, each road has its own crash pattern, as the results show that the coefficients for the roads are statistically significant for all the developed models. The results also showed that by increasing shoulder, lane, and median widths, the probability of crashes is likely to decrease. Finally, the presences of either horizontal curves and/or U-turns are most likely to reduce the probability of crash occurrence.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1721
Session Title	Highway Safety Performance Research
Paper Number	20-01603
Paper Title	Safety Evaluation of Median U-Turn Crossover-Based Intersections
Abstract	Alternative innovative designs for intersections were defined to enhance traffic operation and safety. Median U-Turn (MUT) and Restricted Crossing U-Turn (RCUT) intersections are among the types of alternative intersections that enable drivers to make left-turn movements at median U-turn crossovers downstream of the main intersection. Recently, municipalities and transport agencies tend to implement these types of intersections. However, their effectiveness in crash reduction has not been adequately determined in the previous studies. This is due to the limited number of alternative intersections which were considered in these studies. In addition, there was no consideration for the unusual new geometric design of these intersections. In this study, a safety evaluation was conducted while considering the new intersection-related areas at MUT and RCUT intersections to clarify and quantify their effectiveness in crash reduction. This study considered 82 MUT and 13 RCUT intersections from six states. Two types of MUT intersections along with partial MUT intersections were considered in this study. Crash Modification Factors (CMF) for MUT and RCUT intersections were estimated by using before-after and cross-sectional methods. The results indicated that MUT and RCUT intersections are safer than conventional intersections. MUT intersections are effective in reducing total, PDO, rear-end, and sideswipe crashes, although they significantly increase single-vehicle and non-motorized crashes. RCUT intersections are effective in reducing injury, fatal-and-injury, head-on, and angle crashes. Findings of this research provide clear evaluation for decision makers about the effectiveness of MUT and RCUT intersections in crash reduction.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-01893
Paper Title	Injury Severity Effects of an Active Traffic Management System Using Bayesian Modeling
Abstract	Active traffic management (ATM) systems have been used by transportation agencies to dynamically manage recurrent and non-current congestion based on real-time conditions. While these systems have been shown to have some safety benefits, their impact on injury severity outcomes is currently uncertain. This paper used full Bayesian mixed logit models to quantify the impact of an ATM deployment on injury severity outcomes. The estimation results revealed that ATM deployment was associated with reductions in injury severity levels. Marginal effects showed that ATM that featured hard shoulder running (HSR) reduced the propensity of severe plus moderate injury crashes by 15.9% and the propensity of minor injury crashes by 10.1%. ATM without HSR produced reductions in the propensity of severe plus moderate and minor injury crashes by 12.4% and 8.33%, respectively. The model performed well on validation data with a low forecast error of 0.301 and 0.304 for the two models.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-01934
Paper Title	How and What Factors Influence the Injury Severity in Single-Bicycle Crashes
Abstract	Even though cyclist crashes are primarily single-bicycle crashes, the majority of research in the field of bicyclist's injury severity relates to bicycle-motor vehicle crashes. This study explores the use of a latent class ordered probit framework to model the injury severity of cyclists subject to single-bicycle crashes. This method allows us to address heterogeneity arising from unobserved groups in the crash population. Hereby this study provides novel insight on the factors contributing to the injury severity of cyclists, subject to single-bicycle crashes. The study uses single-bicycle crash data obtained through medical records data merged with road data collected by the municipality Aarhus in the period between 2010-2015. The data provides 3 severity classes: severe, slight, 'no evident injury' The presented model proves statistically superior to a regular ordered probit. The estimation procedure arrives at 4 latent classes to best describe the data. Which reveal older women to be associated with the highest baseline likelihood of severe injuries and young women the lowest. The unconditional results reveal several factors to more than double the likelihood of severe injury, with all other variables kept constant. These results highlight factors surrounding the bicycle lane and the maintenance thereof. Specifically; bad or adequate maintenance of bicycle lane, lack of bicycle lane, crazing or fretting and the road being to blame, but also darkness and winter conditions. Notably the results also imply that the bicyclist's behaviour being at fault for the accident greatly increases the likelihood of severe injury.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-01993
Paper Title	Highway Safety Manual Calibration: Variance of the Calibration Factor and the Sample Size
Abstract	Crash frequency has been identified by many experts as one of the most important safety measures, and the Highway Safety Manual (HSM) encompasses the most commonly accepted predictive models to predict the crash frequency for specific road segments and intersections. The HSM recommends that the models should be calibrated using data from a jurisdiction where the models will be applied. One of the most common start-up issues with the calibration process is how to estimate the required sample size to achieve a specific level of precision, which can be a function of the variance of the calibration factor. The published research has indicated great variance in sample size requirements, and some of the sample size requirements are so large that they may deter state departments of transportation from conducting calibration studies. In this study, an equation is derived to estimate the sample size based on the coefficient of variation of the calibration factor and the coefficient of variation of the observed crashes. This equation is verified using a regression analysis on a dataset from two recent calibration studies, South Carolina and North Carolina. Whereas, the minimum sample size requirement published in the HSM is based on the summation of the observed crashes, this paper demonstrates that the summation of the observed crashes may result in calibration factors that are less likely to be equally precise and the coefficient of the variation of the observed crashes can be considered instead.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-02070
Paper Title	Influencing factors for Right Turn Lane Crash Frequency from Multi-source Datasets
Abstract	Right-turn lane (RTL) crashes are one of the most contributors to intersection crashes in the US. This study investigates the traffic safety performance of the RTL based on the multi-source datasets, including official crash reports, official database, and field study. To understand the influencing factors for the RTL crashes, we introduce a random effect negative binomial model to specify the spatial-correlated effects among crashes and adopt the robustness test to verify the reliability of estimations. The influencing factors are measured from various measurements, for instance, environmental factors, spatial and temporal factors, and RTL geometric factors. Moreover, we propose component effects with both RTL geometrics and intersection characteristics under the econometric modeling framework. The new term can address the selectivity bias and endogeneity issues, which is barely discussed in the literature. Last, we develop a case study with the help of INDOT. A string similarity method is proposed to create a unique RTL identity while merging multi-source datasets. Then, a hierarchical agglomerative clustering approach is applied to find homogeneous counties. The empirical analyses indicate that the random effect negative binomial model outperforms other fixed effect ones. In addition to the environmental, spatial and temporal factors, the result suggests that RTL crash frequency is mainly influenced by turn radius, traffic control, and three component effects: right-turn type and speed limit; channelized type and AADT; acceleration lane and AADT.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-02263
Paper Title	Development of Multinomial and Ordinal Logistic Models for Bicyclist and Pedestrian Crashes across Divisions 13 and 14 of North Carolina
Abstract	Pedestrians and bicyclists can be put in the category of vulnerable road users due to lack of traffic protection. The State of North Carolina Division of Highways 13 and 14 recorded 61.6% and 58.6% of pedestrian crashes respectively because of an absence of traffic controls between 2007 to 2016. In this study, exploratory analysis for pedestrian and bicyclist crashes in highway divisions 13 and 14 is performed to understand the trends in the environment variables of these crashes. Eleven locations in highway division 13 were identified to be hotspots for pedestrian and bicyclist crashes. Six locations in highway division 14 were also identified as hotspots for pedestrian and bicyclist crashes within the study period. Multinomial logit and ordinal logistic models were used to examine the contribution of several environmental key factors to the injury severity of bicyclists crashes. The multinomial logit model results identified motorist left turn – opposite direction crash type, intersections, weekdays, traffic control, clear weather and dry road condition as more likely to result to injuries relative to fatal and disabling injury crashes. The developed ordinal logistic regression model results revealed that bicyclists age group 30-39 who are involved in motorist left turn – opposite direction crashes where there are no control present on weekdays on dry roads are more likely to suffer fatal and disabling injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-02317
Paper Title	Multilevel Analysis of Road Accident Frequency: The Impact of the Road Category
Abstract	When dealing with road safety issues, every single road with different characteristics needs to be investigated separately. This study tries to build up a general model for predicting accident frequency at the micro- and macro-level. The study assumes that the number of accidents may vary according to the roadway category and the characteristics of their small segments. Every individual road segment has distinguished geometrical and traffic features. In contrast, every group of road segments within a single roadway can share similar characteristics that may differ from other road categories. To solve the nested relationship between individual road segments and different road categories a multilevel model has been developed. The multilevel analysis presents an opportunity to study the hierarchical nature of road accident properties on the micro- and macro-level, attempting to understand the risk of individual road segments within different roadway categories. To do so, fifty-seven roadways have been selected from the Hungarian's map included five main categories (according to the Hungarian specifications): motorway, expressway, primary arterial, secondary main road, and local road. Furthermore, every roadway has been divided into a number of flexible length segments, distinguished in their traffic and geometrical characteristics. The result verifies that accident frequency per road segment is more likely to vary across the different roads with different categories. Moreover, road categories with low design standards, even with lower speed limits and traffic volumes, are riskier than well-designed roadways.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-02457
Paper Title	Harnessing Big Data Generated by Connected Vehicles to Monitor Safety Performance: Application of Geographically Weighted Negative Binomial Regression
Abstract	Emergence of high-resolution big data generated by connected and automated vehicles provides promising opportunity to monitor and evaluate the performance of the transportation system. This study develops a conceptual framework to harness big data generated by connected vehicles to monitor the safety performance of the system by incorporating human behavior to identify high risk locations. The main advantage of this method is proactively monitoring the system safety performance compared to traditional methods that reactively identify high risk locations. The Safety Pilot Model Deployment data collected in Ann Arbor, MI, is utilized. More than 2.2 billion Basic Safety Messages transmitted between more than 2800 connected vehicles are processed, analyzed and linked with crash data. This study captures the temporal dimension of driving volatility by quantifying variations in instantaneous driving decisions. Several volatility measures are applied to vehicular speed, longitudinal, and lateral accelerations of vehicles, and their correlations with crash frequency are explored. To address unobserved heterogeneity in safety performance and spatial correlations, Geographically Weighted Poisson and Negative Binomial models are estimated. Results reveal that driving volatility is positively and significantly correlated with crash frequency, and these associations vary substantially across space. Variations in longitudinal and lateral vehicle movements are associated with higher crash frequencies. In order to identify hotspot locations where driving volatility is high while crash frequency is low, k-means clustering is performed. Given the hotspot locations, further research is needed to identify reasons that drivers exhibit volatile behavior and explore countermeasures to reduce driving volatility to decrease crash risk.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-02482
Paper Title	Single-Vehicle Truck Accidents: An Analysis of Injury Severity in The Context of Developing Countries
Abstract	Freight movement plays a vital role in economic development, especially for developing countries. However, an increment in truck movements in Iran due to the economic growth has increased roadway safety issues. Although there have been sizable efforts to investigate the severity of truck-involved accidents, the influential factors on the severity of single-vehicle truck accidents are not clearly understood. This study aims to uncover significant factors associated with injury severities sustained by truck drivers in single-vehicle truck accidents in the context of developing countries. It uses 2011 Iran road accident data from the Iranian Traffic Police. Based on this data, several contributing factors including truck driver characteristics, accident-related variables, truck features, roadway variables, and temporal characteristics are determined, and their influence on the severity of single-vehicle truck accidents are explored. Accounting for the threshold heterogeneity, a hierarchical ordered probit model is utilized to predict the likelihood of three injury severities: property damage only, body injury, and fatal. The likelihood test shows the statistical superiority of the hierarchical ordered probit model as compared to the ordered probit model. Marginal effects are also computed to accurately interpret the effect of significant variables on injury severity outcomes. According to the results, factors such as driver age, accident types, seasons, the presence of different curve types, roadway classification, and speed limit contribute to the severity of the accidents. The findings of this study can be helpful for transportation authorities to mitigate the severity of single-vehicle truck accidents by performing efficient safety countermeasures.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-02544
Paper Title	Application of Geographically and Temporally Weighted Regression Models for Estimating Safety Performance Functions of Multilane Rural Highways in Tennessee
Abstract	Although the Highway Safety Manual (HSM) provides default SPFs, they recommend that states develop jurisdiction-specific SPFs using local crash data. Accordingly, crash and road inventory data were integrated for multi-lane rural highway segments in Tennessee covering 2013-2017. Besides developing SPFs similar to those contained in HSM, this study applied a new methodology that can capture variation in crashes both in space and over time. Specifically, Geographically and Temporally Weighted Regression (GTWR) models for localization of SPFs were developed. The new aspect is incorporating temporal aspects of crashes in the models as the impact of a specific variable on crash frequency may vary over time due to several reasons. Results indicate that negative binomial models have a better fit with the crash data than Poisson models and that GTWR models remarkably outperform the traditional regression models by capturing spatio-temporal heterogeneity. Moreover, a majority of parameter estimates vary substantially across space and over time. In other words, the association of contributing variables with the number of crashes can vary from one region and period of time to another. This fact weakens the idea of transferring default SPFs to other states and even applying a single localized SPF for all regions of a state. Enabled by growing computational power, the results emphasize the importance of accounting for spatial and temporal heterogeneity and developing highly localized SPFs. The methodology of this study can be used by researchers to follow the temporal trend and location of critical factors and identify sites for safety improvements.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-02595
Paper Title	Safety Performance Functions for Rural Two-Way Stop-Controlled Intersections
Abstract	Rural intersection safety continues to be a crucial issue throughout the United States. More than 20 percent of all traffic fatalities in the United States occur at intersections, and over 80 percent of intersection-related fatalities in rural areas occur at unsignalized intersections. The first edition of Highway Safety Manual (HSM) has already published the crash prediction models based on the intersection data from several states. Considering each state has unique situations, this paper introduces a safety model development for two-way stop-controlled intersections on rural two-lane highway. After a lenthy data verification process, totally 2,658 rural stop-controlled intersections including both three-leg (3T) and four-leg (4T) from all Parishes (counties) in Louisiana were used for the model development. A series of safety performance functions were developed with Zero-inflated Poisson (ZIP) models with the most recent five-year crash data. The results indicate thatgreater curve radiuses of major roads, greater curve lengths of major roads, greater lane widths of minor roads, and higher speed limits of major roads led to significantly smaller expected crash frenquencies for both 3ST and 4ST intersections. However, unlike 4ST intersections, exclusive right-turn lanes increase the likelihood of crashes at 3ST intersections. In addition to traffic volume, intersections located in the middle of curves led to significantly greater crash occurrences. The results of Louisiana specific models are different from that of HSM models and the difference varies by AADT. The data sources, sample size, modeling structure, and the direct variable selection could have contributed to the difference as well.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-02652
Paper Title	Examination of Factors Affecting Injury Severity in Crashes Occurring on Interstate Freeways by Vehicle Type: Analysis of the Arizona Megaregion
Abstract	According to the Arizona Department of Transportation (ADOT), the annual number of traffic crash fatalities has generally been increasing in recent years in the state of Arizona. With a continuously growing population and consequently more vehicles on the road, it is imperative to identify and analyze factors that affect injury severity when crashes occur, particularly those occurring on high-speed freeways. To examine this issue, this study utilized Arizona crash data for the years 2010 through 2017 to analyze factors affecting the injury severity of persons involved in crashes on occurring on interstate freeways in the Arizona megaregion. This is accomplished through estimation of random parameters ordered logit models to investigate the effect of several person, vehicle, crash, roadway, traffic, and environmental variables on the injury severity of crash-involved persons. Since crash characteristics may vary significantly depending on types of vehicles involved, separate models were estimated for crashes involving only passenger vehicles, crashes involving freight vehicles (e.g. large trucks), and crashes involving motorcycles. Several variables including crash type, roadway geometry characteristics, and person-related variables, among several others, were found to be significantly associated with injury outcomes, and those variables and their effects varied by vehicle type involvement. The findings presented in this study provide insights which can be used to assist in developing and planning countermeasures aimed at improving freeway transportation safety.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-02676
Paper Title	Improving the Transferability of the Crash Prediction Model Using the TrAdaBoost.R2 Algorithm
Abstract	The crash prediction model is a useful tool for traffic administrators to identify significant risk factors, estimate crash frequency, and screen hazardous locations. Since only limited or low-quality data can be collected for some jurisdictions interested in traffic safety analysis, calibration methods should be applied to an available crash prediction model. The problem with current calibration methods is that the aggregate method limits prediction accuracy and the disaggregate method is resource-consuming. Transfer learning is a technique aimed toward learning knowledge from old data domains to solve problems in new data domains. TrAdaBoost.R2, an instance-based transfer learning technique, is adopted in this paper since it meets the requirement of site-based crash prediction model transfer. A comparison was made to examine TrAdaBoost.R2's efficiency in extracting knowledge from spatially outdated source data domain (old data domain). The target data domain (new data domain) was split into two parts to test the technique's adaptability to a small sample size. Calibration factor based on a negative binomial model was employed to compare predictive performance of the transfer learning technique. Mean square error was calculated to evaluate the prediction accuracy. Two cities in China, Shanghai and Guangzhou, were taken as source data domain and target data domain mutually. Results show that the models constructed with TrAdaBoost.R2 improve the prediction accuracy compared to the negative binomial model. The TrAdaBoost.R2 is further recommended due to its predictive performance and adaptability to a small sample size.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-02756
Paper Title	Assessing the Variation of Curbside Safety at the City Block Level
Abstract	Investigating the dynamics behind the likelihood of vehicle crashes has been a focal research point in the transportation safety field for many years. However, the abundance of data in today's world generates opportunities for deeper comprehension of the various parameters affecting crash frequency. This study incorporates data from many different sources including geocoded police-reported crash data, curbside infrastructure data and socio-demographic data for the city of San Francisco, CA. In order to handle over-dispersion, negative binomial (NB) models were developed, and in order to capture additional unobserved heterogeneity, two-component finite mixture negative mixture models were formulated, one with fixed priors (FMNB) and another with varying priors (GFMNB). Findings reveal that the GFMNB model provides a better statistical fit than the FMNB and NB model in terms of AIC and log likelihood, while the NB model outperformed both mixture models in terms of BIC due to model complexity of the latter. Among the significant variables, TNC pick-ups/drop-offs and duration of parked vehicles were positively associated with segment-level crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-02801
Paper Title	Investigating the Severity of Crashes from NAIS Database in China Using Structural Equation Modeling
Abstract	This study aimed to investigate the characteristics of NAIS crash database and analyse the level of crash severity based on various aspects of crashes. The crash data were collected from NAIS (National Automobile Accident In-Depth Investigation System) set up by China's General Administration of Quality Supervision, Inspection and Quarantine. The descriptive statistics were employed to investigate the severity of crash happened in China in terms of information about the collision, driver, passenger, environment, road, vehicle conditions, traffic conditions and treatment of accident participants. Structural equation modeling (SEM) was then adopted to capture the complex relationship between considered latent variables (human, vehicle, road condition and environment condition) and the severity of crashes. The results suggested that the level of crash severity (endogenous variable) was mutually correlated with the considered variables classified as road factor, human factor, vehicle factor and environment factor (exogenous variable). Road-related and vehicle-related factors had a positive effect on the level of crash severity. By contrast, human factor and environment factor affected the level of crash severity with a negative coefficient. Different observed exogenous variables were also assessed for the level of crash severity. The results of this study have the potential to provide an insight into the severity evaluation of crash from the respect of all traffic accident participants.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02847
Paper Title	Investigate Factors Affecting Driver Injury Severity in Snow-Related Rural Single-Vehicle Crashes
Abstract	Snow weather is consistently considered as a hazardous factor due to its potential leading to severe fatal crashes. A seven-year crash dataset including all the snow-related rural highway single vehicle crashes from 2010 to 2016 in Washington state is applied in the present study. Pseudo elasticity analysis is conducted to investigate significant impact factors and the temporal stability of model specifications is tested via a likelihood ratio test. The proposed model based on the seven-year dataset is able to capture the individual-specific heterogeneity across crash records for four significant factors, i.e., male, not impaired and no insurance for minor injury, and not impaired for serious injury and fatality. Their estimated parameters were found to be normal distribution instead of fixed value over the observations. Other significant impact factors with fixed effects are: traffic object, animal, overturn, out-of-control, snow surface, smoke surface, sleet surface, curve horizontal design, medium and high speed limits, young and old aged, impaired condition, no belt usage, pickup car type, airbag deployment. The results of temporal stability test show that the model specification is generally not temporally stable for driver injury severity model based on the years of crash data that were used, especially for longer period (more than 3-year dataset). Models that allow the explanatory variables to track temporal heterogeneity, are of great interest and can be explored in future research.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02863
Paper Title	The Problem of, and a Possible Solution to, Comparison Site Selection in Scheme Evaluation
Abstract	Before-and-after studies provide by far the most common method for evaluating the treatment effect of a road safety scheme. The most common among these remain Bayesian methods, which are popular among researchers and practitioners due to their ability to account for the Regression To the Mean (RTM) effect, by using a Safety Performance Function (SPF) built from untreated comparison sites. Failing to accurately estimate the RTM effect immediately leads to a biased estimate of the treatment effect, and so ensuring a well-fitting SPF is vital. It is commonly accepted that an important part of this process is ensuring the comparison sites used to build the SPF are sufficiently similar, or exchangeable, with the treated sites being analysed. Whilst this has been accepted by many authors as intuitively true, no work has been done to numerically demonstrate the consequences of using a non-exchangeable comparison pool in a before-and after study. In this paper we use simulated data to objectively demonstrate that using non-exchangeable comparison sites directly leads to an increase in bias of RTM estimates (and hence of the treatment effect). We investigate methods of comparison site selection using categorical subsetting and propensity score matching (PSM) based methods. We finally demonstrate a new method for making most efficient use of a candidate comparison pool by weighting the SPF according to propensity score similarity, known as propensity score weighted regression (PSWR).

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02889
Paper Title	Meso-Level Hotspot Identification for Suburban Arterials
Abstract	Accurate identification of hotspot as well as the relationship between crashes and the influencing factors contribute to safety improvement on suburban arterials. Micro-level hotspot identification studies treat road segments and intersections as isolated units. It is not consistent with field practices because police department usually identify hotspot based on arterial-level, which consists of multiple segments and intersections. Moreover, dense access density deteriorates traffic safety on both segments and intersections, but the overall safety impact may be underestimated by analyzing segments and intersections separately. In addition, either micro-level or macro-level studies cannot capture the specific impact of road network pattern adjacent to the arterials. This study proposed a novel meso-level approach applying Full Bayesian method (FB) and potential for safety improvement (PSI) to identify hotspots for suburban arterials. In order to reduce the effect of spatial correlation, meso-level analysis units were obtained by combining intersections and their adjacent segments according to the spatial distribution of crashes. Bayesian Poisson-lognormal conditional autoregressive model (PLN-CAR) was selected as prediction model due to its strength in accounting for the spatial correlation among analysis units. The PSI value of each unit was calculated and compared with crash frequency. Results show that 1) meso-level hotspot identification can provide a reasonable reference for police department to improve traffic safety; 2) arterials with more parallel roads and less access density were associated with fewer crashes. The meso-level hotspot identification method proposed in this study are expected to be useful in field application of safety improvement on suburban arterials.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02893
Paper Title	Macro-Level Traffic Safety Analysis and Model Updating in Shanghai, China
Abstract	Macro-level traffic crash analyses and modeling are prevalent in many countries in order to incorporate traffic safety into long-term transportation planning. Due to the burgeoning urban development and hysteretic nature of data collection, however, many existing studies might be outdated and poorly adaptable. To address the problem, this study updated a macro-level safety model for 263 traffic analysis zones (TAZs) within the urban area of Shanghai. Independent variables for 2009 and 2016 from four categories were investigated to identify specific contributing factors for traffic crashes: socio-economic factors, traffic patterns, road characteristics, and land use features. A Bayesian conditional autoregressive negative binomial (CAR-NB) model was estimated to account for the spatial correlations among TAZs. The 2016 model was developed by using the two-stage Bayesian updating method to provide informative priors for 2009 model. Results show that higher crash frequency is associated with greater population, total length of major and minor arterials, trip frequencies, and shorter intersection spacing. The fact that most variables have similar significance for the two years is indicative of the good flexibility and interpretability of Bayesian CAR-NB model. Additionally, the informative priors are capable of providing theoretically based expectations without losing flexibility. This study helps to fill the gap in formulating informative priors for independent variables in macro-level traffic safety studies. Moreover, urban policy decision makers and traffic police can benefit from this study and implement area-wide engineering, education, and enforcement countermeasures to enhance regional traffic safety.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-03205
Paper Title	Developing Safety Performance Functions for Rural Multilane Highways in Tennessee: Accounting for Unobserved Heterogeneity
Abstract	This study investigates the safety performance of divided and undivided multilane rural highways and explores the presence of unobserved heterogeneity on such highways. First, a unique database was created with five years of crash data (2013-2017), traffic (AADT) data, and roadway inventory data, extracted from various sources of Tennessee Department of Transportation. Then, in addition to testing different functional forms and distributional assumptions, specifications for safety performance functions were developed. The results indicate that statewide calibration factors for divided and undivided multilane highways are 2.573 and 2.347 respectively—this implies that the Highway Safety Manual substantially under-predicts crashes in Tennessee, or that the safety performance on such roadways, as indicated by crash frequency is substantially worse than predicted by HSM. That is, the observed crashes on divided and undivided multilane highways are at least 1.573 and 1.347 times greater than predicted by HSM. Further, substantial heterogeneity was uncovered by estimating random parameter crash count models for multilane divided highways, with the effects of lane width (feet) and average five years' AADT (in 1000s) their varying substantially across different road segments. For undivided multilane highways, the average five years' AADT, and indicators for commercial and residential land use showed substantial heterogeneity. The study underscores the importance of accounting for unobserved heterogeneity and shows that on similar roadways, the factors that account for heterogeneity can be different. The findings can help practitioners and transportation agencies apply more appropriate and highly localized countermeasures to improve safety performance.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-03261
Paper Title	Development of Network Screening Safety Performance Functions for Roadway Departure Safety in Virginia
Abstract	Roadway departure (RD) crash is recognized as one of eight emphasis areas in Virginia's 2017-2021 Strategic Highway Safety Plan, and the Virginia Department of Transportation (VDOT) has been using annual counts of RD crashes to identify locations for RD safety improvement. However, identifying locations based on crash counts is subject to bias and inaccuracy. The safety performance functions (SPFs) developed and deployed by VDOT for statewide network screening might be used for RD safety, but this could lead to undesirable outcomes in that those SPFs are intended for all crash types and RD safety issues are believed to be different from other crash types. This study was to develop RD SPFs that should be implemented for statewide network screening in Virginia using existing resources. A total of 93 RD SPFs were successfully developed with three functional forms: (1) SPFs with AADT in the logarithmic form, (2) SPFs with AADT in a customized functional form, and (3) SPFs with AADT and other predictors in customized functional forms. The study found that the RD SPFs vary in their functional forms across site types. The logarithmic form of AADT, regarded as a standard for an SPF, is deemed suitable in general for a typical range of AADT. However, that form could be severely deviated from the underlying relationship. Therefore, a proper functional form of AADT for an RD SPF should be determined for each site type and by severity level separately whenever possible.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1259
Session Title	Taxis, Wealth, Speed, and Active Commuters: Informing Safety with Diverse Data Sources
Paper Number	20-03276
Paper Title	Investigating the Impact of Road Network Patterns on Active Commuters' Safety
Abstract	Many cities worldwide are adopting sustainable development patterns in urban design. This is expected to allow easier commuting for active transportation. However, the safety implications of the various road network patterns on vulnerable road users (VRUs) need to be investigated beforehand. This study evaluated the road network within City of Vancouver' 134 traffic analysis zones (TAZs), where quantitatively defined network indicators, i.e. average geodesic distance, overall clustering coefficient, betweeness centrality, are developed for each TAZ. The negative binomial (NB) crash modeling technique was used to build macro-level crash models (CMs) for cyclists and pedestrians using each of the three indicators along with traffic exposure measures. Negative associations were found between the cyclist/pedestrian crashes and the three network indicators, while a positive association was found with vehicle kilometers travelled (VKT). A composite indicator was developed to come up with a quantitative scale of the road network patterns by aggregating the three network indicators using their Z-Scores. Lastly, CMs are developed using active commuters' traffic exposure, i.e. bike kilometers travelled (BKT) and walk trips (W), along with VKT, to assess the associations between the composite indicator and cyclist/pedestrian crashes. Policy recommendations were proposed accordingly.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-03303
Paper Title	Two-Way Stop-Controlled Intersection Analysis with Zero-inflated Models
Abstract	Intersection safety continues to be a crucial issue throughout the United States. In 2016, 27 percent of the 37,461 traffic fatalities on U.S. roadways occurred at or near intersections. Nearly 70 percent of intersection-related fatalities occured at unsignalized intersections. At such intersections, vehicles stopping or slowing to turn create speed differentials between vehicles traveling in the same direction. This is particularly problematic on two-lane highways. Research was performed to analyze safety performance for intersections on rural, two-lane roadways, with stop control on the minor roadway. Roadway, traffic, and crash data were collected from 4,148 stop-controlled intersections of all 64 Parishes (counties) statewide in Louisiana, for the period of 2013 to 2017. Four count approaches, Poisson, Negative Binomial (NB), Zero-inflated Poisson (ZIP) and Zero-inflated Negative Binomial (ZINB) were used to model the number of intersection crashes for different severity levels. The results indicate thatZIP models provide a better fit than all other models. In addition to traffic volume, greater curve radius of major and minor roads, greater curve lengths of major roads, and greater lane widths of minor roads led to significantly smaller crash occurrences. However, intersections close to the beginning of curves, or located in the middle of curves, higher speed limits of minor roads, and urban areas led to significantly greater crash occurrences. Four-leg stop-controlled (4ST) intersections have 35 percent greater total crashes, 49 percent greater fatal and injury crashes, and 25 percent greater property damage only (PDO) crashes, relative to three-leg (3ST) intersections.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-03379
Paper Title	Safety Analysis of Displaced Left-Turn Intersections
Abstract	Displaced left-turn intersections (DLTs) are designed to enhance the operational performance of conventional intersections that are congested due to heavy left-turn traffic volumes by excluding the left-turn movements at the main intersection. This results in reducing the number of potential conflict points and increasing the intersection capacity. However, since drivers are not familiar with DLTs' operation, there is a need to assess the safety and operational efficiency of this type of intersections. This paper evaluates the safety performance of DLTs using two common methods, which are a before-and-after study with comparison group and cross-sectional analysis. Furthermore, it investigates the operational performance of DLTs using a general linear model describing the relationship between a selected measure of performance and other operational and geometric characteristics based on high-resolution traffic data. The safety analysis indicates that DLTs can increase the crash frequency in comparison to conventional intersections. In addition, the operational analysis implies that DLTs have a potential to reduce the delay at intersections. The study concludes that DLTs are more dangerous than conventional intersections for many crash types; but it might be more efficient for operational performance. It is recommended that appropriate safety countermeasures should be developed and implemented to enhance traffic safety at DLTs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03424
Paper Title	Exploring Factors Influencing Injury Severity of Accidents between Motor Vehicles and Non-Motor Vehicles Using Generalized Ordered Logit Model
Abstract	Identifying factors that affect accidents between motor vehicle (MV) and non-motor vehicle (NMV) and understanding how these factors affect injury severity is vital in improving traffic safety. Factors including human characteristics, vehicles, road and environment conditions were investigated using the generalized ordered logit model. Police-reported crashes data from the period 2005 to 2017 in Shaanxi Province, China were used to develop the models. Injury severity was classified as no injury, slight injury, serious injury and fatal injury. The results of this study reveal that the following factors increase the likelihood of serious or fatal injuries: age of NMV drivers, compulsory third party insurance, type of MV, road type, season. The results also indicate that hukou, type of NMV, driving state of MV, type of roadside protection, road structure, road linearity, weather, time of accident and visibility level influence the risk of serious or fatal injuries. To reduce serious or fatal injury rate in traffic crashes, measures such as isolating NMV and MV (especially heavy or large vehicles), educating drivers especially those from rural areas and improving road and environment conditions should be taken. Traffic management and enforcement of traffic regulations are crucial in decreasing traffic injury severity as well. Conclusions drawn in this research will be helpful to police or policy makers to modify safety measures to reduce the occurrence of serious or fatal crashes and improve the traffic safety level.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03549
Paper Title	Investigation of Safety-in-numbers for Pedestrians and Bicyclists at a Macroscopic Level with Various Exposure Variables
Abstract	Safety-in-numbers effect is a phenomenon that crash risks of road users decrease when their numbers increase. Although a number of previous studies have confirmed the safety-in-numbers effect at microscopic scales, few study investigated the safety-in-numbers effect at a macroscopic level (e.g., census tracts). In this study, the safety-in-numbers phenomenon is investigated at a greatly larger scale unit, metropolitan statistical area (MSA), which are usually composed of multiple counties. Various pedestrian and bicyclist exposure data were obtained from the National Household Travel Survey, i.e., trips, miles, and hours. The preliminary results show that the number of fatal crashes involving pedestrians and bicyclists are significantly larger where walking and bicycle activities are higher. A series of Bayesian Poisson lognormal models confirm the safety-in-effects with the different exposure variables at a large-scaled geographic level (i.e., MSA). The findings imply that regions' travel behavior and cultures to respect vulnerable road users play a key role in the level of pedestrian and bicyclist safety. In addition, the results reveal other important factors to vulnerable road user involved crashes, including but not limited to climate, demographic, socio-economic, and travel characteristics of the study regions.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03662
Paper Title	Predicting Crash Frequency for Urban Expressway Considering Collision Types using Negative Binomial Regression Model
Abstract	Current studies on traffic crash prediction mainly focus on the crash frequency and crash severity of freeways or arterials. However, collision type for urban expressway crash is rarely considered. Meanwhile, with the rapid development of urban expressway systems in China in recent years, traffic safety problems have attracted more attentions. In addition, the speed is considered to be a potentially important predictor of traffic accidents, however, its impact on traffic crash occurrence has been controversial. Therefore, a crash frequency predicting model for urban expressway considering collision types is proposed in this study. The loop detector traffic data and historical crash data were aggregated based on the similarities of the traffic conditions 5 minutes before crash occurrence, among which crashes were divided by collision type (rear-end collision and side-impact collision). The impact of average speed along with other traffic and weather variables as well as their interactions on crash frequency was modelled by using Negative Binomial regression model. The results indicated that the influence of traffic and weather factors on two crash types shared similar trend, but different level. For rear-end collisions, crash frequency increased with lower average speed and high traffic volume under low speed limit. And when the speed limit is high, higher average speed coupled with larger volume increase the probability of crash. Higher average speed and traffic volume increase the probability of side-impact collisions, regardless of the speed-limit. The findings of present study could help to determine efficient safety countermeasures aimed at improving the safety performance of

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03782
Paper Title	Application of the Poisson-Tweedie Distribution in Analyzing Crash Frequency Data
Abstract	This paper evaluates the application of the Poisson-Tweedie family of distributions in developing crash frequency models. The Poisson-Tweedie model is a unified approach, which can fit overdispersed, underdispersed, and long-tailed data. The form of its variance function is specified as mean + dispersion × meanP, where P is the power parameter that can take any real number and thus offers greater flexibility. Special cases of the Poisson-Tweedie models include Neyman Type A or linear form of negative binomial (NB1) with P = 1, geometric Poisson with P = 1.5, quadratic form of negative binomial (NB2) with P = 2, and Poisson-inverse gaussian (PIG) with P = 3. A series of models were developed in this study using the Poisson-Tweedie distribution without any restrictions on the power parameter as well as with a fixed set of power parameters representing NB1, geometric Poisson, NB2, and PIG models. The models were fitted with fixed and varying dispersion parameter (i.e., dispersion as a function of covariates). Three years of crash data (2012-2014) from urban three-leg stop-controlled intersections and urban four-leg signalized intersections in the state of Florida were used to develop the models. The results show that the Poisson-Tweedie models or the geometric Poisson models perform better when the dispersion parameter is constant. With a varying dispersion parameter, the NB2 and PIG models may perform better, with both performing equally well. Also, values of the dispersion parameter are found to be smaller in models that have a higher value of the power parameter.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-03859
Paper Title	Estimate of the Safety Effect of All-Way Stop Control Conversion: A Case Study in Washington D.C.
Abstract	This study evaluated safety effects associated with converting Traditional Stop Control (TSC) to All-Way Stop Control (AWSC) at 53 intersections in Washington DC. The study utilized an observational treatment group and a randomly selected comparison group. Multiple linear regression modeling was used to estimate the effect of of AWSC conversion on crash outcomes, controlling for confounding factors and check its statistical significance. The study also examined potential covariates that could influence AWSC crash outcomes, such as the number of legs and functional classification. This study found an overall 36% reduction in all crashes and a 42% reduction in injury crashes associated with converting intersections from TSC to AWSC. In addition, the study revealed a statistically significant reduction in right-angle crashes along with a statistically significant increase in straight hit pedestrian crashes. For all the other collision types, including right turn, left turn, rear end, sideswipes and bicycle crashes, no statistically significant coefficients were found. With many Vision Zero cities considering increased use of AWSC to help achieve their safety goals, it is important to understand and communicate AWSC safety effects.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-03906
Paper Title	Evaluation of the Relationship between Driving Speed and Crashes on Urban and Suburban Arterials
Abstract	The objective of this research was to examine the link between driving speed and crash experience on urban and suburban roadway segments, taking into account roadway characteristics that influence both speed and crash frequency and/or severity. Using the SHRP 2 Naturalistic Driving Study Data and the associated Roadway Inventory Database, the research examined individual drivers' speeds along more than 100 two-lane undivided and four-lane divided urban and suburban arterial study segments. Both variations within individual trips and among drivers on the same roadway segment over a few years were evaluated. Using both the RID and roadway and roadside characteristics obtained from aerial and street-view imagery, the relationship between speed choice and roadway characteristics was also explored. The research found that a number of roadway characteristics are related both to speed and to crash experience for urban/suburban roadway segments and that a higher measure of speed variance between trips was frequently correlated with higher crash frequency (especially for multi-vehicle crashes). Most other speed measures evaluated had no correlation with crash frequency, or had a negative correlation. That is, higher crash rates were often found on road segments with lower speeds, as many of the roadway characteristics were associated both with lower speeds and higher crashes. The research did not find that incorporating a speed term in existing SPFs or developing a speed CMF would substantially improve the existing crash prediction methodology for urban and suburban arterials presented in the HSM.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-03909
Paper Title	Assessment of the Impacts of Volume Completeness and Spatial and Temporal Correlation on Hourly Freeway Crash Prediction Models
Abstract	Traditional traffic safety analyses of crash frequency usually use highly aggregated cross-sectional data and ignore the time-varying nature of some critical factors. This research used 7 years of hourly data from 110 rural 4-lane segments and 80 urban 6-lane segments to develop hourly level crash prediction models and contrasted them against traditional AADT-based models. To account for the over-dispersion of data and unobserved heterogeneity, generalized linear mixed effect models were contrasted against negative binomial models. The models used average hourly volume as a measure of exposure, and the quantity of volume data available for the sites ranged from continuous counts to locations where only a couple of weeks of data were available every other year (short counts). While developing disaggregated models, the difference in data availability from these sources can be a potential source of error, so evaluating the change in performance of prediction models with changes in volume data availability was examined. The results showed that the best models include a combination of average hourly volume, selected geometric variables, and speed related parameters. Hourly models that included speed parameters consistently outperformed AADT models. Further investigation revealed that the positive effect of using a more inclusive and larger dataset was larger than the effect of accounting for data correlation. This showed that using short count stations as a data source does not diminish the quality of the developed models, thus indicating that these methods could be broadly applied across agencies, even when volume data is relatively sparse.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-03930
Paper Title	Severity Analysis of Wildlife-Vehicle Crashes Using Generalized Structural Equation Modeling
Abstract	Each year thousands of wildlife-vehicle crashes (WVCs) occur in North America with negative effects on wildlife welfare, human health and the economy. While previous studies have mainly investigated factors related to WVC frequency, limited research has been conducted on factors affecting WVC severity. Using more than 10,000 WVCs occurred in the province of Saskatchewan (Canada), this study investigated the severity outcomes of WVCs and their influencing factors using structural equation modeling (SEM) with generalized (ordered probit) links. Compared to traditional severity analysis techniques, SEM offers the added advantage of representing, estimating, and testing complex modeling structures that include both measured and latent (unmeasured) variables. Three latent variables were introduced in this study, i.e., driver's speeding attitude (SA), driver's visibility impairment (VI), and crash severity. Measured variables obtained from crash records were included in SEM to define latent constructs and the resulting network of relationships was tested. The results showed that crash data supported well the model hypothesis and measured/latent variables adequately predicted crash severity. Overall, SA and VI were demonstrated to positively affect crash severity with SA being the most influential factor. Moreover, it was demonstrated that road surface condition was the most influential factor of the SA measurement model, and weather condition was the most influential factor with respect to VI. Finally, a comparison between generalized SEM results and traditional crash severity modelling using ordered probit links was conducted. Similarities and differences between these two approaches were discussed at the end of the study.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-03980
Paper Title	Evaluation of Strategies to Mitigate Culvert-Involved Crashes
Abstract	The purpose of this study was to assess potential impacts of installing various safety treatments to mitigate the frequency and severity of collisions in which an errant vehicle strikes a culvert. Culvert-related crashes were identified through a review of standard fields on police crash report forms, as well as through a review of pertinent keywords from the narrative section of these forms. These crashes were then linked to the nearest cross drainage culvert, which was associated with the nearest road segment on the state-maintained road network. Culvert-involved crash rates were estimated for several types of highway facilities. A high-level analysis was performed on the occupant injury data to determine how the severity distribution varied based upon the roadway type. The second stage of the analysis involved the use of the Roadside Safety Analysis Program to estimate the expected crash costs associated with various design contexts. A series of scenarios were evaluated, culminating in guidance as to the most cost-effective treatments for different combinations of roadway geometric and traffic characteristics. Information regarding the installation and maintenance costs were obtained from the Iowa DOT and several online resources. The results of this study suggest that the installation of safety grates on culvert openings provides a promising alternative for most of the cases where the culvert is located within the clear zone. In general, guardrail is recommended when adverse conditions are present or when other treatments are not feasible at a specific location.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-04054
Paper Title	How is Injury Severity Affected by Driver Errors: a Crash Data Based Investigation
Abstract	Unsafe driving behaviors, driver limitations, and conditions that lead to a crash are usually referred to as driver errors. Even though driver errors are widely cited as a critical reason for crash occurrence in crash reports and safety literature, the discussion on their consequences is limited. This study aims to quantify the effect of driver errors on crash injury severity. To assist this investigation, driver errors were categorized as sequential events in a driving task. Possible combinations of driver error categories were created and ranked based on statistical dependences between error combinations and injury severity levels. Binary logit models were then developed to show that typical variables used to model injury severity such as driver characteristics, roadway characteristics, environmental factor, and crash characteristics are inadequate to explain driver errors, especially the complicated ones. Next, ordinal probit models were applied to quantify the effect of driver errors on injury severity for rural crashes. Superior model performance is observed when driver error combinations were modeled along with typical crash variables to predict the injury outcome. Modeling results also illustrate that more severe crashes tend to occur when the driver makes multiple mistakes. Therefore, incorporating driver errors in crash injury severity prediction not only improves prediction accuracy but also enhances our understanding of what error(s) may lead to more severe injuries so that safety intervention can be recommended accordingly.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-04083
Paper Title	Calibration of Wyoming-Specific Safety Performance Functions for Urban and Suburban Five-Lane Arterial Roadway Corridors
Abstract	Urban arterials play a major role in the roadway network system in urban cities providing accessibility and mobility to major zones of cities. According to the National Highway Traffic Safety Administration, 45% (14,414) of the fatal crashes occurred on urban roadways during 2015 in the US. Wyoming experienced 1,630 fatal and injury crashes on urban roads in 2015 which represented 56% of the total fatal and injury crashes. The role of urban arterials in providing accessibility, and mobility, as well as the increased number of fatalities highlight the importance of evaluating their traffic safety. The objective of this study was to calibrate the Highway Safety Manual's (HSM) Safety Performance Functions (SPFs) for Wyoming conditions. The study was conducted using crash data from 2003 to 2012 for five-lane arterials (5T) with a center two-way left-turn lane, and urban and suburban arterial signalized four-leg intersections (4SG). This study assessed the transferability of the HSM SPFs to Wyoming conditions and compared the calibrated HSM's SPFs to newly developed Wyoming-specific SPFs for urban and suburban 5T segments, and 4SG intersections. Furthermore, SPFs were developed for urban and suburban corridors, i.e., 5T and 4SG were combined and compared to individual 5T and 4SG SPFs. SPFs were developed using Negative Binomial regression model for Total, Property Damage Only, and Fatal and Injury crashes. The HSM SPFs were found to over-estimate the total crashes for 5T segments and 4SG intersections in Wyoming. Furthermore, the Wyoming-specific SPFs performed better than the calibrated HSM SPFs in predicting total crashes.

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Sponsoring Committee	Standing Committee on Technology Transfer (ABG30) Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1702
Session Title	Moving Transportation Safety Research into Practice
Paper Number	20-04134
Paper Title	Roadway Safety Management in Small Municipalities
Abstract	Roadway safety management consists of network screening, diagnosis, countermeasure selection, economic appraisal, prioritization, and safety effectiveness. Applications of the safety management process is limited in small municipalities due to data, statistical expertise, and resources required. This paper addresses the challenges faced by small jurisdictions and implementation of the safety management process for Madison metropolitan area in Wisconsin. Jurisdiction specific crash prediction models were developed by intersection type using data from over 4,000 intersections. Performance measures included the Equivalent Property Damage Only (EPDO) average crash frequency with Empirical Bayes adjustments and the Level of Service of Safety (LOSS). Wisconsin Crash Outcome Data Evaluation System (CODES) data was used to estimate local crash costs by severity and type. Sites were provisionally ranked in network screening, and diagnosis was conducted based on intersection observed crash types and distributions. Treatments were selected for each intersection and costs of treatments were obtained from local estimates and available literature. Crash cost benefit and treatment cost were used to estimate benefit-cost ratio by site. A combination of sites that had the greatest overall cost effective safety benefit on the network were selected through an incremental optimization process. This paper contributes to exiting literature by providing guidance for development of jurisdiction specific crash prediction models, integration of pedestrian and cyclist crashes, application of EPDO and LOSS performance measures, and selection of sites with promise through an incremental optimization process for a given budget in a small jurisdiction.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-04159
Paper Title	Safety Effectiveness of All-Electronic Toll Collection System
Abstract	Tolling has been recognized as one of the effective ways to reduce traffic congestion. There are three types of tolling systems commonly in practice, namely, Traditional Toll Plaza (TTP), Hybrid Toll Plaza (HTP) and All-Electronic-Toll-Collection (AETC) system that includes Open Road Tolling (ORT) and High Occupancy Toll (HOT) lanes. The upgrade from toll plazas to the AETC system has demonstrated operational benefits, but little is known about the safety impacts of these new tolling systems. Currently, Texas ranks second in the nation in terms of the length of toll roads. This study determines the safety impacts of the conversion from the HTP to ORT on Loop 1, Austin, and from HOV (High Occupancy Vehicle) to HOT lanes on I-635, Dallas. As the conversions on Loop 1 took place in January 2013, crash data were analyzed from 2010 to 2015. Crashes on I-635 were studied from 2013 to 2018, excluding 2016, as the conversions occurred in October 2016. Empirical Bayes before-after analysis including the development of Safety Performance Functions (SPFs) was separately carried out for Loop 1 and I-635. The results reveal that an upgrade to the ORT system on Loop 1 significantly reduced total, fatal and injury, and property damage crashes. Similarly, conversion from HOV lanes to HOT lanes on I-635 also resulted in a significant reduction in total, fatal and injury, and property damage crashes, although to a lesser extent than that for Loop 1. This study provides more evidence for the crash reduction potential of AETC systems.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-04254
Paper Title	Examining the Underlying Exposures of Hit-and-run and Nonhit-and-run Crashes
Abstract	The act of hit-and-run in a crash without reporting would delay the emergency response for the victims and aggravate the injury severities. Limited knowledge, however, is available to evaluate the discrepancy of injury risks between the hit-and-run and nonhit-and-run crashes, especially the crash exposures which may contribute to the injury severities. The objective of the study is to examine the underlying exposures of hit-and-run and nonhit-and-run crashes and identify the factors influencing the injury severities. Quasi-induced exposure technique is employed to measure the relative crash exposures in two-vehicle hit-and-run and nonhit-and-run crashes; random parameter ordered logit model is adopted to reveal the discrepancy of the factors attributing to the injury risk of the drivers involved in hit-and-run and nonhit-and-run crashes. The study reports that the injury sustained by the remaining drivers at the event of hit-and-run is less severe than those involved in the nonhit-and-run crashes (with Michigan crash data), which is attributed to the differential crash exposures in terms of driver age and vehicle type between two crash types. The injury-severity contributing factors of hit-and-run crashes differ considerably from the nonhit-and-run crashes that variables such as nighttime, intersection area, head-on, angle, and side-swipe crash type, and alcohol involvement significantly increase the injury severities of the staying drivers at the event of hitting-and-running. The findings serve to emphasize the importance of taking into account the crash exposure in the safety research on hit-and-run crashes and propose the effective safety countermeasures to reduce the injury severity for hit-and-run crashes.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1721
Session Title	Highway Safety Performance Research
Paper Number	20-04363
Paper Title	Safety Performance of One-Way Arterials
Abstract	Safety analysts are generally interested in understanding the differences in the safety performance when a two-way street is converted to a one-way operation or vice-versa. Literature exists to understand and predict the safety of two-way streets. However, safety prediction procedures are currently not available for assessing the safety performance of one-way arterials. This research was undertaken to develop the safety prediction models for one-way arterials. To accomplish this objective, data collected in California, Illinois, Michigan, Oregon, and Texas were assembled that included a wide range of geometric design features, traffic control features, traffic characteristics, and crash records. The data were used to calibrate predictive models, each of which included a safety performance function (SPF) and several crash modification factors (CMFs). Separate SPFs were developed for fatal and injury crashes (i.e., fatal, incapacitating injury, non-incapacitating injury, and possible injury crash) and property-damage-only crashes. The SPFs were estimated using the negative binomial modeling structure. Severity distribution functions (SDFs) were also calibrated using the fatal and injury data. These functions can be used with the predictive models to estimate the expected crash frequency for each of four injury severity levels.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Act I, Session 1338; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-04597
Paper Title	Incorporating Demographic Proportions into Crash Count Models by Quasi-Induced-Exposure Method
Abstract	Quasi-induced exposure (QIE) is an effective technique for estimating a specific driving or vehicle population exposure when real exposure data are not available. Typically crash prediction models are carried out at the site level, i.e., segment or intersection. Driving population characteristics are generally not available at this level, and thus omitted from count models. Due to the sparsity of traffic crashes, estimating driving population distributions at the site level using crash data at individual sites is challenging. This study proposes a technique to obtain demographic proportions to incorporate in the count models as an exposure at each site by aggregating similar adjacent sites until significant demographic proportions are obtained. Driver gender, age and vehicle type information are obtained by QIE using five years (2010-2014) of crash data; and road inventories are obtained for 1264 urban four-lane divided highway segments in California. Count models including only site level factors were compared with models including both crash level and site level factors. The latter outperformed the former in terms of mean prediction bias (MPB) and mean absolute deviation (MAD) statistics on hold out sample predictions. Results indicate that teen drivers are more crash prone in total and fatal plus injury severity crashes where senior driver crash risk increases with the increase in severity level. Presence of vehicles other than passenger cars and trucks reduces total and property damage only crash counts. Female drivers exhibit an increase in total and fatal plus injury crash counts.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-04782
Paper Title	Examining Driver Injury Severity in Left-turn Crashes Using Hierarchical Ordered Probit Models
Abstract	According to the National Highway Traffic Safety Administration (NHTSA), crash injuries and fatalities caused by left-turning movements occupy a large proportion of the total numbers in the United State. However, few existing studies in the literature devoted efforts to examine the driver injury severity in left-turn crashes. To fill this research gap, this paper implements three hierarchical ordered probit (HOPIT) models, utilizing eight-year left-turn crash dataset from 2010 to 2017 in Utah, to investigates the impact factors on left-turn crashes and the corresponding injury severity. As the driving condition during the wintertime of Utah could be greatly different from other seasons, according to the temperature, snowing condition, and other factors, this study divided the whole crash dataset into “winter” and “other-season” datasets so as to compare the injury severity pattern in the different seasons. The results revealed that snows would decrease the probability of occurring minor-injury in a left-turn crash by 12.6% during the wintertime and higher speed limit would significantly increase the injury severity in a left-turn crash. Compared with the other seasons, the probability of occurring minor-injury related to a head-on collision in a left-turn crash is dramatically increased in winter of Utah.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-04801
Paper Title	The Impact of Demographics of all Drivers on the Highest Driver Injury Severity in Multi-Vehicle Crashes of Rural Two-Lane Roads in California
Abstract	The injury severity of a driver in the crash is significantly dependent on characteristics of the crash such as driver's age, gender and vehicle characteristics. Most previous studies have used the information of a single driver to explain the severity of the crash. However, the demographic information of all other drivers involved in the crash can also be significantly important for predicting the severity of the crash. To identify the impact of all drivers in a crash, this study uses demographic information of all drivers involved in a multi-vehicle crash to predict the injury severity of the most severely injured driver. Three different discrete outcome models-Multinomial Logit (MNL), Ordered Logit (OL), and Partial Proportional Odds (PPO) were used to estimate the effect of different factors on injury severity. Models incorporating demographic information and vehicle characteristics of all drivers involved in a crash were compared with the models only considering information about the most severely injured driver in terms of significance of factors and prediction accuracy. The results from all three models consistently indicate that although young drivers are likely to have lower levels of injury severity compared to working age drivers, injury severity increases if the number of young driver increases in a multi-vehicle crash. Drivers indicated to be not at fault frequently were more severely injured than drivers at fault. Finally, the inclusion of all drivers' demographic information shows an improvement in the prediction accuracy of crash severity of the most severely injured driver.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-04840
Paper Title	SPF Real-time Data vs AADT
Abstract	Annual Average Daily Traffic (AADT) has been one of the most fundamental exposure variables used in developing Safety Performance Functions (SPFs). However, since AADT is an aggregate measure of traffic conditions, it does not reflect the real-time traffic variations. In other words, while AADT gives the number of vehicles per day averaged over a year, the actual number of vehicles on a roadway varies drastically with season, day of week, and time of day. It is therefore hypothesized that developing SPFs using disaggregate traffic data instead of aggregated AADT could yield better crash predictions. With the increasing availability of exhaustive real-time traffic data, it is crucial to determine if developing SPFs using real-time data improves the crash predictions. This research sets out to use Level of Service (LOS) as a proxy for real-time data in lieu of AADT to develop SPFs for freeways. The paper attempts to answer the following questions: would simple SPFs developed using LOS alone perform better than the simple SPFs developed using AADT? If so, could the crash predictions be improved by considering other influential variables in addition to LOS? The analysis was based on 2016-2018 crash data on I-75 in Florida. The results indicated that the SPFs based on LOS alone predicted the crashes better than the SPFs developed using AADT. Further, the simple SPFs developed using LOS alone and those developed using additional influential variables showed almost similar prediction performance. Therefore, SPFs developed using LOS alone would yield acceptable crash predictions on freeway facilities.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-04893
Paper Title	Safety Performance Functions for Fatal Crashes on National Highways under Heterogeneous Traffic Flow
Abstract	The objective of this paper is to explore the effect of the road elements of two-, four- and six-lane National Highways (NHs) under heterogeneous traffic (including pedestrians) flow on fatal crashes. The generalized linear model technique, i.e., negative Binomial (NB) regression is used for analyzing linear and non-linear effect of continuous and categorical predictor variables on discreet dependent variable (fatal crashes) separately for each NH segments. In India, NHs are not usually access controlled, and heterogeneous vehicles travel on highways. The probable explanatory variables are short-listed after thorough literature review, and availability of data. These variables comprise of vehicular traffic, highway elements, and roadside land use. The fatal crash data for the historic period (2009-2013), traffic and highway inventory data have been collected for NHs having varying lane configuration: two-lane NH-8, four-lane NH-24 and six-lane NH-1. The study results revealed negative binomial regression model fit the data statistically, and also identified number of statistically significant variables ('segment length', 'roadside land use', 'presence of service road (SR)' and 'terrain type') to estimate fatal crashes at NHs segments. The results of the safety performance functions (SPFs) showed that out of seven explanatory variables examined for each NH (segments), the significant explanatory variable is found to be 'segment length' in km for all three models of NHs (segments). Other significant variable is 'land use' along NHs for both two-lane NH-8 and four-lane NH-24. Similarly, the explanatory variables 'presence of SR' and 'terrain type' are found significant for four-lane NH-24 and two-lane NH-8 respectively.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-04921
Paper Title	The Variability of Urban Safety Performance Functions for Different Road Elements: an Italian Case Study
Abstract	Safety performance functions are used to predict crash frequencies based on several possible variables which include at least traffic volumes, geometric, and traffic-control variables. In urban environments, safety predictions are usually differentiated for homogeneous road elements: segments and intersections. Further disaggregations are often considered, such as one-way/two-way, one-lane/multilane segments, three/four-legged, signalized/unsignalized intersections. In the context of a National research project, data about crashes, traffic, geometric, traffic-control and additional variables were collected for the road network of the City of Bari, Italy. 320 homogeneous segments and 120 intersections were included in the sample of sites, on which more than 1,500 fatal+injury crashes have occurred in a 5-years period (2012-2016). The study was conceived for research purposes and for being useful for practitioners. The main research questions concerned: a) finding the best possible subsets for segments and intersections for safety modelling purposes, by discussing the related problems, and inquiring into the variability of predictors within subsets; b) comparing the modelling results with existing literature to highlight common trends and/or main differences; c) assessing the importance of additional crash predictors, besides traditional variables. As a result of the study, six detailed models were developed for: one-way/two-way homogeneous segments, three/four-legged, signalized/unsignalized intersections. Crash predictors greatly vary within the different subsets considered. The effect of vertical signs on minor roads/driveways, critical sight distance, cycle crossings, pavement/markings maintenance was specifically discussed. Some common trends but also notable differences in both types and effect of crash predictors were found by comparing results with relevant literature.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-04949
Paper Title	Exploring Temporal Distribution of Crash Counts in California
Abstract	Compared with other safety studies based on a single time interval, considerably less research has relied on the use of multiple time units, especially for the time intervals of less than one year. The research aims to fill the gap by investigating the temporal distribution of crash counts using multiple time spans including hour, weekday and month. The data are obtained from Highway Safety Information System (HSIS) which covers the crash cases in California of 2014. To illustrate the most accurate results possible, both the Chi-square test and Cochran-Mantel-Haenzel tests were employed to explore the independence of various time units based on two-way and three-way contingency tables. The interaction plots were also analyzed to check the potential existence interaction among the different time variables. In addition, eight Negative Binomial models were developed which can be classified into four groups including Complete Independence, Joint Independence, Conditional Independence, and Homogeneous Association. Finally, a set of evaluation criteria including Alkaline Information Criteria, Mean Squared Error based on Cross-Validation, the correlation between actual and estimated crash counts, and Analysis of variance tests were utilized for evaluation of the model performance. The research indicates that both main and all interactive effects of time variables must be included for model development, which otherwise might yield misleading information. It is anticipated that the research results shed some light on both safety practitioners and researchers for a more efficient allocation of safety resources and better development of models involving time variables.

Authors	Ishtiak Ahmed, North Carolina State University Billy Williams, Institute for Transportation Research and Education Shoaib Samandar, North Carolina State University Gyounghoon Chun, North Carolina State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-05020
Paper Title	Investigating the Relationship between Freeway Rear-end Crash Rates and Macroscopically Modelled Reaction Time
Abstract	Prior research support the contention that rear-end crash occurrences are associated with traffic state oscillations. Due to traffic oscillations, drivers often fail to react in time and collide with the leading vehicle. This study explores the hypothesis that an analytically derived estimate of the required driver reaction time for asymptotic stability, based on the macroscopic Gazis, Herman, and Rothery (GHR) model, can serve as an effective indicator of the impact of traffic oscillations on rear-end crashes. If separate GHR models are fit discontinuously for the uncongested and congested regimes, the local drop in required reaction time between the two regimes can also be estimated. This study evaluates the relationship between freeway rear-end crash rates and this drop in driver reaction time. The hypothesis is that a higher drop in reaction time will be associated with a higher expected frequency of target crashes. Traffic data from 28 sensors collected over one year were used to calibrate the two-regime GHR model. Rear-end crash rates for the segments surrounding the sensor locations are estimated using archived crash data over four years. The rear-end crash rates exhibited a strong positive correlation with the reaction time drop at the density-breakpoint of the congested regime. A linear form model provided the best fit compared to other forms in terms of R-square, standard error, and homoscedasticity. These results

motivate follow-on research to incorporate macroscopically derived reaction time in road-safety planning. More generally, the study demonstrates a useful application of a discontinuous macroscopic traffic model.

Authors	Irfan Ahmed, University of Wyoming Mohamed Ahmed, Federal Highway Administration (FHWA) Haun Wulff, University of Wyoming
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-05079
Paper Title	Using No-U-Turn Hamiltonian Monte Carlo Bayesian Method to Investigate the Contributing Factors of Crash Injury Severity in Very Low-Volume Rural Roads of Wyoming
Abstract	In Wyoming, the percentage of traffic fatalities on rural roadways have always surpassed traffic fatalities in urban roadways. Crash count models provided in the Highway Safety Manual (HSM), as a function of traffic volume and segment length might not be adequate to relate the various crash contributing factors to different types of crashes and severity, especially for low-volume rural roadways. Hence, crash injury severity models with discrete severity outcomes are modelled with respect to roadway, driver, environmental, and other crash characteristics. A dataset was prepared using crash records from the years 2007-2016 of 28 different two-way two-lane roadways in Wyoming with average annual daily traffic less than 400 vehicles per day. A binary logistic model was developed to carry out the crash injury severity analysis using a Bayesian approach. Fixed- and random-effects models were developed to investigate the relationship between the crash injury severity and its associated contributing factors. Results showed that the random-effects model is a better fit to the data than the fixed-effects model. Parameter estimates are sampled from the posterior distributions using a No-U-Turn Hamiltonian Monte Carlo sampling technique which is a more efficient method than other Markov chain Monte Carlo methods. The population-averaged estimates included driver impairment, improper use of restraint, speeding, lane departure, and motorcycle involvement and were found to increase the odds of a fatal/injury crash. Furthermore, the combined effect of nightly crashes and improper driving action leads to increased likelihood of fatal/injury crash.

Authors	Ming-heng Wang, Taiwan Police College
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05153
Paper Title	Analysis of Factors Affecting the Injury Severity in E-bike with Vehicle Crashes in Taiwan
Abstract	To understand the characteristics of e-bike involved crashes and the factors affecting the injury severity (fatal or non-fatal) of the e-bikers, this study uses eight years (2011-2018) of police reported traffic crash data in Taiwan and the multivariable logistic regression model for the analysis. The results found that most e-bike involved crashes occurred at rural areas and intersections and with by side-impact crash types. Most e-bike involved crashes collided with motorcycles, male drivers, vehicles going straight, and drivers failing to look properly. Most e-bikers involved in crashes were female, aged more than 65 years old, riding an e-bike without pedals, and going straight prior to the crash. Factors that significantly affected the severity of an e-biker's injuries includes the crash type, collision part, crash location, road geometry, vehicle type, driver's license status, vehicle's motion prior to the crash, crash cause due to the drivers, e-biker's gender, age, and helmet usage. Crashes in head-on collision type and e-bikes collided with front head or right head corner of vehicle and colliding with big sized vehicles and by impaired drivers resulted in the highest possibility of e-bike's fatalities in e-bike involved crashes. Male e-bikers aged over 55 years old and not wearing a helmet tended to suffer a higher fatality rate in crashes. The enhancement of advanced safety systems and law enforcement on drunk, speeding and invalid drivers is recommended. The requirement of helmet use should also be necessary for riding an e-bike.

Authors	Jason Owens, Florida A&M University Doreen Kobelo, Florida Agricultural and Mechanical University Luciano Lalika, University of North Florida Thobias Sando, University of North Florida Angela Kitali, Florida International University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05172
Paper Title	Understanding Factors Influencing Aging Pedestrian Fatalities using Bayesian Networks
Abstract	This study mainly applies the Bayesian logistic regression (BLR) model and Bayesian Networks (BN) model to identify risk influencing variables of fatalities of aging pedestrians. Bayesian logistic regression model was used to identify the risk influencing factors of crash severity. Bayesian Networks model was applied to estimate the potential probabilistic association between pedestrian crash severity and explanatory variables. The models were developed with data from 913 pedestrian-vehicle crashes involving aging pedestrians that occurred in Florida from 2016 through 2018. The results from BLR model show that vehicle maneuver, lighting condition, shoulder type, trafficway, AADT, driver gender, pedestrian age and driver age are significant. Among the significant variables, results from BN model reveal that vehicle maneuver, lighting condition, trafficway and driver age are directly associated with crash severity. The findings from this study can be used to develop effective countermeasures for reducing the number of fatalities of aging pedestrians in pedestrian-vehicle crashes.

Authors	Subasish Das, Texas A&M Transportation Institute Anandi Dutta, Ohio State University Ioannis Tsapakis, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-05173
Paper Title	Traffic Collisions Involving Autonomous Vehicles in California: Bayesian Model Based Clustering
Abstract	The emerging technology of autonomous vehicles (AV) has been rapidly advancing. This new technology is accompanied by various positive and negative potentials. It is expected to affect the costs mainly by reducing the number of crashes and travel time, as well as improving fuel efficiency and parking benefits. On the other hand, safety outcomes from AV deployment is a critical issue. Ensuring safety of AVs requires a multi-disciplinary approach which monitors every aspect of these vehicles. To promote safety, the California Department of Motor Vehicles has mandated that autonomous car crash reports be made public in recent years. This study collected all crash reports filed by different manufacturers that are testing autonomous vehicles in California (September 2014 to May 2019). The data provides important information on autonomous vehicles crash frequencies and associated contributing factors. This study provides an in-depth exploratory analysis of the critical variables. The research team demonstrated a variational inference algorithm for Bayesian latent class models. The Bayesian latent class model identified six classes of collision patterns. Classes associated with turning, multi-vehicle collisions, dark lighting conditions with streetlights, and sideswipe and rear-end collisions, were also associated with a higher proportion of injury severity level. The authors anticipate that these results will provide a significant contribution to the area of AV and safety outcomes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-05220
Paper Title	Analysis of Wrong-Way Driving (WWD) Crash Severity on Arterials
Abstract	Wrong-way driving studies and mitigation strategies have exclusively been focused towards limited access facilities. However, it has recently been established that WWD crashes on arterial corridors are relatively more common. As such, this study focused on determining the factors influencing the severity of WWD crashes on arterials. The analysis was based on five years (2012-2016) WWD crashes that occurred on arterial corridors in Florida. Police reports for the 2,879 crashes deemed “wrong-way” in the database were downloaded and individually reviewed. The manual review of the police reports revealed that of the 2,879 WWD crashes, only 1,890 crashes (i.e., 65.6%) actually crashes that occurred as a result of vehicles traveling the wrong way. The ordinal regression models were then developed to establish the relationship between the severity of WWD crashes and different driver attributes, temporal factors, roadway and traffic characteristics. Results indicated that severity of WWD crashes on arterials was significantly influenced by season of the year, day of the week, lighting condition, age and gender of the wrong-way driver, number of vehicles involved, roadway functional classification, airbag deployment, alcohol involvement, speed limit, ratio of the speed of the wrong-way driver to the speed limit, and head-on crashes. Based on the model results, specific countermeasures pertaining to Education, Engineering, Enforcement, and Emergency response, were discussed. Possible Transportation Systems Management and Operations (TSM&O) strategies for WWD detection systems on arterials were further proposed in order to minimize WWD incidents.

Authors	Ian Hamilton, VHB Thanh Le, VHB Craig Lyon, Persaud and Lyon Inc./Traffic Injury Research Foundation Richard Porter, VHB
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources (Act II, Session 1339; Act III, Session 1340; Act IV, Session 1356)
Paper Number	20-05284
Paper Title	A Practical Approach to Macro-Level Safety Data Integration and Crash Prediction Model Development
Abstract	Macro-level crash prediction models (CPMs) predict an average crash frequency, by crash type and severity, for a defined area, such as a census block group, census tract, traffic analysis zone (TAZ), or county. Despite the practical role that macro-level CPMs can fill in the transportation planning process, they must be proven to be a reliable and transferable predictor of crashes across geographic boundaries. This research reviewed the literature surrounding past attempts to develop macro-level CPMs, assessed their methods for data integration and model development, and constructed parallel geographic models that can produce similar and compatible results. Based on the literature review, the authors applied a spatial Bayesian modeling technique that considers spatial correlation within the model parameter estimation to test two models, one based on TAZs and the other on census block groups. The models were developed for two specific types of crashes, multi-vehicle (MV) and single-vehicle (SV) crashes, using a multi-jurisdictional dataset within a nine city and county study area in Richmond, Virginia. This research found relatively consistent performance between models based on TAZs and census block groups and recommends that future research on macro-level CPMs should focus on modeling unique crash types rather than total crashes within a given jurisdiction.

Authors	Taehun Lee, North Carolina State University Thomas Chase, Institute for Transportation Research and Education Christopher Cunningham, North Carolina State University Shannon Warchol, Institute for Transportation Research and Education
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-05366
Paper Title	Movement-Based Safety Performance Functions for Signalized Intersections
Abstract	The traditional safety performance functions (SPFs) for signalized intersections predict the total crash frequency using annual average daily traffic (AADT). By its nature, the traditional SPF has limitations in evaluating the safety of individual movements. To improve on this limitation, this study proposes a novel crash prediction method using movement-based SPFs. Movement-based SPFs consist of two models: the conflict point (CP) SPF that predicts the crashes for a CP using the CP types (crossing, merging and diverging) and conflicting movement volumes; and the non-conflict point (NCP) SPF that predicts the NCP crashes using AADTs at intersection-level. The intersection-level SPF with the traditional SPF model form is developed as a reference model. The 1,689 crashes observed from 2010 to 2017 at 21 conventional signalized intersections were used for model estimation. Three crash frequency models for severities (TOT, FI, and PDO) were estimated for movement-based SPFs and intersection-level SPF using the negative binomial regression model. The results showed most of the estimated coefficients in movement-based SPFs are statistically significant at 95% confidence level. Also, it showed the crossing CP has obviously higher crash risk than merging and diverging CPs. The model validation was conducted by CURE plots and model performance measures. The results showed movement-based SPFs have unbiased prediction for the entire range of exposure variables and outperform the intersection-level SPF. The applicability of movement-based SPFs can be extended for the quantitative safety evaluation for new or highly unrepresentative intersection designs such as alternative intersections or interchanges.

Authors	Dusan Jolovic, Garver LLC Milos Pljakic, Univerzitet u Pristini
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-05464
Paper Title	The Effects of Traffic Signal Control Parameters on Vehicular Crash Frequency at 4-leg Signalized Intersection Approaches
Abstract	This paper provides an insight into the correlation between the signal timing parameters and the crash frequency at the 4-leg signalized intersection approaches. Crash data were obtained from 2003 to 2013 for Fort Lauderdale, FL. The authors investigated 162 intersections. Crash frequency was modeled using Poisson model, Negative Binomial model, Poisson Zero Inflated, and Negative Binomial Zero Inflated models. Multicollinearity was tested using Poisson correlation coefficient. The matrix of multicollinearity of all the observed independent variables in the models was developed and there was no high correlation reported. Model comparison was conducted to choose the best performing model based on the Aikake Information Criterion (AIC) and Bayesian Information Criterion (BIC). The results showed that the Negative Binomial model performed best when compared to other models. The results were obtained for the total number of crashes, rear-ends crashes only, and the lane-change crashes only. The results were consistent across the sets. The AADT, cycle length, and the number of phases within a cycle were statistically significant across all tested options.

Authors	Yue Zhang, Tongji University Yajie Zou, Tongji University Lingtao Wu, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05512
Paper Title	A Linear Poisson Autoregressive Model for Analyzing Dynamic Fatal Traffic Accident Data
Abstract	Annual fatal traffic accident data often demonstrates characteristics of time series. The existing traffic safety analysis approaches (e.g., Negative Binomial (NB) model) often cannot accommodate the dynamic feature in fatal traffic accident data and may result in biased parameter estimation results. In order to consider the time series characteristics of the count traffic accident data, a linear Poisson autoregressive (PAR) model is proposed in this study. The objective of this study is to apply the PAR model to analyze the dynamic impact of traffic laws on the frequency of fatal traffic accident occurred from 1975 to 2016 in Illinois. In addition to the PAR model, the NB model and the autoregressive integer moving average (ARIMA) model are also developed and their performance and impact multipliers are compared. The important conclusions from the modeling results can be summarized as follows: (1) The PAR model outperforms the NB and ARIMA models in terms of analyzing the dynamic influences and fitting performance. The PAR model is more suitable for analyzing the dynamic impact of traffic laws on annual fatal traffic accidents, especially the instantaneous impacts. (2) The law allowing red running leads to an increase in the frequency of annual fatal traffic accidents in both the short and long term. Thus, the modeling results suggest that the PAR model is more suitable for annual fatal traffic accident data and has an advantage in estimating the dynamic impact of traffic laws.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05619
Paper Title	Comparison of Non-Motorist Injury Severities in Rural and Urban Areas in Florida
Abstract	This research investigated significant factors influencing non-motorist injury severities of a single-vehicle crash and spatial clustering of locations of severely injured non-motorists in rural and urban areas in Florida. Mixed logit model with heterogeneity in mean and variance was developed to understand the interrelationship between the different levels of injuries while comprehensively accounting for unobserved heterogeneity within the obtained crash data. Our analysis results showed that there was a significant difference between the variables influencing the injury severity in rural and urban areas involved with non-motorist in single-vehicle crashes. Factors such as non-motorist gender, driver gender, vehicle speed and few more had a significant influence on injury severities in both rural and urban areas, but factors such as nighttime crash time was found to be significant only in rural areas but not in urban areas. Many other factors such as weather and lighting conditions, roadway characteristics, etc. were found to be potentially affecting the likelihood of severe and minor injuries in non-motorist involved single-vehicle crashes. Spatial analysis revealed the locations of clusters in rural and urban areas. Non-motorists severely injured in a single-vehicle crash tend to cluster in urban areas. A majority of urban clusters were observed in Orange, Duval, Pasco, and Pinellas counties. Rural areas experience less clustering. The finding of this study suggests that for a better understanding, the influence of injury severities in the vulnerable group of road users it is required to investigate different types of non-motorist individually in rural and urban areas.

Authors	Tao Tao, University of Minnesota
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05628
Paper Title	Exploring the Pedestrian and Bicycle Crash Risk in Highway Intersections: Systemic Approach Applied in the Twin Cities Metro Area
Abstract	Pedestrians and bicyclists become more vulnerable to the increasing crash risk resulted from the growing auto-dependent development. The pedestrian and bicycle crashes in the highway intersections happened less frequently than those in local streets but could be more severe due to the faster speed of the vehicles, and thus, need more attention. Using the systemic approach, we explored the pedestrian and bicycle crashes in the trunk highway intersections of the Twin Cities metro area. We constructed new crash estimation models with the Negative Binomial Model and searched the high-risk intersections based on the combination of model prediction results and historical crash data. Based on the results, we identified the influential risk factors including vehicular AADT, population density, and traffic facility related and built environment variables. Those risk factors could help to find countermeasures to improve the safety of the highway intersections. The result of the identified high-risk intersections could support the planners or policymakers to prioritize the pedestrian and bicycle facilities planning or improvement projects.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05645
Paper Title	Modeling Pedestrian Injury Severity in Dhaka, Bangladesh
Abstract	This study investigates pedestrian injury severity for Dhaka, Bangladesh. A latent segmentation-based ordered logit (LSOL) model is developed utilizing the police-reported collision records of Dhaka for 2011-2015. Injury severity is modeled in the following three-point ordered scale of: 1) minor injury, 2) major injury, and 3) fatal. The LSOL model is developed to address the ordinal nature of injury severity levels, as well as capture heterogeneity by endogenously distributing pedestrians into discrete latent segments. This study tests the influence of built environment characteristics such as road network configuration, land use, and transportation infrastructure attributes. The LSOL model is estimated for two segments. Model results suggest that segment one can be identified as a high-risk segment; whereas, segment two is a low-risk segment. Parameter estimation results reveal that higher land use mix index, 3-way and 4-way intersections, and mid-block road segments aggravate pedestrians' injury. The model confirms that significant heterogeneity exists across the segments. For instance, collisions occurring at the traffic police controlled intersections in Dhaka are more likely to yield severe pedestrian injury in the high-risk segment. In contrast, the same variable shows a lower likelihood for severe injury in the low-risk segment. The elasticity effect analysis suggests that length of the sidewalk, distance to the railway line, and mid-block road segments show a substantial positive impact on fatality. The findings of this study will assist engineers and planners to develop plans and policies for improving pedestrians' safety in developing countries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-05705
Paper Title	Investigation of Injury Severities in Single-Vehicle Crashes in North Carolina Using Mixed Logit Models
Abstract	Roadway departure (RwD) crashes, comprising run-off-road (ROR) and cross-median/centerline head-on collisions, are one of the most lethal crash types. According to the FHWA, between 2015 and 2017, an average of 52 percent of motor vehicle traffic fatalities occurred each year due to roadway departure crashes. An avoidance maneuver, inattention or fatigue, or traveling too fast with respect to weather or geometric road conditions are among the most common reasons a driver leaves the travel lane. Roadway and roadside geometric design features such as clear zones play a significant role in whether human error results in a crash. In this paper, we used mixed-logit models to investigate the contributing factors on injury severity of single-vehicle ROR crashes. To that end, we obtained five years' (2010- 2014) of crash data related to roadway departures (i.e., overturn and fixed-object crashes) from the Federal Highway Administration's Highway Safety Information System Database. The results indicate that factors such driver conditions (e.g., age), environmental conditions (e.g., weather condition), roadway geometric design features (e.g., shoulder width), and vehicle conditions significantly contributed to the severity of ROR crashes. In addition, it also provides valuable information for traffic design and management agencies to improve roadside design policies and implementing appropriately forgiving roadsides for errant vehicles.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05847
Paper Title	Spatio-Temporal Analysis of Collision Frequency and Injury Severity Involving Unconventional Modes, Pedestrians, and Transit in Dhaka, Bangladesh
Abstract	Road safety is a global concern; particularly, in developing countries due to the significantly high collision occurrences and subsequent deaths. The major reason for the road safety challenges is the limited understanding of the factors that are unique in the context of developing countries, such as the predominant use of unconventional modes. This study presents a spatial and temporal analysis of collision frequency and injury severity of crashes in Dhaka, Bangladesh. The focus is to understand the spatio-temporal trend of collisions involving pedestrians, public transit, and unconventional modes, which are the key collision factors in Dhaka. This research utilizes the police-reported collision record for Dhaka for the years 2011-2015. The temporal analysis suggests that fatalities and major injuries increased by >7% and >31% respectively in the 5-years. Public transit collisions increased from 43.9% to 60.9%. Fatalities among pedestrians and unconventional mode users are 76.6% and 29.8% respectively. The daily distribution suggests that a higher share of severe injuries involving pedestrians (16.6%) and unconventional modes (20.5%) occur on the Fridays and Thursdays respectively. The hourly distribution suggests that pedestrians are more vulnerable from 11:00 am - 12:00 pm on weekends. Unconventional mode users are vulnerable from 7:00 am-8:00 am on weekdays. Spatial analysis is performed adopting a Kernel density estimation technique. The results suggest that the major activity locations of Dhaka such as CBD, airport, business districts, and ferry terminals are collision prone areas. Interestingly, the density of public transit collisions is skewed around the major transit hubs of the city.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Act I, Session 1338; Act II, Session 1339; Act III, Session 1340)
Paper Number	20-06060
Paper Title	Factors Contributing to Single-Vehicle and Multiple-Vehicle Crashes on Express Lane Facilities
Abstract	The objective of this research was to evaluate the safety performance of express lanes by exploring factors contributing to single-vehicle (SV) and multiple-vehicle (MV) crashes on these facilities. The analysis was based on traffic and crash data for the years 2012-2014 from the express lane facilities in California. The probabilistic relation among the factors that contribute to SV and MV crashes was evaluated using a Bayesian Network (BN) model. A Bayesian logistic regression model with a random effect parameter was first used to identify significant variables which were used as input in the BN model. The BN was trained using the Bayesian Dirichlet equivalent uniform as a scoring function. The maximum likelihood estimation method was hence used for parameter learning and probabilistic inference. The results indicated that, when considering individual scenarios, concrete barrier separation, wet road surface condition, nighttime condition, and weekend were found to be the major contributing factors for SV crashes. MV crashes were found to be associated with pylon separation, weekdays, and daytime condition. With the combination of the scenarios, the maximum possible probability of MV crashes was expected when: the road surface condition is dry, rolling/mountainous terrain, during daytime, on weekday, whereby the separator type is pylon. A combination of wet, rolling/mountainous terrain, nighttime, weekend, and double solid white line separation resulted in the highest probability of SV crashes. The proposed BN model may be used to evaluate the safety performance of express lane facilities following the installation of a countermeasure.

5 Crash Severity Prediction

Alfonso Montella, Filomena Mauriello, and Maria Rella Riccardi
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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 **fifty-three 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 2020 (19 in 2012, 25 in 2013, 16 in 2014, 29 in 2015, 24 in 2016, 41 in 2017, 40 in 2018, 52 in 2019, and 53 in 2020), 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: 1339 Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods (Monday 3:45 PM – 5:30 PM), 1356 Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored (Monday 6:00 PM – 7:30 PM), and 1358 Focus on Pedestrian and Bicycle Safety (Monday 6:00 PM – 7:30 PM).

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 (20-00957, 20-02955, 20-04054, 20-04771, 20-04902, 20-05079, 20-06009);
- Multinomial logit model (20-00948, 20-00951, 20-00955, 20-02263, 20-04801);
- Random parameters (mixed) logit model (20-00424, 20-00597, 20-01296, 20-05079);
- Bayesian multinomial logit model (20-05172);
- Bayesian mixed logit model (20-01893, 20-05079);
- Firth's penalized-likelihood logistic regression model (20-02123), and
- Multivariate regression model (20-03374, 20-05153).

The following ordered regression modeling approaches were used:

- Ordered logit model (20-01906, 20-02263, 20-04801, 20-05220);
- Random parameters (mixed) ordered logit model (20-02652, 20-04251, 20-04254, 20-05705);
- Random parameters (mixed) ordered logit model with Heterogeneity in Means and Variances (20-04097, 20-05256, 20-05619);
- Latent segmentation-based logit (LSOL) model (20-05645);
- Partial proportional odds (PPO) logit model (20-02168, 20-04801, 20-04902);
- Generalized ordered logit model (20-03424);
- Latent class ordered probit model (20-01934)
- Ordered probit model (20-01155, 20-04054);
- Bivariate Ordered probit model (20-00392, 20-03523);
- Random parameters (mixed) ordered probit model (20-05700)
- Multivariate Poisson-Lognormal (20-00467,
- Hierarchical ordered probit model (20-02482, 20-04782); and
- Zero-inflated hierarchical ordered probit model with correlated disturbances (20-01221).

Some papers used data mining techniques, such as:

- Bayesian Network Approach (20-01580, 20-05172);
- Crash Tree Analysis (20-03791);
- Fusion Convolutional Neural Network with Random Term (FCNN-R) model (20-02587)
- Generalized Structure Equation Models (GSEM) (20-03930); and
- Structure Equation Models (SEM) (20-02801).

One paper used a Multivariate Poisson-Lognormal (MVPLN) model to estimate the crash counts by different severity levels simultaneously and a Joint Negative Binomial - Generalized Ordered Probit Fractional Split (NB-GOPFS) model to jointly estimate total crash counts and crash proportions by severity level (20-00467). Two papers combined Negative Binomial and Multinomial Logistic regression (MNL) to investigate Injury Severity (20-00951, 20-00955).

One paper used data mining techniques and discrete choice models (20-01296) by a two-step method integrating data mining tools and multinomial random parameter logit model.

One paper (20-02587) proposed a fusion convolutional neural network with random term (FCNN-R) model consisting of a set of sub-neural networks (sub-NNs) and a multi-layer convolutional neural network (CNN). Then, a comparison of FCNN-R model results with the multinomial model, the neural network, the CNN model, and a fusion convolutional neural network model shows that the proposed model outperforms all the other methods.

One paper used pseudo elasticity analysis to investigate significant impact factors and the temporal stability of model specifications via a likelihood ratio test (20-02847).

Two papers used Support Vector Machine algorithms (SVM) for crash severity analysis. One paper optimized the SVM using the firefly algorithm (20-05997). One paper proposed a non-parametric machine learning approach that use the Support Vector Machine and improves the model performance by statistical analysis (Binary logit) (20-02955).

Two papers proposed quasi-induced exposure technique (QIE)(20-04254, 20-04597). One of these proposed a combined use of quasi-induced exposure technique to measure the relative crash exposures in two-vehicle hit-and-run and nonhit-and-run crashes and random parameter ordered logit model to reveal the discrepancy of the factors attributing to the injury risk of the drivers involved in hit-and-run and nonhit-and-run crashes (20-04254).

A paper proposed taxicab correspondence analysis (TCA) to investigate the complex interaction between multiple factors under a two-dimensional map (20-04592).

A paper used spatio-temporal analysis of collision frequency and injury severity (20-05847) to understand the spatio-temporal trend of collisions involving pedestrians. Another paper used the combined proactive and reactive approach to assess pedestrian safety (20-05873).

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

- Environmental factors (20-00392, 20-00424, 20-00597, 20-00948, 20-00951, 20-00955, 20-00957, 20-01221, 20-01934, 20-02168, 20-02263, 20-02482, 20-02652, 20-02801, 20-02847, 20-03374, 20-03424, 20-03930, 20-04054, 20-04097, 20-04251, 20-04592, 20-04771, 20-04782, 20-04902, 20-05079, 20-05256, 20-05172, 20-05220, 20-05619, 20-05641, 20-05705, 20-05997, 20-06009);
- Highway characteristics (20-00424, 20-00467, 20-00948, 20-00951, 20-00955, 20-00957, 20-01155, 20-01296, 20-01580, 20-01934, 20-02123, 20-02168, 20-02263, 20-02482, 20-02652, 20-02801, 20-02847, 20-02955, 20-03424, 20-03930, 20-04054, 20-04251, 20-04592, 20-04902, 20-05153, 20-05172, 20-05619, 20-05641, 20-05645, 20-05700, 20-05705, 20-05997, 20-06009);
- Road users' characteristics and behaviour (20-00392, 20-00424, 20-01155, 20-01221, 20-01580, 20-01934, 20-02168, 20-02263, 20-02482, 20-02652, 20-02801, 20-02847, 20-03374, 20-03424, 20-03523, 20-03930, 20-04054, 20-04097, 20-04251, 20-04254, 20-04592, 20-04597, 20-04771, 20-04801, 20-04902, 20-05079, 20-05256, 20-05153, 20-05172, 20-05220, 20-05619, 20-05700, 20-05705, 20-05997, 20-06009);
- Roadside features (20-01296, 20-02123, 20-05705, 20-05997);
- Traffic control devices (20-00951, 20-00955, 20-01221, 20-01296, 20-01893, 20-01906, 20-02263, 20-02482, 20-02847, 20-04592, 20-04782, 20-05079, 20-05220, 20-05641, 20-05645, 20-06009);
- Traffic characteristics (20-00392, 20-00424, 20-00948, 20-00951, 20-00955, 20-00957, 20-01155, 20-01221, 20-01296, 20-01906, 20-02482, 20-02652, 20-02801, 20-02847, 20-04054, 20-04254, 20-04597, 20-04782, 20-05256, 20-05153, 20-05172, 20-05220, 20-05847, 20-05873, 20-05997);

- Vehicle characteristics (20-00424, 20-00467, 20-00597, 20-01155, 20-01221, 20-02168, 20-02482, 20-02587, 20-02652, 20-02801, 20-03424, 20-03523, 20-04097, 20-04251, 20-04254, 20-04592, 20-04597, 20-04771, 20-04801, 20-05079, 20-05256, 20-05153, 20-05172, 20-05705, 20-05873, 20-05997); and
- Workzone characteristics (20-00424, 20-01580).

The papers investigated also **vulnerable road users**, such as:

- Cyclists (20-01934, 20-02263, 20-05153, 20-05700);
- Motorcyclits (20-01296, 20-04771, 20-05079); and
- Pedestrians (20-02263, 20-05172, 20-05645, 20-05847, 20-05873, 20-06009).

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

Authors	Jia Yang, Toyota Transportation Research Institute Peng Ren, China Academy of Transportation Sciences Ryosuke Ando, Toyota Transportation Research Institute
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-00392
Paper Title	Examining Drivers` Injury Severity of Two-Vehicle Crashes between Passenger Cars and Light Motor Trucks
Abstract	This study aims to investigate the important factors affecting the drivers` injury severity of two-vehicle crashes between passenger cars (PCRs) and light motor trucks (LMTRs). To consider the difference in crash pattern between elder drivers and non-elder drivers, 889 vehicle crash data for elder LMTR drivers and 4,690 vehicle crash data for non-elder LMTR drivers in Fukuoka Prefecture, Japan is used as the research sample. The injury severity of PCRs with LMTRs for elder drivers and that for non-elder drivers are modeled by two bivariate ordered probit models, respectively. Each ordered probit model in a bivariate ordered probit model is used to measure the injury severity of one driver, and the covariance measures the correlation of injury severity. The major findings suggest: 1) that weather condition, traffic condition, manner of collision have different effects for injury severity of LMTR drivers in two types of crashes; 2) that time of day and road level do not have any effects for injury severity of LMTR drivers in two types of crashes; 3) that the injury severity of two drivers involved in two types of crashes are negatively correlated, since two crash patterns i.e. no injury with minor injury and minor injury with no injury accounted for large ratios inside two types of crashes, which indicated that there is only one driver injured in most crashes of PCRs with LMTRs.

Authors	Mouyid Islam, University of South Florida Fred Mannering, University of South Florida Nawaf Alnawmasi, University of South Florida
Sponsoring Committee	Standing Committee on Statistical Methods (ABJ80)
Session Number	1098
Session Title	Emerging Methods in Statistical and Econometric Modeling
Paper Number	20-00424
Paper Title	Unobserved Heterogeneity and Temporal Instability in the Analysis of Work Zone Crash-Injury Severities
Abstract	In the State of Florida, work-zone related crashes and their resulting injury severities have been increasing recently, particularly over the 2015 to 2017 time period. In the current study, we seek provide insights into the factors that have been influencing this trend. Using work zone data from the 2012 to 2017 time period, resulting driver-injury severities in single-vehicle work zone crashes were studied using random parameters logit models that allow for possible heterogeneity in the means and variances of parameter estimates. The available data included a wide variety of factors known to influence driver injury severity including data related to the crash characteristics, vehicular characteristics, roadway attributes, prevailing traffic volume, driver characteristics, and spatial and temporal characteristics. The model estimates produced significantly different parameters for the 2012-14 time period versus the 2015-17 time period, and a fundamental shift in unobserved heterogeneity, suggesting statistically significant temporal instability. In addition, in several key instances, the marginal effects of individual parameter estimates show marked differences between these two time periods. The model estimation findings add to the growing body of literature that suggests that driver behavior has been changing in fundamental ways in recent years, and that this change could have profound effects on the safety performance of new vehicle and highway-safety technologies as well as various policy-related safety countermeasures.

Authors	Kai Wang, University of Connecticut Tanmoy Bhowmik, University of Central Florida Shanshan Zhao, University of Connecticut Naveen Eluru, University of Central Florida Eric Jackson, University of Connecticut
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-00467
Paper Title	Assessment of Statistical Methodologies for Crash Prediction by Severity
Abstract	Predicting crash counts by severity plays a dominant role in identifying roadway sites that experience overrepresented crashes, or an increase in the potential for crashes with higher severity levels. The results of this process allow for the implementation of effective countermeasures to improve highway safety. This paper uses urban & suburban intersection data in Connecticut, along with two commonly used modeling approaches, to accommodate for the unobserved factors in predicting crash counts by severity level. Specifically, a Multivariate Poisson-Lognormal (MVPLN) model is used to estimate the crash counts by different severity levels simultaneously. A Joint Negative Binomial - Generalized Ordered Probit Fractional Split (NB-GOPFS) model is used to jointly estimate total crash counts and crash proportions by severity level. Furthermore, crash prediction models based on vehicle damage level are estimated using the two methodologies. These models can be used to supplement the injury severity in estimating crashes by severity when the sample mean of severe injury crashes is very low. The model estimation results highlight the presence of correlations of crash counts among severity levels, as well as the crash counts in total and crash proportions by different severity levels. A comparison of results indicates that injury severity and vehicle damage are highly consistent. This finding suggests that when crash data samples have challenges associated with the low observed sampling rates for severe injury crashes, vehicle damage can be appropriate as an alternative to injury severity in crash prediction by severity.

Authors	Majbah Uddin, Oak Ridge National Laboratory Nathan Huynh, University of South Carolina
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	1341
Session Title	Truck and Bus Safety Research
Paper Number	20-00597
Paper Title	Injury Severity Analysis of Truck-Involved Crashes under Different Weather Conditions
Abstract	This paper investigates truck-involved crashes to determine the statistically significant factors that contribute to injury severity under different weather conditions. The analysis uses crash data from the state of Ohio between 2009 and 2013 available from the Highway Safety Information System. To determine if weather conditions should be considered separately for truck safety analyses, parameter transferability tests are conducted; the results suggest that weather conditions should be modeled separately with a high level of statistical confidence. To this end, three separate mixed logit models are estimated for three different weather conditions: normal, rain and snow. The estimated models identify a variety of statistically significant factors influencing the injury severity. Different weather conditions are found to have different contributing effects on injury severity in truck-involved crashes. Rear-end crashes, dark-lighted, time of crash and asphalt pavement were found to be factors that have significantly different levels of impact on injury severity in truck-involved crashes. Findings from this study can help traffic safety engineers, transportation planners and policy makers identify appropriate countermeasures to reduce the number and severity of truck-involved crashes under different weather conditions.

Authors	Kahlil Andrews, Tennessee State University Deo Chimba, Tennessee State University Suleiman Swai, Tennessee State University
Sponsoring Committee	Standing Committee on Highway/Rail Grade Crossings (AHB60)
Session Number	1424
Session Title	Research on Highway-Rail Grade Crossings
Paper Number	20-00948
Paper Title	Statistical Screening of Rail Crossing Related Crashes and Injury Severities in Tennessee
Abstract	The study investigated highway-railroad grade crossing crashes and injury severities in the state of Tennessee. Research used year 2017railroad crash and incident data obtained from the Tennessee Department of Transportation (TDOT). It was found that 550 different types of this type of crashes occurred in 2017. Crashes were categorized in five injury severity levels with 1.6% being fatal, 71% PDO (over $400), 7% PDO (under $400), 18% were suspected minor injury and 2.4% were suspected serious injury. Two models were used to evaluate the factors associated with these highway-railroad grade crossing injury crashes including Multinomial Logit (MNL) and Negative Binomial (NB). The MNL results showed that the accidents which occurs during the day are likely to result in lower injury severity than the base (serious injury/fatal), the odds are nearly 7 times for PDO under and 5 times for minor injury. For crash in dark crossings without light there is high probability of resulting in minor severity with 280% and 99% more likely to be PDO under and PDO over respectively. When vehicles collides in rear end and angle collision have high probability of resulting in serious injury or fatal injury severity. Negative Binomial model results showed that as the traffic volume increases the crash frequency is likely to increase, also as the directional distributional of traffic increases the probability of crash occurrence also increases. Based on these findings, installation of lighting near rail-road crossings is recommended as a countermeasure to reduce these types of crashes and lower the severities.

Authors	Cam'Ron Mckinney, Tennessee State University Christian Mbuya, County of Modoc Road Department Deo Chimba, Tennessee State University Suleiman Swai, Tennessee State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-00951
Paper Title	Analysis and Modelling of Ramp Related Crashes in Tennessee
Abstract	The study analyzed ramp related crashes in Tennessee. The paper identified explanatory variables that were significant predictors of crash frequency and injury severity Using NB and MNL. The analysis showed that factors which tend to significantly increase ramp related crash frequency includes: rural and commercial land use areas, crashes that occur during morning, ramps with posted speed limits between 35 mph to 45 mph, and high traffic (AADT) locations. The study found that most of the ramp-related crashes (77.7%) are Property damage only compared to evident injury, incapacitating injuries or fatal. Crashes due to a vehicle hitting the guardrails are highly likely to result in PDO, the odds of sustaining evident injuries is 14% less likely compared to PDO/Base injury. With each crash due to an overturned vehicle, the odds of evident and fatal injuries will increase by 93% and 265% respectively. The study also indicates that crashes occurring during day time and on weekdays are less likely to result in fatal crashes and the odds of the severity being fatal/incapacitating injury will decrease by 30.2% for each crash occurring during the day and 17% in weekday. Rear end and angle collision compared to sideswipe collision will increase the odds of evident injury by 21.6% and 24.3% respectively. Also, rural and commercial land uses, high speed limits, AADT and DHV have shown to significantly increase crash frequency while low speed limit, residential land use and fewer number of lanes have shown to decrease crash frequency.

Authors	Dominique Wallace, Tennessee State University Tinotenda Jonga, Tennessee State University Deo Chimba, Tennessee State University Suleiman Swai, Tennessee State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-00955
Paper Title	Rural Intersection-Related Crashes and Injury Severities in Tennessee
Abstract	This study focuses on intersections in a rural context within the State of Tennessee for a 5-year period (2011-2015). The importance of this paper lies in the fact that rural intersections and roads are seldom considered in transportation safety strategies as compared to urban roads and intersections. For a state such as Tennessee which is mostly rural, the study is highly essential. 5-year crash data were obtained from Tennessee Department of Transportations' (TDOT) database. A negative binomial (NB) model was used to determine the relationship between crash frequency and the investigated independent variables. Injury severity was categorized into four different levels and Multinomial Logit (MNL) model was used for the analysis. IBM SPSS Statistics software and MS Excel were utilized, and the resulting models were assessed. It was found that high AADT, absence of illumination, fringe & commercial, the high number of lanes and arterial roads were associated with an increase in crash frequency. But collector roads, low speeds, residential land uses, and presence of illumination were associated with low crash frequency. At rural intersections, the total number of vehicles involved, absence of intersection lighting, manner of collision such as head-on collisions showed higher severity. While rear-end crashes, harsh weather conditions, adequate lighting and crash due to collision with ditch showed lesser injury severity (PDO). Based on these findings, a recommendation can be proposed to lessen injury severity by installing adequate lighting for all the rural intersections in Tennessee and moderating speed limits to reduce crash frequency.

Authors	KeAnna Dakwa, Tennessee State University Ethan Messimore, Tennessee State University Deo Chimba, Tennessee State University Suleiman Swai, Tennessee State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-00957
Paper Title	Analyzing the Traffic Circles as they Pertain to Crash Severity
Abstract	The study used Binary logistic regression and Negative Binomial regression to assess the injury severity and crash frequency on the traffic circles at three regions in the state of Tennessee. The data were obtained from E-Trims then MS excel and Stata were used for the analysis. Angle/head-on collisions have shown to have high likelihood (more than 4 times) of resulting in injury/fatal severity than PDO. For rear end crashes the odds are 60% more on injury/fatal severity while for side-swipe collision the odds are 83% in favor of PDO. Also, for each additional car involved in a crash there is 73% more chance that it will result in PDO severity compared to injury/fatal. Crashes which occurs in unclear weather are likely to result in injury /fatal severity than PDO, the odds are 7% more in injury/fatal than PDO. While For crashes which occurs on weekend, during entering the traffic circle and in no light condition there is high probability of resulting in injury/fatal severity category than PDO and odds are 115%, 112% and 111%respectively. From Negative Binomial model it shows having multiple lanes, high traffic volume and high percentage of passenger cars in the traffic circle increases the crash frequency. Furthermore, the model results show the directional hourly distribution has a negative coefficient which shows as the directional distribution increases the likelihood of crash frequency decreases. Transportation engineers and planners can use the results in their recommendations and design plans for safer traffic circles.

Authors	Younshik Chung, Yeungnam University Jong-Jin Kim, Yeungnam University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-01155
Paper Title	Injury Severity Analysis of Crashes in Korean Freeway Tunnels: An Application of an Ordered Probit Model
Abstract	Roadway tunnels are generally used to overcome complex driving environments in mountainous terrain. However, crashes that occur in these tunnels have can be more severe than those in open road sections. Moreover, crashes and fatalities in Korean freeway tunnels have respectively increased annually by 4.2% and 21.3% from 2013 to 2017. However, there has been no effort to analyze the injury severity of tunnel crashes in Korean freeway systems, and only a few such studies have been conducted in other countries. Therefore, the objective of this study is to explore factors that affect the injury severity of such crashes in the Korean freeway system. This objective was achieved using an ordered probit model and five years of tunnel crash data (2013-2017) for the entire Korean freeway system. The analysis results show an increasing probability of severe injuries due to crashes by older drivers (40+ years), crashes from drowsy driving, rear-end collisions, secondary crashes, rollover after crashes, bus-involved crashes, truck-involved crashes, crashes in exit zones, crashes in longer tunnels, crashes in the month of March, and crashes with more vehicles involved. However, crashes on a wet tunnel surface and single-vehicle crashes were associated with lower probability of severe injuries.

Authors	Grigorios Fountas, Edinburgh Napier University Achille Fonzone, Edinburgh Napier University Niaz Gharavi, Edinburgh Napier University Tom Rye, Edinburgh Napier University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources
Paper Number	20-01221
Paper Title	The Joint Effect of Weather and Lighting Conditions on Injury Severities of Single-Vehicle Accidents
Abstract	This study seeks to identify and analyze variations in the effect of contributing factors on injury severities of single-vehicle accidents across various lighting and weather conditions. To that end, injury-severity data from single-vehicle, injury accidents occurred in Scotland, United Kingdom in 2016 and 2017 are statistically modeled. Upon the conduct of a likelihood ratio test, separate models of accident injury severities are estimated for various combinations of weather and lighting conditions taking also into account the presence and operation of roadside lighting infrastructure. To account for the possibility of unobserved regimes underpinning the injury-severity mechanism, the zero-inflated hierarchical ordered probit approach with correlated disturbances is employed. The approach also relaxes the fixed threshold restriction of the traditional ordered probability models and captures systematic unobserved variations between the underlying regimes. The model estimation results showed that a wide range of accident, vehicle, driver, trip and location characteristics have varying impact on injury severities when different weather and lighting conditions are jointly considered. Even though several factors are identified to have overall consistent effects on injury severities, the simultaneous impact of unfavorable weather and lighting conditions is found to introduce significant variations, especially in the effect of vehicle- and driver-specific characteristics. The findings of this study can be leveraged in vehicle-to-infrastructure or in-vehicle communication technologies that can assist drivers in their responses against hazardous environmental conditions.

Authors	Bahar Dadashova, Texas A&M Transportation Institute Chiara Silvestri-Dobrovolny, Texas A&M University System Marcelina Perez, Texas A&M University System Jayveersinh Chauhan, Texas A&M University System Roger Bligh, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	1126
Session Title	Current Research in Motorcycle Safety—Hybrid Session
Paper Number	20-01296
Paper Title	Severity Analysis of Roadway Departure Motorcycle Crashes As They Relate to Roadside Fixed Objects and Safety Systems
Abstract	Past years have witnessed a significant rise in the use of a motorcycle as a vehicle to commute due to various reasons. With an increasing number of motorcycles on the road, there is an urgent need to consider motorcycle safety as one of the important aspects while designing roadside safety systems. Data suggests that the fatalities related to motorcycle impact against roadside safety devices and fixed objects are greater than those from the impact of passenger cars users against the same roadside safety devices. The objective of this paper is to assess the severity of roadway departure (RwD) motorcycle crashes involving roadside fixed objects and safety devices. The secondary objective of the paper is to provide guidelines for the selection of high-risk locations for further improvement. We have used data mining and multinomial random parameter logit model to conduct exploratory and inferential data analysis. The results of both data mining and data analysis show that roadside safety devices and fixed objects have a significant impact on RwD motorcycle crash severity. Additionally, roadway characteristics (horizontal and vertical curvature, lane width, urban-rural classification) and operational factors (traffic volume and posted speed limit) are found to be associated with the RwD motorcycle crash severity. Hence, to identify the high-risk locations (i.e., locations with potential for improvement) these roadway elements need to be accounted for

Authors	Yaochao Song, Southeast University Siyuan Kou, Southeast University Chen Wang, Southeast University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-01580
Paper Title	Modeling Crash Severity by Considering Risk Indicators of Driver and Roadway: A Bayesian Network Approach
Abstract	Traffic crashes could result in property damage, injury and death, and cost billions of dollars every year. The severity of crashes could be affected by various factors and a good understanding of those factors is of practical importance. In this study, some new risk indicators of road users and roadways were developed based on prior violation and crash records (e.g., cumulative crash frequency of a roadway), in order to reflect certain aspect or degree of their driving risk. To explore the impacts of those indicators on crash severity and complex interactions among all contributing factors, a Bayesian network approach was adopted, based on citywide crash data collected in Kunshan, China from 2016 to 2018. A variable selection procedure based on information value was developed to identify significant variables, and the Bayesian network was employed to explicitly explore statistical associations between crash severity and significant variables. In terms of balanced accuracies and AUCs, the proposed approach performed reasonably well. Bayesian network reference analyses indicated that the risk indicators of road users and roadways significantly affected crash severity and uncovered some hidden risk patterns. For example, migrant workers tend to have high injury risk due to their dangerous violation behaivors, such as retrograding, red-light running, and right-of-way violation. Results also showed that some combinations of variables had larger impacts on severity outcome than single variables. The proposed methodology and modeling results provide insights for developing effective countermeasures to reduce crash severities and improve traffic system safety performance. Keywords: Bayesian network, Information value, Crash severity, Risk indicators

Authors	Zulqarnain H. Khattak, Oak Ridge National Laboratory Michael D. Fontaine, VTRC
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-01893
Paper Title	Injury Severity Effects of an Active Traffic Management System Using Bayesian Modeling
Abstract	Active traffic management (ATM) systems have been used by transportation agencies to dynamically manage recurrent and non-current congestion based on real-time conditions. While these systems have been shown to have some safety benefits, their impact on injury severity outcomes is currently uncertain. This paper used full Bayesian mixed logit models to quantify the impact of an ATM deployment on injury severity outcomes. The estimation results revealed that ATM deployment was associated with reductions in injury severity levels. Marginal effects showed that ATM that featured hard shoulder running (HSR) reduced the propensity of severe plus moderate injury crashes by 15.9% and the propensity of minor injury crashes by 10.1%. ATM without HSR produced reductions in the propensity of severe plus moderate and minor injury crashes by 12.4% and 8.33%, respectively. The model performed well on validation data with a low forecast error of 0.301 and 0.304 for the two models.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-01906
Paper Title	Investigation of Crash Precursors of Collision Type and Crash Severity in the Framework of Three-Phase Traffic Flow Theory
Abstract	Based on three-phase traffic flow theory, this study explored the crash precursors to rear-end/sideswipe collisions and severe crashes on freeways by logistic and ordered logistic regression respectively. Based on the 5-year crash data and traffic data from a freeway section on the Interstate 880 in California, the regressions were developed for each traffic states. The results showed that the factors contributing to collision types and crash severity were quite different across various traffic states. The difference in vehicle speed over time lead to the increase of rear-end collision probability in free flow, while lead to the increase of sideswipe collision probability in the transition from free flow to synchronized flow. The standard deviation of detector occupancy makes the crash lighter in free flow but more serious in transition from synchronized flow to wide moving jam. The three-phase traffic flow theory can help us better understand the mechanism of crash occurrences in various traffic states. The results suggested that the heterogeneity between different traffic states should be considered when designing control measures to prevent serious or certain types of crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-01934
Paper Title	How and What Factors Influence the Injury Severity in Single-Bicycle Crashes
Abstract	Even though cyclist crashes are primarily single-bicycle crashes, the majority of research in the field of bicyclist's injury severity relates to bicycle-motor vehicle crashes. This study explores the use of a latent class ordered probit framework to model the injury severity of cyclists subject to single-bicycle crashes. This method allows us to address heterogeneity arising from unobserved groups in the crash population. Hereby this study provides novel insight on the factors contributing to the injury severity of cyclists, subject to single-bicycle crashes. The study uses single-bicycle crash data obtained through medical records data merged with road data collected by the municipality Aarhus in the period between 2010-2015. The data provides 3 severity classes: severe, slight, 'no evident injury' The presented model proves statistically superior to a regular ordered probit. The estimation procedure arrives at 4 latent classes to best describe the data. Which reveal older women to be associated with the highest baseline likelihood of severe injuries and young women the lowest. The unconditional results reveal several factors to more than double the likelihood of severe injury, with all other variables kept constant. These results highlight factors surrounding the bicycle lane and the maintenance thereof. Specifically; bad or adequate maintenance of bicycle lane, lack of bicycle lane, crazing or fretting and the road being to blame, but also darkness and winter conditions. Notably the results also imply that the bicyclist's behaviour being at fault for the accident greatly increases the likelihood of severe injury.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-02123
Paper Title	A Penalized-Likelihood Approach to Characterizing Bridge-Related Crashes in New Jersey
Abstract	A roadway departure crash is one in which a vehicle crosses an edge line, a centerline, or otherwise leaves the traveled way. These crashes that involve run-off-road and cross-median/centerline head-on collisions tend to be more severe than other crash types. According to the NHTSA Fatality Analysis Reporting System database, a total of 7,833 people perished in crashes involving fixed roadside objects in 2017, accounting for 21 percent of the total number of fatalities in the United States. Several studies have reported that rural bridge-related crashes result in more fatalities due to their being mostly the fixed-object crash type. As such, further in-depth investigation of this type of crash is necessary. Due to the lack of a comprehensive database that includes bridge-related crashes and bridge characteristics, identifying the key factors contributing to this type of crash is a challenging task that is addressed in this paper. We gathered and compiled five years of crash data from the New Jersey crash database and the characteristics of bridges from the Long-Term Bridge Performance portal. A Firth's penalized-likelihood logistic regression model was developed to examine the influence of explanatory variables on crash severity. This model is an appropriate tool for controlling the influence of all the confounding variables on the probability of bridge-related crashes while considering the rareness of the event. Based on the obtained odds ratio, the various effects of the identified variables are discussed and recommendations made regarding countermeasures policymakers can establish to reduce the number of these crashes in New Jersey.

Authors	Pengfei Liu, University of North Carolina at Charlotte Yi Qi, Texas Southern University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	1341
Session Title	Truck and Bus Safety Research
Paper Number	20-02168
Paper Title	Analyzing Injury Severity of Large Truck Crashes Using a Partial Proportional Odds Model: A Case Study in Texas
Abstract	Large truck crashes have considerable economic and societal impacts. To prevent and mitigate large truck crashes, the contributing factors that significantly affect the injury severity of large truck crashes need to be identified before the appropriate countermeasures can be explored. For this purpose, a partial proportional odds (PPO) model is developed to investigate the factors that influence the injury severity of large truck crashes. The analysis is performed based on data collected from Texas Crash Records Information System (CRIS) from 2011 to 2015. The dataset contains a total of 75,778 large truck crashes with information about driver, vehicle, roadway, and environmental characteristics for each crash. The results of this research demonstrate that driving under influence of alcohol or drugs, fatigue, rural roadways, grade or curve roadway configurations, fog, and dark light condition could increase the severity of large truck crashes. Ice surface condition, roadways with median, and rain/snow could decrease the severity of large truck crashes.

Authors	Yaa Acquaah, North Carolina Agricultural and Technical State University John Vine-Hodge, North Carolina Department of Transportation Hyoshin Park, North Carolina Agricultural and Technical State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-02263
Paper Title	Development of Multinomial and Ordinal Logistic Models for Bicyclist and Pedestrian Crashes across Divisions 13 and 14 of North Carolina
Abstract	Pedestrians and bicyclists can be put in the category of vulnerable road users due to lack of traffic protection. The State of North Carolina Division of Highways 13 and 14 recorded 61.6% and 58.6% of pedestrian crashes respectively because of an absence of traffic controls between 2007 to 2016. In this study, exploratory analysis for pedestrian and bicyclist crashes in highway divisions 13 and 14 is performed to understand the trends in the environment variables of these crashes. Eleven locations in highway division 13 were identified to be hotspots for pedestrian and bicyclist crashes. Six locations in highway division 14 were also identified as hotspots for pedestrian and bicyclist crashes within the study period. Multinomial logit and ordinal logistic models were used to examine the contribution of several environmental key factors to the injury severity of bicyclists crashes. The multinomial logit model results identified motorist left turn – opposite direction crash type, intersections, weekdays, traffic control, clear weather and dry road condition as more likely to result to injuries relative to fatal and disabling injury crashes. The developed ordinal logistic regression model results revealed that bicyclists age group 30-39 who are involved in motorist left turn – opposite direction crashes where there are no control present on weekdays on dry roads are more likely to suffer fatal and disabling injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-02482
Paper Title	Single-Vehicle Truck Accidents: An Analysis of Injury Severity in The Context of Developing Countries
Abstract	Freight movement plays a vital role in economic development, especially for developing countries. However, an increment in truck movements in Iran due to the economic growth has increased roadway safety issues. Although there have been sizable efforts to investigate the severity of truck-involved accidents, the influential factors on the severity of single-vehicle truck accidents are not clearly understood. This study aims to uncover significant factors associated with injury severities sustained by truck drivers in single-vehicle truck accidents in the context of developing countries. It uses 2011 Iran road accident data from the Iranian Traffic Police. Based on this data, several contributing factors including truck driver characteristics, accident-related variables, truck features, roadway variables, and temporal characteristics are determined, and their influence on the severity of single-vehicle truck accidents are explored. Accounting for the threshold heterogeneity, a hierarchical ordered probit model is utilized to predict the likelihood of three injury severities: property damage only, body injury, and fatal. The likelihood test shows the statistical superiority of the hierarchical ordered probit model as compared to the ordered probit model. Marginal effects are also computed to accurately interpret the effect of significant variables on injury severity outcomes. According to the results, factors such as driver age, accident types, seasons, the presence of different curve types, roadway classification, and speed limit contribute to the severity of the accidents. The findings of this study can be helpful for transportation authorities to mitigate the severity of single-vehicle truck accidents by performing efficient safety countermeasures.

Authors	Hao Yu, University of Hawai'i, Manoa Zhenning Li, University of Hawai'i at Manoa Runze Yuan, University of Hawai'i at Manoa Guohui Zhang, University of Hawai'i at Manoa David Ma, University of Hawai'i at Manoa
Sponsoring Committee	Standing Committee on Statistical Methods (ABJ80)
Session Number	1279
Session Title	New Challenges in Transportation Data Analysis
Paper Number	20-02587
Paper Title	Driver Injury Severity Prediction Using Highway Single-Vehicle Crash Data: A Fusion Convolutional Neural Network Approach
Abstract	In this study, a fusion convolutional neural network with random term (FCNN-R) model is proposed for driver injury severity analysis. The proposed model consists of a set of sub-neural networks (sub-NNs) and a multi-layer convolutional neural network (CNN). More specifically, the sub-NN structure is designed to deal with categorical variables in crash record; multi-layer CNN structure captures the potential nonlinear relationship between impact factors and driver injury severity outcomes. Seven-year (2010-2016) single-vehicle crash data acquired from Washington State is applied in this study. The whole dataset is divided into three parts, which are the training set, the validation set, and the test dataset. Different model with difference number of CNN layers are tested using the validation set, as well as different model layouts with or without dropout layer and regularization term in objective function. It is found that different model layouts provide reasonable predictive performance. With the limited training data, more CNN layers result in the prematurity of the training procedure. Moreover, it is found that the dropout layer and the regularization technique help improve the stability of the effects of different variables. Comparisons are also conducted between the proposed model and four typical approaches, including the multinomial model, the neural network, the CNN model, and a fusion convolutional neural network model. The comparison results show that the proposed model outperforms all the other methods. Future research is recommended to include more information for improving predictive performance.

Authors	Cristopher Aguilar, Arizona Department of Transportation Emmanuel James, Northern Arizona University Brendan Russo, Northern Arizona University Edward Smaglik, Northern Arizona University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-02652
Paper Title	Examination of Factors Affecting Injury Severity in Crashes Occurring on Interstate Freeways by Vehicle Type: Analysis of the Arizona Megaregion
Abstract	According to the Arizona Department of Transportation (ADOT), the annual number of traffic crash fatalities has generally been increasing in recent years in the state of Arizona. With a continuously growing population and consequently more vehicles on the road, it is imperative to identify and analyze factors that affect injury severity when crashes occur, particularly those occurring on high-speed freeways. To examine this issue, this study utilized Arizona crash data for the years 2010 through 2017 to analyze factors affecting the injury severity of persons involved in crashes on occurring on interstate freeways in the Arizona megaregion. This is accomplished through estimation of random parameters ordered logit models to investigate the effect of several person, vehicle, crash, roadway, traffic, and environmental variables on the injury severity of crash-involved persons. Since crash characteristics may vary significantly depending on types of vehicles involved, separate models were estimated for crashes involving only passenger vehicles, crashes involving freight vehicles (e.g. large trucks), and crashes involving motorcycles. Several variables including crash type, roadway geometry characteristics, and person-related variables, among several others, were found to be significantly associated with injury outcomes, and those variables and their effects varied by vehicle type involvement. The findings presented in this study provide insights which can be used to assist in developing and planning countermeasures aimed at improving freeway transportation safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-02801
Paper Title	Investigating the Severity of Crashes from NAIS Database in China Using Structural Equation Modeling
Abstract	This study aimed to investigate the characteristics of NAIS crash database and analyse the level of crash severity based on various aspects of crashes. The crash data were collected from NAIS (National Automobile Accident In-Depth Investigation System) set up by China's General Administration of Quality Supervision, Inspection and Quarantine. The descriptive statistics were employed to investigate the severity of crash happened in China in terms of information about the collision, driver, passenger, environment, road, vehicle conditions, traffic conditions and treatment of accident participants. Structural equation modeling(SEM) was then adopted to capture the complex relationship between considered latent variables (human, vehicle, road condition and environment condition) and the severity of crashes. The results suggested that the level of crash severity (endogenous variable) was mutually correlated with the considered variables classified as road factor, human factor, vehicle factor and environment factor (exogenous variable). Road-related and vehicle-related factors had a positive effect on the level of crash severity. By contrast, human factor and environment factor affected the level of crash severity with a negative coefficient. Different observed exogenous variables were also assessed for the level of crash severity. The results of this study have the potential to provide an insight into the severity evaluation of crash from the respect of all traffic accident participants.

Authors	Runze Yuan, University of Hawai'i at Manoa Hao Yu, University of Hawai'i, Manoa Zhenning Li, University of Hawai'i at Manoa Guohui Zhang, University of Hawai'i at Manoa David Ma, University of Hawai'i at Manoa
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02847
Paper Title	Investigate Factors Affecting Driver Injury Severity in Snow-Related Rural Single-Vehicle Crashes
Abstract	Snow weather is consistently considered as a hazardous factor due to its potential leading to severe fatal crashes. A seven-year crash dataset including all the snow-related rural highway single vehicle crashes from 2010 to 2016 in Washington state is applied in the present study. Pseudo elasticity analysis is conducted to investigate significant impact factors and the temporal stability of model specifications is tested via a likelihood ratio test. The proposed model based on the seven-year dataset is able to capture the individual-specific heterogeneity across crash records for four significant factors, i.e., male, not impaired and no insurance for minor injury, and not impaired for serious injury and fatality. Their estimated parameters were found to be normal distribution instead of fixed value over the observations. Other significant impact factors with fixed effects are: traffic object, animal, overturn, out-of-control, snow surface, smoke surface, sleet surface, curve horizontal design, medium and high speed limits, young and old aged, impaired condition, no belt usage, pickup car type, airbag deployment. The results of temporal stability test show that the model specification is generally not temporally stable for driver injury severity model based on the years of crash data that were used, especially for longer period (more than 3-year dataset). Models that allow the explanatory variables to track temporal heterogeneity, are of great interest and can be explored in future research.

Authors	Samira Ahangari, Morgan State University Mansoureh Jeihani, Morgan State University Amirreza Nickkar, Morgan State University Celeste Chavis, Morgan State University Montrae Jones, Morgan State University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	1341
Session Title	Truck and Bus Safety Research
Paper Number	20-02955
Paper Title	Prediction Model of Commercial Motor Vehicle (CMV) Crash Severity in Maryland, Applying Support Vector Machine Classification
Abstract	Commercial Motor Vehicle (CMV)'s crashes are major safety hazards so that prediction of their crash severity has drawn researchers attention. This study applied statistical analysis (Binary logit) and data mining (support vector machine) analysis using the Maryland crash data from 2013 to 2018 obtained from U.S. Department of Transportation to find the effect of road surface condition on crash severity. An accuracy of 87% was achieved using a support vector machine.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-03374
Paper Title	Record Linkage of Crashes with Injuries and Medical Cost: Case Study of Puerto Rico
Abstract	Cost considerations are critical in the analysis and prevention of traffic crashes. Integration of cost data to crash datasets facilitates the crash-cost analyses with all their related attributes, but also, is a challenging task due to the availability of unique identifiers across the databases, and the privacy and confidentiality regulations. This study performed a record linkage comparison between deterministic and probabilistic approach using attributes matching techniques with numerical distance and weight pattern under the Fellegi-Sunter approach. As a result, the deterministic algorithm developed using the exact match of the 14-digit police accident record number had an overall matching performance of 52.38% of real matched records while the probabilistic algorithm had an overall matching performance of 70.41% with a quality measurement of Sensitivity of 99.99%. The deterministic approach was outperformed by the probabilistic approach by approximately 20% more of records matched. The probabilistic matching with numerical variables seems to be a good matching strategy supported by quality variables. For the proportion of non-matched records, a cost imputation was performed by regressing the personal injury insurance cost data against weekday, time and municipality of a crash, and number of claimants in the personal injury insurance records. After the record matching, a multivariate regression model was developed to estimate and identify the crash circumstances that increase the medical cost of the crash injured claimants in Puerto Rico.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03424
Paper Title	Exploring Factors Influencing Injury Severity of Accidents between Motor Vehicles and Non-Motor Vehicles Using Generalized Ordered Logit Model
Abstract	Identifying factors that affect accidents between motor vehicle (MV) and non-motor vehicle (NMV) and understanding how these factors affect injury severity is vital in improving traffic safety. Factors including human characteristics, vehicles, road and environment conditions were investigated using the generalized ordered logit model. Police-reported crashes data from the period 2005 to 2017 in Shaanxi Province, China were used to develop the models. Injury severity was classified as no injury, slight injury, serious injury and fatal injury. The results of this study reveal that the following factors increase the likelihood of serious or fatal injuries: age of NMV drivers, compulsory third party insurance, type of MV, road type, season. The results also indicate that hukou, type of NMV, driving state of MV, type of roadside protection, road structure, road linearity, weather, time of accident and visibility level influence the risk of serious or fatal injuries. To reduce serious or fatal injury rate in traffic crashes, measures such as isolating NMV and MV (especially heavy or large vehicles), educating drivers especially those from rural areas and improving road and environment conditions should be taken. Traffic management and enforcement of traffic regulations are crucial in decreasing traffic injury severity as well. Conclusions drawn in this research will be helpful to police or policy makers to modify safety measures to reduce the occurrence of serious or fatal crashes and improve the traffic safety level.

Authors	Jaeyoung Lee, Central South University Mohamed Abdel-Aty, University of Central Florida Suyi Mao, Central South University
Sponsoring Committee	Standing Committee on Occupant Protection (ANB45)
Session Number	1640
Session Title	Occupant Protection Posters
Paper Number	20-03523
Paper Title	Bivariate Ordered Modeling of the Injury Severity Levels of Drivers and School-Age Child Passengers in Traffic Crashes
Abstract	Traffic safety has been a serious public health issue, and there have been considerable efforts to minimize the injury severity of crashes if it is inevitable to avoid the occurrence. A number of previous studies have explored the severity of traffic crashes. Among them, multiple studies have analyzed the highest severity level of crashes with characteristics of drivers, vehicles, roadway, etc. On the other hand, some other studies have investigated the severity level of individual road users including vehicle occupants, pedestrians, bicyclists, etc. Nevertheless, no studies have explored the severity of multiple passengers, simultaneously. As it is expected that vehicle occupants in the same vehicle are likely to receive a similar level of crash impact, it would be desirable to consider the shared effects the severity levels of a driver and passenger. In this study, the authors aim at analyzing the severity level of driver and school-age child passenger by adopting a bivariate ordered probit model to explore four severity levels (i.e., no injury, possible injury, non-incapacitating injury, and the sum of incapacitating injury and fatal injury). The results indicate that the contributing factors for the severity level of drivers and school-age passengers are quite different. They include individual, vehicle, and residence socio-economic characteristics. It is expected that the findings from this study will contribute to an efficient strategic plan to reduce the injury severity of vehicle occupants.

Authors	Roozbeh Rahmani, University of Florida Nithin Agarwal, University of Florida Sivaramakrishnan Srinivasan, University of Florida Ilir Bejleri, University of Florida Xingjing Xu, University of Florida Jia Fang, University of Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-03791
Paper Title	Cross-Comparison and Objective-Based Crash Tree Development and Analysis for Small Counties in Florida
Abstract	The Federal Highway Administration (FHWA) developed the Systemic Safety Project Selection Tool that lists six steps to integrate existing safety management practices and safety analysis tools. The first step is to identify and understand the risk factors commonly associated with the focus crash types. Crash trees have been adopted by agencies to identify the focus facility types and crash types. For most organizations and departments of transportation (DOTs), the concept behind developing a crash tree is a stepwise elimination process where higher value in the crash tree is retained and the rest of the branch is eliminated. This paper demonstrates some of the challenges with the conclusions of this traditional approach and proposes an alternative structure using a cross-comparison framework that not only compares the raw counts from the crash data but also compares focus county's crash percentage and ranking to other similar counties or jurisdictions. This approach assists the decision-makers in understanding the intensity of overrepresentation. This study developed a tool that applied the cross-comparison crash tree approach for 27 small rural counties in Florida to determine the percentage and crash severity ranking. The results demonstrated the benefits of this approach by prioritizing the focus areas and the counties by normalizing the counts and the intensity of the overrepresentation.

Authors	Iman Gharraie, University of Saskatchewan Emanuele Sacchi, University of Saskatchewan
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-03930
Paper Title	Severity Analysis of Wildlife-Vehicle Crashes Using Generalized Structural Equation Modeling
Abstract	Each year thousands of wildlife-vehicle crashes (WVCs) occur in North America with negative effects on wildlife welfare, human health and the economy. While previous studies have mainly investigated factors related to WVC frequency, limited research has been conducted on factors affecting WVC severity. Using more than 10,000 WVCs occurred in the province of Saskatchewan (Canada), this study investigated the severity outcomes of WVCs and their influencing factors using structural equation modeling (SEM) with generalized (ordered probit) links. Compared to traditional severity analysis techniques, SEM offers the added advantage of representing, estimating, and testing complex modeling structures that include both measured and latent (unmeasured) variables. Three latent variables were introduced in this study, i.e., driver's speeding attitude (SA), driver's visibility impairment (VI), and crash severity. Measured variables obtained from crash records were included in SEM to define latent constructs and the resulting network of relationships was tested. The results showed that crash data supported well the model hypothesis and measured/latent variables adequately predicted crash severity. Overall, SA and VI were demonstrated to positively affect crash severity with SA being the most influential factor. Moreover, it was demonstrated that road surface condition was the most influential factor of the SA measurement model, and weather condition was the most influential factor with respect to VI. Finally, a comparison between generalized SEM results and traditional crash severity modelling using ordered probit links was conducted. Similarities and differences between these two approaches were discussed at the end of the study.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-04054
Paper Title	How is Injury Severity Affected by Driver Errors: a Crash Data Based Investigation
Abstract	Unsafe driving behaviors, driver limitations, and conditions that lead to a crash are usually referred to as driver errors. Even though driver errors are widely cited as a critical reason for crash occurrence in crash reports and safety literature, the discussion on their consequences is limited. This study aims to quantify the effect of driver errors on crash injury severity. To assist this investigation, driver errors were categorized as sequential events in a driving task. Possible combinations of driver error categories were created and ranked based on statistical dependences between error combinations and injury severity levels. Binary logit models were then developed to show that typical variables used to model injury severity such as driver characteristics, roadway characteristics, environmental factor, and crash characteristics are inadequate to explain driver errors, especially the complicated ones. Next, ordinal probit models were applied to quantify the effect of driver errors on injury severity for rural crashes. Superior model performance is observed when driver error combinations were modeled along with typical crash variables to predict the injury outcome. Modeling results also illustrate that more severe crashes tend to occur when the driver makes multiple mistakes. Therefore, incorporating driver errors in crash injury severity prediction not only improves prediction accuracy but also enhances our understanding of what error(s) may lead to more severe injuries so that safety intervention can be recommended accordingly.

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Sponsoring Committee	Standing Committee on Managed Lanes (AHB35) Standing Committee on Congestion Pricing (ABE25)
Session Number	1143
Session Title	Managed Lane and Congestion Pricing Showcase, Part 2
Paper Number	20-04097
Paper Title	Evaluating the Impact of Traffic Violations on Crash Injury Severity on Wyoming Interstates: an Investigation with a Random Parameters Model with Heterogeneity in Means Approach
Abstract	This study investigated the impact of traffic violations on crash injury severity on Wyoming's interstate highways. Crash data from 2013 to 2015 for interstates in Wyoming was used for the analysis. A random parameters multinomial (MNL) logit model with heterogeneity in means was estimated as an alternative to the mixed logit model. This was done to better account for unobserved heterogeneity in the crash data. The results indicated that the random parameters model with heterogeneity in means provided a better fit to the data and offered more insights into the factors influencing injury severity. Various factors were found to impact crash injury severity on Wyoming's interstate highways. These included traffic violations, crash characteristics, and environmental factors among others. With regards to traffic violations, driving too fast for prevailing conditions and driving under the influence of alcohol and drugs were identified as the main violations that significantly influenced crash severity. Among other useful insights, the heterogeneity in mean specification indicated that the interactive effect between non-trucks (vehicles not classified as trucks) and driving too fast for conditions increases the likelihood of severe injury crashes. This study provided important information on the impact of traffic violations on crash severity. Results from the study will help enforcement agencies in the state to better identify appropriate countermeasures to mitigate the impact of violations on crash severity.

Authors	Ali Behnood, Purdue University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	1341
Session Title	Truck and Bus Safety Research
Paper Number	20-04251
Paper Title	Weekday and Weekend Instability Analysis of the Factors Affecting Injury Severities in Crashes Involving Large Trucks
Abstract	In the past, many attempts have been made to study the injury-severity of crashes involving large trucks. However, the exact effects of weekdays and weekends on the injury-severity of these types of crashes is lacking. In this study, crash data from Los Angeles was used to investigate the transferability of the large-truck crash injury-severity determinants across weekdays and weekends. Crash-injury severities were estimated using random parameters logit models while considering three categories of injury-severity levels: severe injury, minor injury, and no injury. The model estimation was done by considering several parameters that could potentially affect the crash injury severities such as truck's characteristics, drivers' attributes, driver actions, weather conditions, crash time, and roadway attributes. The transferability of the model estimation results across weekdays and weekends was assessed using likelihood ratio tests. Moreover, the stability of the explanatory variables was investigated using the calculated marginal effects. The results show that although some explanatory variables are stable across weekdays and weekends, large-truck crash-injury severity models are not transferable. The findings in this research could be used by trucking companies and decision makers to better regulate the traffic or trucking rules for weekdays and weekends.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1356
Session Title	Safety Data, Analysis, and Evaluation, Act IV: Rollover, Trucks, Wildlife, and Other Crash Circumstances Explored
Paper Number	20-04254
Paper Title	Examining the Underlying Exposures of Hit-and-run and Nonhit-and-run Crashes
Abstract	The act of hit-and-run in a crash without reporting would delay the emergency response for the victims and aggravate the injury severities. Limited knowledge, however, is available to evaluate the discrepancy of injury risks between the hit-and-run and nonhit-and-run crashes, especially the crash exposures which may contribute to the injury severities. The objective of the study is to examine the underlying exposures of hit-and-run and nonhit-and-run crashes and identify the factors influencing the injury severities. Quasi-induced exposure technique is employed to measure the relative crash exposures in two-vehicle hit-and-run and nonhit-and-run crashes; random parameter ordered logit model is adopted to reveal the discrepancy of the factors attributing to the injury risk of the drivers involved in hit-and-run and nonhit-and-run crashes. The study reports that the injury sustained by the remaining drivers at the event of hit-and-run is less severe than those involved in the nonhit-and-run crashes (with Michigan crash data), which is attributed to the differential crash exposures in terms of driver age and vehicle type between two crash types. The injury-severity contributing factors of hit-and-run crashes differ considerably from the nonhit-and-run crashes that variables such as nighttime, intersection area, head-on, angle, and side-swipe crash type, and alcohol involvement significantly increase the injury severities of the staying drivers at the event of hitting-and-running. The findings serve to emphasize the importance of taking into account the crash exposure in the safety research on hit-and-run crashes and propose the effective safety countermeasures to reduce the injury severity for hit-and-run crashes.

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Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	1341
Session Title	Truck and Bus Safety Research
Paper Number	20-04592
Paper Title	Uncovering Deep Structure of Determinants in Large Truck Fatal Crashes
Abstract	The number of fatalities and severe injuries in large truck-related crashes has significantly increased since 2009. According to safety experts, this recent increase in large truck-related crashes can largely be explained by the significant growth in freight tonnage all over the U.S. in the past few years. This notable freight-haul growth has allowed continuous day-night movement of freight on roads and highways, exposing the trucks to a greater number of potential crashes or near-crash scenarios. There are many ongoing research efforts that aim to identify the different factors that influence large truck crashes; however, further research with innovative approaches is still needed to understand the relationship between crash-related factors better. In this study, the project team applied taxicab correspondence analysis (TCA), an artificial intelligence method known for dimension reduction, to large truck fatal crash data in order to investigate the complex interaction between multiple factors under a two-dimensional map. For this study, six years (2010-2015) of large truck fatal crash data from the Fatality Analysis Reporting System (FARS) were used. The study found five clusters of attributes that show patterns of association between different crash attributes such as roadway classification and two-way separation, intersection types, speed limit, crash types, number of vehicles, driver impairment, and weather. The findings of this study will help the safety professionals, trucking industry, and policymakers to make decisions for safer road design, truck driver training, and education.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-04597
Paper Title	Incorporating Demographic Proportions into Crash Count Models by Quasi-Induced-Exposure Method
Abstract	Quasi-induced exposure (QIE) is an effective technique for estimating a specific driving or vehicle population exposure when real exposure data are not available. Typically crash prediction models are carried out at the site level, i.e., segment or intersection. Driving population characteristics are generally not available at this level, and thus omitted from count models. Due to the sparsity of traffic crashes, estimating driving population distributions at the site level using crash data at individual sites is challenging. This study proposes a technique to obtain demographic proportions to incorporate in the count models as an exposure at each site by aggregating similar adjacent sites until significant demographic proportions are obtained. Driver gender, age and vehicle type information are obtained by QIE using five years (2010-2014) of crash data; and road inventories are obtained for 1264 urban four-lane divided highway segments in California. Count models including only site level factors were compared with models including both crash level and site level factors. The latter outperformed the former in terms of mean prediction bias (MPB) and mean absolute deviation (MAD) statistics on hold out sample predictions. Results indicate that teen drivers are more crash prone in total and fatal plus injury severity crashes where senior driver crash risk increases with the increase in severity level. Presence of vehicles other than passenger cars and trucks reduces total and property damage only crash counts. Female drivers exhibit an increase in total and fatal plus injury crash counts.

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Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	1126
Session Title	Current Research in Motorcycle Safety—Hybrid Session
Paper Number	20-04771
Paper Title	Logit Model with Social Factors for Motorcycle Accident Gravity
Abstract	The objective of this research is to know the characteristics of transport accidents involving motorcycles, as well as the victims' socioeconomic attributes to control if there is a relationship with the accident's severity. A Logit model was used to determine the factors that influence traffic accidents severity. Two levels of severity were considered a) traffic injury that may or may not have caused permanent disability and b) death. Data from 1220 questionnaires with social and accident information government insurance applicants (DPVAT) at Alagoas Transit Department headquarters, between the years 2013 and 2019, were used to estimate the model. The results show that the significant variables are gender, age, schooling, motorcycle type, use of safety equipment, having a driver's license and accidents on weekends. Expressly, in addition to the factors related to the accident, as wearing a helmet, factors inherent to the individual's social group influence their probability of death.

Authors	Zhao Zhang, University of Utah Runan Yang, University of South Florida Glenn Blackwelder, Utah Department of Transportation Xianfeng Yang, University of Utah
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-04782
Paper Title	Examining Driver Injury Severity in Left-turn Crashes Using Hierarchical Ordered Probit Models
Abstract	According to the National Highway Traffic Safety Administration (NHTSA), crash injuries and fatalities caused by left-turning movements occupy a large proportion of the total numbers in the United State. However, few existing studies in the literature devoted efforts to examine the driver injury severity in left-turn crashes. To fill this research gap, this paper implements three hierarchical ordered probit (HOPIT) models, utilizing eight-year left-turn crash dataset from 2010 to 2017 in Utah, to investigates the impact factors on left-turn crashes and the corresponding injury severity. As the driving condition during the wintertime of Utah could be greatly different from other seasons, according to the temperature, snowing condition, and other factors, this study divided the whole crash dataset into “winter” and “other-season” datasets so as to compare the injury severity pattern in the different seasons. The results revealed that snows would decrease the probability of occurring minor-injury in a left-turn crash by 12.6% during the wintertime and higher speed limit would significantly increase the injury severity in a left-turn crash. Compared with the other seasons, the probability of occurring minor-injury related to a head-on collision in a left-turn crash is dramatically increased in winter of Utah.

Authors	Md Julfiker Hossain, University of Connecticut John Ivan, University of Connecticut Shanshan Zhao, University of Connecticut Kai Wang, University of Connecticut Sadia Sharmin, University of Connecticut Nalini Ravishanker, University of Connecticut Eric Jackson, University of Connecticut
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-04801
Paper Title	The Impact of Demographics of all Drivers on the Highest Driver Injury Severity in Multi-Vehicle Crashes of Rural Two-Lane Roads in California
Abstract	The injury severity of a driver in the crash is significantly dependent on characteristics of the crash such as driver’s age, gender and vehicle characteristics. Most previous studies have used the information of a single driver to explain the severity of the crash. However, the demographic information of all other drivers involved in the crash can also be significantly important for predicting the severity of the crash. To identify the impact of all drivers in a crash, this study uses demographic information of all drivers involved in a multi-vehicle crash to predict the injury severity of the most severely injured driver. Three different discrete outcome models-Multinomial Logit (MNL), Ordered Logit (OL), and Partial Proportional Odds (PPO) were used to estimate the effect of different factors on injury severity. Models incorporating demographic information and vehicle characteristics of all drivers involved in a crash were compared with the models only considering information about the most severely injured driver in terms of significance of factors and prediction accuracy. The results from all three models consistently indicate that although young drivers are likely to have lower levels of injury severity compared to working age drivers, injury severity increases if the number of young driver increases in a multi-vehicle crash. Drivers indicated to be not at fault frequently were more severely injured than drivers at fault. Finally, the inclusion of all drivers’ demographic information shows an improvement in the prediction accuracy of crash severity of the most severely injured driver.

Authors	Sarvani Duvvuri, University of North Carolina at Charlotte Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-04902
Paper Title	Factors Influencing the Likelihood of Occurrence of a Wrong-Way Driving Crash and Injury Severity
Abstract	Head-on and sideswipe collisions are the possible consequences of a driver traveling in the direction opposite to the mainline flow. Higher fatality rates associated with the wrong-way driving (WWD) crashes calls for an investigation of these crashes along with identification of their corresponding contributing factors. Crash data for the years 2012-15 for the State of North Carolina was gathered. The crashes resulting due to driving in the opposite direction were identified for the analysis and modeling. This research is two-fold. The former examines and identifies risk factors contributing to the occurrence of WWD crashes while the latter identifies the factors associated with various levels of injury severity. Binary logistic regression model and partial proportionality odds model were developed to examine and identify the crash risk factors, significant at a 95% confidence interval. The results indicate that driver-related characteristics, crash location characteristics, weather condition, driver impairment (DUI), time of the day, day of the week and the pavement characteristics are significantly associated with the likelihood of the occurrence of a WWD crash. Similarly, driver characteristics, weather condition, variables corresponding to the crash location, and temporal factors were found to have a significant effect on the injury severity of the crash. This research assists by identifying the characteristics of areas/locations prone to wrong-way entries. The results from the models help the agencies proactively plan and reduce the occurrence of WWD crashes and associated injury severity.

Authors	Irfan Ahmed, University of Wyoming Mohamed Ahmed, Federal Highway Administration (FHWA) Haun Wulff, University of Wyoming
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-05079
Paper Title	Using No-U-Turn Hamiltonian Monte Carlo Bayesian Method to Investigate the Contributing Factors of Crash Injury Severity in Very Low-Volume Rural Roads of Wyoming
Abstract	In Wyoming, the percentage of traffic fatalities on rural roadways have always surpassed traffic fatalities in urban roadways. Crash count models provided in the Highway Safety Manual (HSM), as a function of traffic volume and segment length might not be adequate to relate the various crash contributing factors to different types of crashes and severity, especially for low-volume rural roadways. Hence, crash injury severity models with discrete severity outcomes are modelled with respect to roadway, driver, environmental, and other crash characteristics. A dataset was prepared using crash records from the years 2007-2016 of 28 different two-way two-lane roadways in Wyoming with average annual daily traffic less than 400 vehicles per day. A binary logistic model was developed to carry out the crash injury severity analysis using a Bayesian approach. Fixed- and random-effects models were developed to investigate the relationship between the crash injury severity and its associated contributing factors. Results showed that the random-effects model is a better fit to the data than the fixed-effects model. Parameter estimates are sampled from the posterior distributions using a No-U-Turn Hamiltonian Monte Carlo sampling technique which is a more efficient method than other Markov chain Monte Carlo methods. The population-averaged estimates included driver impairment, improper use of restraint, speeding, lane departure, and motorcycle involvement and were found to increase the odds of a fatal/injury crash. Furthermore, the combined effect of nightly crashes and improper driving action leads to increased likelihood of fatal/injury crash.

Authors	Ming-heng Wang, Taiwan Police College Steven Schrock, University of Kansas
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05153
Paper Title	Analysis of Factors Affecting the Injury Severity in E-bike with Vehicle Crashes in Taiwan
Abstract	To understand the characteristics of e-bike involved crashes and the factors affecting the injury severity (fatal or non-fatal) of the e-bikers, this study uses eight years (2011-2018) of police reported traffic crash data in Taiwan and the multivariable logistic regression model for the analysis. The results found that most e-bike involved crashes occurred at rural areas and intersections and with by side-impact crash types. Most e-bike involved crashes collided with motorcycles, male drivers, vehicles going straight, and drivers failing to look properly. Most e-bikers involved in crashes were female, aged more than 65 years old, riding an e-bike without pedals, and going straight prior to the crash. Factors that significantly affected the severity of an e-biker's injuries includes the crash type, collision part, crash location, road geometry, vehicle type, driver's license status, vehicle's motion prior to the crash, crash cause due to the drivers, e-biker's gender, age, and helmet usage. Crashes in head-on collision type and e-bikes collided with front head or right head corner of vehicle and colliding with big sized vehicles and by impaired drivers resulted in the highest possibility of e-bike's fatalities in e-bike involved crashes. Male e-bikers aged over 55 years old and not wearing a helmet tended to suffer a higher fatality rate in crashes. The enhancement of advanced safety systems and law enforcement on drunk, speeding and invalid drivers is recommended. The requirement of helmet use should also be necessary for riding an e-bike.

Authors	Jason Owens, Florida A&M University Doreen Kobelo, Florida Agricultural and Mechanical University Luciano Lalika, University of North Florida Thobias Sando, University of North Florida Angela Kitali, Florida International University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05172
Paper Title	Understanding Factors Influencing Aging Pedestrian Fatalities using Bayesian Networks
Abstract	This study mainly applies the Bayesian logistic regression (BLR) model and Bayesian Networks (BN) model to identify risk influencing variables of fatalities of aging pedestrians. Bayesian logistic regression model was used to identify the risk influencing factors of crash severity. Bayesian Networks model was applied to estimate the potential probabilistic association between pedestrian crash severity and explanatory variables. The models were developed with data from 913 pedestrian-vehicle crashes involving aging pedestrians that occurred in Florida from 2016 through 2018. The results from BLR model show that vehicle maneuver, lighting condition, shoulder type, trafficway, AADT, driver gender, pedestrian age and driver age are significant. Among the significant variables, results from BN model reveal that vehicle maneuver, lighting condition, trafficway and driver age are directly associated with crash severity. The findings from this study can be used to develop effective countermeasures for reducing the number of fatalities of aging pedestrians in pedestrian-vehicle crashes.

Authors	Cecilia Kadeha, Florida International University Henrick Haule, Florida International University MD Sultan Ali, Florida International University Priyanka Alluri, Florida International University Raj Ponnaluri, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-05220
Paper Title	Analysis of Wrong-Way Driving (WWD) Crash Severity on Arterials
Abstract	Wrong-way driving studies and mitigation strategies have exclusively been focused towards limited access facilities. However, it has recently been established that WWD crashes on arterial corridors are relatively more common. As such, this study focused on determining the factors influencing the severity of WWD crashes on arterials. The analysis was based on five years (2012-2016) WWD crashes that occurred on arterial corridors in Florida. Police reports for the 2,879 crashes deemed “wrong-way” in the database were downloaded and individually reviewed. The manual review of the police reports revealed that of the 2,879 WWD crashes, only 1,890 crashes (i.e., 65.6%) actually crashes that occurred as a result of vehicles traveling the wrong way. The ordinal regression models were then developed to establish the relationship between the severity of WWD crashes and different driver attributes, temporal factors, roadway and traffic characteristics. Results indicated that severity of WWD crashes on arterials was significantly influenced by season of the year, day of the week, lighting condition, age and gender of the wrong-way driver, number of vehicles involved, roadway functional classification, airbag deployment, alcohol involvement, speed limit, ratio of the speed of the wrong-way driver to the speed limit, and head-on crashes. Based on the model results, specific countermeasures pertaining to Education , Engineering , Enforcement , and Emergency response , were discussed. Possible Transportation Systems Management and Operations (TSM&O) strategies for WWD detection systems on arterials were further proposed in order to minimize WWD incidents.

Authors	Mouyid Islam, University of South Florida Anurag Pande, California Polytechnic State University, San Luis Obispo
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1691
Session Title	Highway Safety Performance Research
Paper Number	20-05256
Paper Title	Single-Vehicle Roadway Departure Crashes on Rural Curved Segments: Analysis of Injury Severity Using Random Parameters with Heterogeneity in Means and Variances
Abstract	Roadway departure crashes are one of the core emphasis areas in Strategic Highway Safety Plans (SHSP). These crashes, especially on rural roads, lead to a disproportionately higher number of fatalities and serious injuries. The focus of this study to identify and quantify the factors affecting injury severity outcomes for single-vehicle roadway departure (SV-RwD) crashes on rural curved segments in Minnesota. The crash data is extracted from the Highway Safety Information System (HSIS) from 2010 to 2014. 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, traffic, and/or environmental conditions. This analysis adds value to the growing body of literature because it uncovers some unobserved heterogeneity in the form the attributes specific to driver injury severities in contrast with the standard mixed logit approach. The model results indicate that there is a complex interaction of driver characteristics and actions (male drivers, age below 30 years, unsafe speed and distraction), roadway and traffic characteristics (two-lane undivided road, county roadways, and low traffic volume), environmental conditions (adverse weather, cloudy weather, dark condition and dry surface condition), crash event (rollover), and vehicle characteristics (vehicle type – sport utility vehicle). The results also provide some evidence of the effectiveness of a highway curve safety improvement program implemented in one of the Minnesota Department of Transportation (MnDOT) districts.

Authors	Rakesh Rangaswamy, University of South Florida Elzbieta Bialkowska-Jelinska, University of South Florida Cong Chen, University of South Florida Pei-Sung Lin, University of South Florida Athanasios Theofilatos, Loughborough University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05619
Paper Title	Comparison of Non-Motorist Injury Severities in Rural and Urban Areas in Florida
Abstract	This research investigated significant factors influencing non-motorist injury severities of a single-vehicle crash and spatial clustering of locations of severely injured non-motorists in rural and urban areas in Florida. Mixed logit model with heterogeneity in mean and variance was developed to understand the interrelationship between the different levels of injuries while comprehensively accounting for unobserved heterogeneity within the obtained crash data. Our analysis results showed that there was a significant difference between the variables influencing the injury severity in rural and urban areas involved with non-motorist in single-vehicle crashes. Factors such as non-motorist gender, driver gender, vehicle speed and few more had a significant influence on injury severities in both rural and urban areas, but factors such as nighttime crash time was found to be significant only in rural areas but not in urban areas. Many other factors such as weather and lighting conditions, roadway characteristics, etc. were found to be potentially affecting the likelihood of severe and minor injuries in non-motorist involved single-vehicle crashes. Spatial analysis revealed the locations of clusters in rural and urban areas. Non-motorists severely injured in a single-vehicle crash tend to cluster in urban areas. A majority of urban clusters were observed in Orange, Duval, Pasco, and Pinellas counties. Rural areas experience less clustering. The finding of this study suggests that for a better understanding, the influence of injury severities in the vulnerable group of road users it is required to investigate different types of non-motorist individually in rural and urban areas.

Authors	Mingchen Li, University of South Florida Zhenyu Wang, University of South Florida Pei-Sung Lin, University of South Florida Runan Yang, University of South Florida Abhijit Vasili, University of South Florida Edith Wong, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Visibility (AND40)
Session Number	1427
Session Title	Approaches to Modeling Visibility and Safety Effects
Paper Number	20-05641
Paper Title	A Machine Learning-based Diagnosis of Lighting Patterns Contributing to Nighttime Crash Severity on Roadway Corridors
Abstract	Roadway lighting pattern is a significant factor that influences nighttime safety. Since the illumination distribution along roadway corridors presents an intricate pattern, the traditional photometric measure, such as average horizontal illuminance and ratio-based uniformity, cannot capture the patterns that truly contribute to the injury severity of a nighttime crash on roadway corridors. This study aimed to develop a machine learning model for accurately predicting the crash injury severity based on horizontal illuminance patterns and other features, such as geometric, traffic control, and environmental factors. The SVM model was used to classify the crash injury severity (severe injury—fatal and incapacitating and non-severe injury—others) because of its significant accuracy with less computation. Two variables were used to describe the crash-related lighting patterns: buffer length —representing the longitude spatial range of lighting patterns contributing to a crash outcome, number of sub-zones —describing lighting features with more detail. A grid search approach was applied to find the best buffer length and sub-zone numbers that can reach the highest prediction performance. The best model was trained with a buffer length of 0.125 miles and ten sub-zones. The model testing results show that the developed SVM model effectively captures the traits of lighting patterns. Even without the information of factors during and after a crash, the developed SVM model effectively predict the crash injury severity based on lighting patterns.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05645
Paper Title	Modeling Pedestrian Injury Severity in Dhaka, Bangladesh
Abstract	This study investigates pedestrian injury severity for Dhaka, Bangladesh. A latent segmentation-based ordered logit (LSOL) model is developed utilizing the police-reported collision records of Dhaka for 2011-2015. Injury severity is modeled in the following three-point ordered scale of: 1) minor injury, 2) major injury, and 3) fatal. The LSOL model is developed to address the ordinal nature of injury severity levels, as well as capture heterogeneity by endogenously distributing pedestrians into discrete latent segments. This study tests the influence of built environment characteristics such as road network configuration, land use, and transportation infrastructure attributes. The LSOL model is estimated for two segments. Model results suggest that segment one can be identified as a high-risk segment; whereas, segment two is a low-risk segment. Parameter estimation results reveal that higher land use mix index, 3-way and 4-way intersections, and mid-block road segments aggravate pedestrians' injury. The model confirms that significant heterogeneity exists across the segments. For instance, collisions occurring at the traffic police controlled intersections in Dhaka are more likely to yield severe pedestrian injury in the high-risk segment. In contrast, the same variable shows a lower likelihood for severe injury in the low-risk segment. The elasticity effect analysis suggests that length of the sidewalk, distance to the railway line, and mid-block road segments show a substantial positive impact on fatality. The findings of this study will assist engineers and planners to develop plans and policies for improving pedestrians' safety in developing countries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05700
Paper Title	Towards Vision Zero for Cyclists: New Insights & Methods for Assessing Bicycle Crash Severity
Abstract	Cycling represents an increasingly common mode of travel in the United States, as well as an increasing share of fatal and serious injury crashes; transportation professionals are still working to understand how different types of riding behavior and roadway infrastructure can impact the number and severity of bicycle crashes, particularly in lower-density, suburban-type areas. A lack of consistent and comprehensive data to characterize cyclist behavior and crash contributing factors is part of this challenge; additionally, many crash severity models are constrained when it comes to interpreting specific influencing factors – these models often interpret such factors to either universally increase or decrease crash severity, with no ability to account for different levels of effect for a single variable. This study furthers the understanding of factors influencing bicycle crash severity, by examining five years of crash data, coded using FHWA's Pedestrian and Bicycle Crash Analysis Tool (PBCAT), from two counties in the State of Michigan. We apply an ordered probit model with random parameters to better account for the range of potential impacts, both positive and negative, that individual variables may have. Our model confirms existing research findings, such as the elevated risk of severe crashes outside of intersection areas, while also illustrating [through the random parameters specification] several cases where variables have a range of positive and negative effects on crash severity.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-05705
Paper Title	Investigation of Injury Severities in Single-Vehicle Crashes in North Carolina Using Mixed Logit Models
Abstract	Roadway departure (RwD) crashes, comprising run-off-road (ROR) and cross-median/centerline head-on collisions, are one of the most lethal crash types. According to the FHWA, between 2015 and 2017, an average of 52 percent of motor vehicle traffic fatalities occurred each year due to roadway departure crashes. An avoidance maneuver, inattention or fatigue, or traveling too fast with respect to weather or geometric road conditions are among the most common reasons a driver leaves the travel lane. Roadway and roadside geometric design features such as clear zones play a significant role in whether human error results in a crash. In this paper, we used mixed-logit models to investigate the contributing factors on injury severity of single-vehicle ROR crashes. To that end, we obtained five years' (2010- 2014) of crash data related to roadway departures (i.e., overturn and fixed-object crashes) from the Federal Highway Administration's Highway Safety Information System Database. The results indicate that factors such driver conditions (e.g., age), environmental conditions (e.g., weather condition), roadway geometric design features (e.g., shoulder width), and vehicle conditions significantly contributed to the severity of ROR crashes. In addition, it also provides valuable information for traffic design and management agencies to improve roadside design policies and implementing appropriately forgiving roadsides for errant vehicles.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05847
Paper Title	Spatio-Temporal Analysis of Collision Frequency and Injury Severity Involving Unconventional Modes, Pedestrians, and Transit in Dhaka, Bangladesh
Abstract	Road safety is a global concern; particularly, in developing countries due to the significantly high collision occurrences and subsequent deaths. The major reason for the road safety challenges is the limited understanding of the factors that are unique in the context of developing countries, such as the predominant use of unconventional modes. This study presents a spatial and temporal analysis of collision frequency and injury severity of crashes in Dhaka, Bangladesh. The focus is to understand the spatio-temporal trend of collisions involving pedestrians, public transit, and unconventional modes, which are the key collision factors in Dhaka. This research utilizes the police-reported collision record for Dhaka for the years 2011-2015. The temporal analysis suggests that fatalities and major injuries increased by >7% and >31% respectively in the 5-years. Public transit collisions increased from 43.9% to 60.9%. Fatalities among pedestrians and unconventional mode users are 76.6% and 29.8% respectively. The daily distribution suggests that a higher share of severe injuries involving pedestrians (16.6%) and unconventional modes (20.5%) occur on the Fridays and Thursdays respectively. The hourly distribution suggests that pedestrians are more vulnerable from 11:00 am - 12:00 pm on weekends. Unconventional mode users are vulnerable from 7:00 am-8:00 am on weekdays. Spatial analysis is performed adopting a Kernel density estimation technique. The results suggest that the major activity locations of Dhaka such as CBD, airport, business districts, and ferry terminals are collision prone areas. Interestingly, the density of public transit collisions is skewed around the major transit hubs of the city.

Authors	Dipanjan Mukherjee, Indian Institute of Technology Kharagpur Sudeshna Mitra, The World Bank
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05873
Paper Title	Pedestrian Safety Analysis of Urban Intersections in Kolkata, India Using a Combined Proactive and Reactive Approach
Abstract	Assessment of pedestrian safety is often conducted in a reactive way by analyzing pedestrian crash data. However, in a developing country, the availability of reliable crash data is a major challenge. Therefore, without relying solely on reactive approach, it is essential to combine some methods that can proactively assess pedestrian safety. In this background, the present study proposed a methodology combining both reactive and proactive approach to assess pedestrian safety at urban intersections in Kolkata, India. The method developed in the present study utilizes a combination of the historical crash data analysis, the analysis of pedestrian-vehicular conflict (i.e., pedestrian-vehicular post-encroachment time), along with pedestrians' risk perception towards the built environment and traffic parameters, to identify potential risk-prone intersections in Kolkata. Based on the combined reactive and proactive assessments, there is evidence that the high traffic volume, pedestrian-vehicular interaction captured through pedestrian and vehicle volume ratio, the absence of police personnel, high approaching speed, the presence of commercial area, inadequate sight distance, the presence of slum population, and a high population density near the intersection significantly increase the risk of pedestrian crashes. Finally, using this combined proactive-reactive approach, the present study also identifies and ranks 25 high risk-prone intersections for pedestrians. This is a significant step towards scientific decision making and allowing use of information beyond historical crash records.

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Sponsoring Committee	Standing Committee on Managed Lanes (AHB35) Standing Committee on Congestion Pricing (ABE25)
Session Number	1143
Session Title	Managed Lane and Congestion Pricing Showcase, Part 2
Paper Number	20-05997
Paper Title	Using Support Vector Machine Algorithms for Crash Injury Severity Analysis on Express Lane Facilities
Abstract	Express lanes provide an alternative for improving the capacity of the existing freeway network without expanding the roadway footprint. Although much research has been done to explore factors contributing to crashes on these facilities, there is not much discussion on factors influencing their injury severity. This study used a Support Vector Machine (SVM) model, optimized using the firefly algorithm, to explore the factors influencing the injury severity of crashes. The analysis was based on three years of crash data (2012 to 2014) from four express lane facilities in California. The results indicated that the following factors increased the probability of an injury or a fatal crash: concrete barriers, high AADT, rolling or mountainous terrain, morning peak hours, weekend, young drivers, adverse road surface condition, nighttime condition, and angle crashes. Moreover, medium AADT, multi-vehicle crashes, right and left shoulder widths, and evening peak periods decreased the probability of having an injury or a fatal crash. The results provide insights into the influence of different geometric characteristics and crash-related factors on the severity of crashes. The study findings may assist agencies to better understand the impacts of factors contributing to injury and fatal crashes on express lane facilities, and implement strategies to reduce the severity of these crashes. Future investigation could focus on incorporating the influence of real-time traffic data such as speed, volume, and occupancy on crash risk and injury severity on the facilities with express lanes.

Authors	Rebecca Sanders, Arizona State University Robert Schneider, University of Wisconsin, Milwaukee Frank Proulx, Toole Design
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-06009
Paper Title	Pedestrian Fatalities in Darkness: What Do We Know, and What Can Be Done?
Abstract	Pedestrian fatalities in the U.S. steadily declined between the 1970s and 2010, when they began rising again, culminating in a 28-year high of 6,227 pedestrians killed in 2018. The vast majority of pedestrian fatalities occur in darkness and account for the most of the recent increase in pedestrian fatalities – an alarming trend that merits further investigation. This paper examines six years of data on pedestrian fatalities at the national level and pedestrian fatalities and severe injuries in California to better understand correlates specifically with regard to darkness. Logit models reveal that fatalities and combined KSI are significantly more likely on roadways with higher speeds and numbers of lanes, such as freeways and state highways. Pedestrians are significantly safer where traffic is slowed, such as at traffic control devices and intersections, and when crossing in marked crosswalks (at intersections). Alcohol usage by pedestrians or drivers significantly increases pedestrian fatality and severe injuries, as does a hit-and-run incident. Younger (under age 16) and older (over age 65) pedestrians are at less risk, but Black pedestrians are at increased risk in all models. Future research examining additional correlates, such as temporally-resolved pedestrian exposure data, finer-grained built environment variables, and the influence of mobile phone distraction, could help further illuminate the causes of – and potential solutions for – this complex yet solvable problem. Immediate solutions include roadway design and policies that slow drivers, particularly at night, additional roadway lighting, and adaptive lighting and detection technology for vehicles.

6 Crash Modification Factors

Tarek Sayed and Mohamed Bayoumi Kamel, University of British Columbia

Crash Modification Factors (CMFs) are used to measure the impact on road safety (e.g., crash frequency, crash severity, conflicts) of applying a safety countermeasure. This year, the subcommittee identified **twenty-five papers** dealing with Crash Modification Factors (CMFs).

Eleven studies employed before-after studies (e.g. Al-Omari et al., 20-01603; Wu et al., 20-03041; Lyon, 20-04012, Fitzpatrick et al., 20-00261), while other studies employed cross-sectional analysis (e.g. Al-Omari et al., 20-01603; Lan, 20-05570, Fitzpatrick et al., 20-00261). Most of the papers applied the Empirical Bayes technique (e.g. Wu et al., 20-03041; Lyon et al. 20-04012, Fitzpatrick et al., 20-00261, Hallmark et al., 20-00118), while three papers employed the Full Bayes rechnique (Guo and Sayed, 20-01409, Yang et al., 20-01888, and Hussein et al. 20-00970). The safety impact of countermeasures was generally represented by the change in crash frequency (e.g. Dai et al., 20-00938, Fitzpatrick et al., 20-00261) or crash severity (e.g., Guo and Sayed, 20-01409, Deng et al., 20-03859). Other studies used surrogate measures of safety, such as traffic conflicts (e.g. Ledezma-Navarro et al., 20-03499, Nassereddine et al., 20-05471, Xu et al., 20-02896) and speed and acceleration deviation (Zhao et al., 20-04565).

A before-after analysis with benefit-cost evaluation was applied in two studies (Lyon et al. 20-04012 and Sandt et al., 20-00748). One study developed calibration factors to improve CMF transferability (Tang et al., 20-02676). Also, one study evaluated the variation in CMFs due to the specification measurement error (Adediji and Noland 20-00864).

The evaluated countermeasures included geometric/structure treatments, traffic control devices, and the introduction of autonomous or connected vehicles. The evaluated geometric/structure treatments included median U-turn and restricted crossing U-turn (Al-Omari et al., 20-01603), friction surface treatments (Lyon et al., 20-04012), shoulder rumble strips (Hossain and Ahmed, 20-05578), and wider longitudinal pavement markings (Hussein et al. 20-00970). The evaluated traffic control devices included pedestrian hybrid beacons (Davis et al., 20-00625, Fitzpatrick et al., 20-00261, and Fitzpatrick et al., 20-00186), stop-signs (Ledezma-Navarro et al., 20-03499), driver wearable devices (He et al., 20-00421), fog warning devices (Zhao t al., 20-04565 and), and Chevron Warning (Hallmark et al., 20-00118, Gates et al., 20-03981). One paper investigated the introduction of autonomous and connected vehicles safety impact (Xu et al., 20-02896).

Authors	Gary Davis, University of Minnesota, Twin Cities
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper number	20-00625
Paper Title	Explaining Crash Modification Factors: A Case Study
Abstract	The Highway Safety Manual (HSM) now provides empirical tools for predicting the safety consequences of highway engineering decisions, but these tools represent the driver and vehicle conditions prevailing in the United States during the last few decades. As connected-autonomous vehicles increase their market share these conditions will change, possibly reducing the accuracy of HSM predictions. This paper argues that assessing the transferability of a crash modification factor to a new situation can be seen as a special case of assessing the external validity of an empirical result, and that this almost certainly requires an explanation of how the modification achieves its effect. At present there is little guidance on how such explanations might be posed and tested, and this paper describes a case study where micro-simulation is used to develop an explanation of how pedestrian hybrid beacons (PHB) modify pedestrian crash likelihood. Since the literature indicated that PHBs can affect both pedestrian and driver behavior it was necessary to include both possibilities in the model. To simulate injury severity distributions similar to those recorded in a crash database it was necessary to propose that almost all simulated drivers attempted to brake in pedestrian/vehicle encounters. Then changing the simulated fraction of careful pedestrians from between 0% and 30% to between 80% and 90% gave simulated crash modification factors similar to estimates reported in the literature. The resulting working hypothesis is that PHBs achieve their crash reduction effect in large part by modifying pedestrian behavior. This hypothesis should be tested further, and additional tests are proposed. Guidance is offered to others wishing to develop explanations.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper number	20-01603
Paper Title	Safety Evaluation of Median U-Turn Crossover-Based Intersections
Abstract	Alternative innovative designs for intersections were defined to enhance traffic operation and safety. Median U-Turn (MUT) and Restricted Crossing U-Turn (RCUT) intersections are among the types of alternative intersections that enable drivers to make left-turn movements at median U-turn crossovers downstream of the main intersection. Recently, municipalities and transport agencies tend to implement these types of intersections. However, their effectiveness in crash reduction has not been adequately determined in the previous studies. This is due to the limited number of alternative intersections which were considered in these studies. In addition, there was no consideration for the unusual new geometric design of these intersections. In this study, a safety evaluation was conducted while considering the new intersection-related areas at MUT and RCUT intersections to clarify and quantify their effectiveness in crash reduction. This study considered 82 MUT and 13 RCUT intersections from six states. Two types of MUT intersections along with partial MUT intersections were considered in this study. Crash Modification Factors (CMF) for MUT and RCUT intersections were estimated by using before-after and cross-sectional methods. The results indicated that MUT and RCUT intersections are safer than conventional intersections. MUT intersections are effective in reducing total, PDO, rear-end, and sideswipe crashes, although they significantly increase single-vehicle and non-motorized crashes. RCUT intersections are effective in reducing injury, fatal-and-injury, head-on, and angle crashes. Findings of this research provide clear evaluation for decision makers about the effectiveness of MUT and RCUT intersections in crash reduction.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-00864
Paper Title	Variation in Crash Modification Factors due to Specification and Measurement Error
Abstract	For highway safety projects it is common to use deterministic crash modification factors (CMF) to determine the appropriate safety treatment. CMFs are based on estimates of the correlations of various road geometry attributes with crash frequency, which are derived from models specified according to the analyst's discretion and affected by the analyst's data processing decisions. how data is processed. This means that estimation results are subject to large variations in coefficient estimates. Specifying crash models incorrectly (introducing specification error) and using problematic data (introducing measurement error) can lead to bad decisions on which safety countermeasures to implement. This problem may be exacerbated by standardization through manuals such as the Highway Safety Manual (HSM). Using data from North Carolina, we examined the specification error problem associated with omission of variables and measurement error Deng et missing data. We compared the results of statistical models affected by the speciflication and measurement error to models where we attempted to rectify the problems to see if there was an improvement in results. Results were mixed, showing no substantial change in the coefficients between models affected by specification and measurement error and models unaffected for certain variables while showing notable change for others.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-03041
Paper Title	Examining the Standard Errors of Crash Modification Factors Developed with Empirical Bayes Before-After Studies
Abstract	Estimating crash modification factor (CMF) for safety treatments (i.e., safety effectiveness evaluation) is an important step in the process of roadway safety management. Empirical Bayes (EB) before-after study is the state-of-art approach for developing CMFs amid various methods, and it is always preferred when applicable. The EB method corrects the regression-to-the-mean bias and improves estimation accuracy. However, the performance of the CMFs derived from the EB method has never been fully investigated. The primary objective of this study is to examine the accuracy of CMFs estimated with EB before-after studies. Particularly, the focus is the quality of the estimated CMF standard errors. Artificial realistic data (ARD) and real crash data on rural two-lane roadways are used to evaluate the estimated CMF standard errors. The results indicate that: (1) The CMFs derived with the EB before-after method are very close to the pre-assumed true values. (2) The estimated CMF standard errors do not reflect the true values. The estimation remains at the same level regardless of the pre-assumed CMF standard error. The EB before-after study is not sensitive to the variation of CMF among sites. (3) The analyses on real-world traffic and crash data with dummy treatment indicate that the EB method tends to under-estimate the standard error of the CMF. Safety researchers should recognize that the CMF variance may be biased when using the EB method to evaluate safety effectiveness. It is necessary to revisit the algorithm for estimating CMF variance within the EB method.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-04012
Paper Title	Safety Evaluation of High Friction Surface Treatments
Abstract	The intent of the study was to provide high quality crash modification factors (CMFs) and benefit/cost (B/C) ratios for high friction surface treatments (HFSTs) and in so doing to recommend where and under what conditions to use them to effectively reduce roadway crashes. The state-of-the-art empirical Bayes before-after methodology was applied to evaluate the effects of HFST treatments on various crash types – total, injury, wet road, run-off-road, and head-on plus opposite direction sideswipe (for curves only) using data obtained from West Virginia (curve sites), Pennsylvania (curve sites), Kentucky (curve and ramp sites), and Arkansas (ramp sites). The results for curve sites indicate substantial and highly significant safety benefits (low CMFs) for each State and the 3 States combined. This is especially so for the primary crash types targeted by HFST programs: run-off-road, wet road, and head-on plus opposite direction side-swipe crashes. The results for ramp sites for the two States were inconsistent, except for wet weather crashes for which the benefits are quite large and highly significant). The benefits for all crashes and injury crashes are substantial for Kentucky while there are negligible effects for these crashes in Arkansas. A disaggregate analysis of the curve sites suggested that there appears to be a logical and consistent relationship between CMFs and three variables: friction improvement, traffic volume, and expected crash frequency before treatment. These variables were used in developing recommended crash modification functions.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-05578
Paper Title	The Effect of Intermittent Shoulder Rumble Strips Application Strategy on the Development of Crash Modification Factors
Abstract	Lane departure crashes (LDC) are the most common type of crashes in Wyoming, contributing to 72% of all fatal and incapacitating injury crashes. In the US, single vehicle run off the road crashes contribute to a total societal loss of $80 billion annually. Shoulder Rumble Strips (SRS) have been proven to have a significant effect on reducing LDC. The process of quantifying safety effectiveness of SRS becomes challenging when resurfacing and shoulder rehabilitation may result in an intermittent presence of SRS in some locations as opposed to the assumption of continuous presence.

Authors	Bo Lan, UNC Highway Safety Research Center
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-05570
Paper Title	Comparison of Crash Modification Factors for Engineering Treatments Estimated by Before-After Empirical Bayes and Propensity Score Matching Methods
Abstract	Cross-sectional and the empirical Bayes (EB) before-after are two of the most common methods for estimating crash modification factors (CMFs). The EB before-after method has now been accepted as one way of addressing the potential bias due to regression to the mean (RTM) problem. However, sometimes before-after methods may not feasible due to the lack of data from before and after periods. In those cases, researchers rely on cross-sectional studies to develop CMFs. One of the primary challenges of cross-sectional studies is the issue of confounding. Propensity score (PS) matching methods along with cross-sectional regression models is one of the methods that can be used to address confounding. Though the PS methods are widely used in epidemiology and other studies, there are only a few studies using the PS matching methods in CMF derivations in transportation safety. The intent of this study is to evaluate and compare the performance of cross-sectional regression models with PS matching methods with the results from the EB and traditional cross-sectional methods. These methods were evaluated and compared with the traditional cross-sectional using two carefully selected simulated datasets. The results indicated that a particular type of PS matching method (optimal propensity score distance (PSD) matching with maximum variable ratio of 5) performed quite well compared to the EB and the traditional cross-sectional methods. Keywords: empirical Bayes (EB) before-after, cross-sectional, propensity score

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 1691
Session Title	Highway Safety Performance Research
Paper Number	20-02676
Paper Title	Improving the Transferability of the Crash Prediction Model Using the TrAdaBoost.R2 Algorithm
Abstract	The crash prediction model is a useful tool for traffic administrators to identify significant risk factors, estimate crash frequency, and screen hazardous locations. Since only limited or low-quality data can be collected for some jurisdictions interested in traffic safety analysis, calibration methods should be applied to an available crash prediction model. The problem with current calibration methods is that the aggregate method limits prediction accuracy and the disaggregate method is resource-consuming. Transfer learning is a technique aimed toward learning knowledge from old data domains to solve problems in new data domains. TrAdaBoost.R2, an instance-based transfer learning technique, is adopted in this paper since it meets the requirement of site-based crash prediction model transfer. A comparison was made to examine TrAdaBoost.R2's efficiency in extracting knowledge from spatially outdated source data domain (old data domain). The target data domain (new data domain) was split into two parts to test the technique's adaptability to a small sample size. Calibration factor based on a negative binomial model was employed to compare predictive performance of the transfer learning technique. Mean square error was calculated to evaluate the prediction accuracy. Two cities in China, Shanghai and Guangzhou, were taken as source data domain and target data domain mutually. Results show that the models constructed with TrAdaBoost.R2 improve the prediction accuracy compared to the negative binomial model. The TrAdaBoost.R2 is further recommended due to its predictive performance and adaptability to a small sample size.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Session 1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates (Act I, Session 1338; Act II, Session 1339; Act IV, Session 1356)
Paper Number	20-03499
Paper Title	Does Stop-Signs Improve Safety For All Road Users? A Before-After Study On Stop-Controlled Intersections Using Video Trajectory And Surrogate Methods
Abstract	The conversion of minor-approach-only stop (MAS) intersections to all-way-stops (AWS) intersections are a common safety countermeasure in North America in residential areas. Although there is a positive perception by the general population of the installation of stop-signs in residential areas, there is little research that has looked at the impact of AWS on road safety and road users behaviour. This paper aims at investigating the safety effect of converting MAS to AWS intersections using an observational before and after approach and alternative surrogate measures of safety (SMoS). More specifically, the impact of AWS conversion is investigated using multiple indicators including vehicle and bicycle speed measures, vehicle-pedestrian and vehicle-cyclist conflicts as well as yielding rates. To determine the effect of stop signs, a multilevel regression approach is adopted in order to control for built environment, traffic exposure and intersection geometry factors. In this study, a unique sample of 40 treated intersections is used from which data was collected before and after the implementation of AWS. Using automated video processing and computer vision software, 248 hours of video were processed and corrected; more than 62,000 (32,208 before and 30,127 after treatment) road users' trajectories were obtained from 110 approaches. Results show that the implementation of AWS has a statistically significant effect on the speed reduction of vehicles and cyclist. However, it is observed a small variation after the AWS implementation on the post-encroachment time (PET) values. The DV analysis shows that there is a better performance from the behavioural aspect, having more yielding compliances after the treatment. Future work would investigate the poor fit of the PET and evaluate cyclist behaviour deeply.

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Sponsoring Committee	Standing Committee on User Information Systems (AND20)
Session Number	Session 1342
Session Title	Current Research in User Information Systems
Paper Number	20-00421
Paper Title	Wearable Devices as Vibration Warning for Forward Collision Warning System: An Analysis of Location Effect
Abstract	More effective warning of potential collision risks is important for drowsy and distracted drivers. This study explores the possibility and effectiveness of using smart wearable devices as tactile warnings, including smartwatch worn on the wrist, a smart ring worn on the finger, and smart glasses worn on the head temple area. In our study, participants wore vibrators while performing a simulated car-following task. They all finished four conditions: without warning, warnings at finger, wrist and temple area when the lead vehicle braked intermittently. Results showed that under the conditions that warnings at the finger and the wrist produced shorter braking response time than no warning condition, while warning at the temple area did not produce significant benefit in response time over no warning condition. Participants also preferred warnings at the finger and the wrist than the temple area. For applications, the more effectiveness and preferences for warning at the finger and wrist can advise vehicle designers to design more sophisticated warning designs.

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Sponsoring Committee	Standing Committee on User Information Systems (AND20)
Session Number	Session 1342
Session Title	Current Research in User Information Systems
Paper Number	20-00938
Paper Title	The Influence of Creative Advertisements in Bus Rear-End Safety Campaign
Abstract	Rear-ended collisions in which a vehicle rear ends a bus account for a relatively large proportion of total bus collisions. While the literature does identify transit organizations that have engaged in using rear-end safety advertisements as a collision countermeasure, quantitive studies on the effectiveness of such a countermeasure is lacking. Furthermore, some research suggests that the use of rear-end safety advertisements may stimulate distracted driving, potentially resulting in an increase of collisions. This study involves a before-after analysis with a comparison group to evaluate the influence of creative advertisements used in the Capital Metropolitan Transportation Authority's (Capital Metro) rear-end safety advertisement campaigns. There were two campaign periods, which were studied separately and together (combined). The analysis reveals that there have been reductions in rear-ended crashes following the campaigns. This reduction in crashes was seen across different comparison groups. Due to the limited sample size and small window of time during the after-period, however, only one comparison was statistically significant. The before-after comparison between crashes (rear-ended and non-rear-ended) involving campaign buses showed a 69 percent decrease in rear-ended crashes (statistically significant at the 95 percent confidence interval). This study is an initial exploration for quantifying the effectiveness of creative safety advertisements in reducing rear-ended crashes. This finding is important for Capital Metro and others in the transportation industry when considering countermeasures to address rear-end safety.

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Sponsoring Committee	Standing Committee on User Information Systems (AND20)
Session Number	Session 1342
Session Title	Current Research in User Information Systems
Paper Number	20-04565
Paper Title	Safety Evaluation of Fog Warning System in Connected Vehicle Environment Based on Sample Entropy
Abstract	Changes in driving behavior caused by reduced visibility in fog are likely to cause crashes. Fog warning system based on the connected vehicle (CV) technology can improve driving safety in foggy weather. The objective of the paper is to evaluate the speed stability and driving safety of drivers under different fog levels (i.e., no fog, light fog, heavy fog) and different technical levels (i.e., normal, with dynamic message sign (DMS), with human-machine interface (HMI)) based on the CV test platform of driving simulation. The paper collected driving behaviors data based on driving simulation experiments and divideed the experimental road into four zones: whole zone, clear zone, transition zone and fog zone. Acceleration and standard deviation of speed were identified as indicators in the paper. In addition, the paper proposes the index of acceleration safety entropy and speed standard deviation safety entropy based on sample entropy, and analyzes the changes of each indicator in different zones. The results show that fog warning system can improve the speed stability and driving safety of drivers in fog zone and make the driver decelerate earlier with a smaller deceleration before entering the fog zone. The higher the technical level, the earlier the driver will decelerate. In the light fog condition, the fog warning system with HMI has better effect on improving the speed stability. In the heavy fog condition, the two fog warning systems have little difference. The paper provides evaluation indicators and general evaluation methods for the safety assessment of fog warning system.

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Sponsoring Committee	Standing Committee on User Information Systems (AND20)
Session Number	Session 1342
Session Title	Current Research in User Information Systems
Paper Number	20-05471
Paper Title	Advanced Warning System for Safer Interaction Between Vehicles and Vulnerable Road Users
Abstract	A driving simulator experiment was used to study the impact of detecting pedestrians and bicyclists by participants with and without an advanced warning about the presence of the vulnerable road users ahead. The driving scenario included rural roadways, urban roadways and a 15-mph winding road. The warning system used to communicate the presence of vulnerable road user ahead was a combination of auditory cue and a simultaneous visual cue displayed on the dashboard. Nineteen participants completed the experiment. The participants were asked to detect the presence of pedestrians/bicyclists by pressing a button device on the steering wheel. The reaction distance between the location of an event and the location of detecting an event by the driver was used as the analysis measure. The warning system was activated at 20, 30, and 40 seconds ahead from reaching an event (pedestrians or bicyclists). When the warning system was activated, statistical tests suggest that participants detected the presence of pedestrians/bicyclists 25 ft earlier than when no warning system was activated. While no statistically significant difference was observed between the different activation locations of the warning system (due to the small sample size), the variances in the location where pedestrians/bicyclists were detected were lower when the warning system was activated. No speed reduction was observed for the events with no warning system. When the warning system was activated, there was a speed reduction of 4.9 mph on average observed for approximately 73%. This reduction highlights the effectiveness and benifts of this warning system.

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Sponsoring Committee	Standing Committee on Simulation and Measurement of Vehicle and Operator Performance (AND30)
Session Number	Session 1342
Session Title	Advances in Safety: ITS, ADAS, CAV, and Traffic Engineering Solutions
Paper Number	20-02896
Paper Title	Calibration and Evaluation of Responsibility-Sensitive Safety Model on Autonomous Car-Following Maneuvers Using Naturalistic Driving Study Data
Abstract	Safety guarantees are of primary concern of the automated vehicle (AV) industry and regulatory bodies, and are paramount to the AVs' dependability. Responsibility-Sensitive Safety (RSS), proposed by Mobileye, is a rigorous mathematical model that defines the real-time safety distance that the AV needs to maintain from surrounding vehicles, and helps the AV respond to dangerous situations. However, the RSS's performance has not yet been tested with real driving data. This study aims to calibrate and evaluate the RSS model based on car-following scenarios created from safety-critical events (SCEs) detected in the Shanghai Naturalistic Driving Study. SCEs from the raw data were identified with a trigger method and manually validated . The SCEs were then converted into virtual scenarios, in which the human-driven subject vehicle was replaced with an AV controlled by a model predictive control based adaptive cruise control (ACC) system embedded with RSS. T he RSS model was calibrated with the goal of achieving optimal safety performance, that is, generating the lowest time-integrated TTC (TIT) after the AV algorithms were implemented on the safety-critical scenarios. By comparing the performances of RSS-embedded ACC, ACC-only, and the unassisted human driver, this study found that: 1) RSS-embedded ACC performed best in eliminating underlying safety-critical situations by controlling the average TIT for each 15-second event at 0.31 s 2 ; 2) RSS-embedded ACC generated the highest average acceleration, speed, relative speed, and distance from the lead vehicle; and 3) on average, RSS-embedded ACC was able to perceive the SCEs 0.72 seconds ahead of the human driver.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1349
Session Title	Pedestrian Hybrid Beacons and Enhanced Crosswalk Signage
Paper Number	20-00261
Paper Title	Pedestrian Safety at Pedestrian Hybrid Beacons: Results of a Large-Scale Study in Arizona
Abstract	The pedestrian hybrid beacon (PHB) is a traffic control device used at pedestrian crossings. The focus of an Arizona Department of Transportation research effort is to investigate changes in crashes for different severity levels and crash types (e.g., rear-end crashes) due to the PHB presence as well as in crashes involving pedestrians and bicycles. Two types of methodologies were used to evaluate PHBs: (a) an Empirical Bayes (EB) before-after study, and (b) a cross-sectional observational study. For the EB before-after evaluation, the Research Team considered three reference groups: unsignalized intersections, signalized intersections, and both unsignalized and signalized intersections combined. For the signalized and combined unsignalized and signalized intersection groups, all crash types considered showed statistically significant reductions in crashes (e.g., total crashes, fatal and injury crashes, rear-end crashes, fatal and injury rear-end crashes, angle crashes, fatal and injury angle crashes, pedestrian-related crashes, and fatal and injury pedestrian-related crashes). A cross-sectional study was conducted with a larger number of PHBs (186) to identify relationships between roadway characteristics and crashes at PHBs, especially with respect to the distance to an adjacent traffic control signal. Distance to adjacent traffic signal was found to be significant only for rear-end and fatal and injury (FI) rear-end crashes. This study represents the largest known study to date to evaluate the safety impacts of PHBs.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1349
Session Title	Pedestrian Hybrid Beacons and Enhanced Crosswalk Signage
Paper Number	20-00186
Paper Title	How Well Do Pedestrian Hybrid Beacons Operate on Higher-Speed Roads?
Abstract	The pedestrian hybrid beacon (PHB) is a traffic control device used at pedestrian crossings. It was first included in the 2009 Manual on Uniform Traffic Control Devices and was based on the HAWK developed in Tucson, Arizona. The focus of an on-going Arizona Department of Transportation (ADOT) research effort was on investigating the use of PHBs on higher-speed roads. A total of 10 locations in Arizona representing higher operating speed conditions (85th percentile speed ranged between 44 and 54 mph) were selected for inclusion in this study. Data were collected using a multiple video camera setup. The final dataset reflected about 40 hours of video data and included 1,214 pedestrians or bicyclists crossing at PHBs. Overall, driver yielding for these 10 sites averaged 97 percent, which is similar to driver yielding rates for PHBs installed on lower-speed streets.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1388
Session Title	Speed Feedback Signs, Curve Warning Treatments, and the History/Future of Traffic Control Devices
Paper Number	20-00118
Paper Title	Evaluation of Sequential Dynamic Chevron Warning Systems on Rural Two-Lane Curves
Abstract	Roadway departure crashes are a significant safety concern. A majority of these crashes occur on rural two-lane roadways, with a disproportionate number occurring on horizontal curves. The average crash rate for horizontal curves is about three times that of other highway segments. Curve-related crashes involve a number of roadway and driver causative factors with speed being a preeminent factor. Implementing safety countermeasures on rural horizontal curves to address these crash types can improve the safety performance. Chevron alignment signs provide additional emphasis and guidance for drivers negotiating curves. To further emphasize the curve, some agencies have started using a Sequential Dynamic Chevron Warning System (SDCWS) which uses LED lights within each chevron sign to provide sequential lighted guidance through the curve. The research team evaluated eighteen rural horizontal curves where a SDCWS had been implemented on rural 2-lane curves. Control sites with similar characteristics were selected and included in the study. Models were developed using an EB methodology for non-intersection (total) crashes and injury crashes. Additional countermeasures were present at some of the sites and were included in the model. Using these data, the study developed crash modification factors for SDCWS with a resulting Crash Modification Factor (CMF) of 0.34 for total crashes (non-intersection) and 0.49 for injury crashes.

Authors	Timothy Gates, Michigan State University Anthony Ingle, Michigan State University Peter Savolainen, Michigan State University
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1388
Session Title	Speed Feedback Signs, Curve Warning Treatments, and the History/Future of Traffic Control Devices
Paper Number	20-03981
Paper Title	Evaluation of Sequential Dynamic Chevron Warning Systems on Rural Two-Lane Curves
Abstract	Roadway departure crashes are a significant safety concern. A majority of these crashes occur on rural two-lane roadways, with a disproportionate number occurring on horizontal curves. The average crash rate for horizontal curves is about three times that of other highway segments. Curve-related crashes involve a number of roadway and driver causative factors with speed being a preeminent factor. Implementing safety countermeasures on rural horizontal curves to address these crash types can improve the safety performance. Chevron alignment signs provide additional emphasis and guidance for drivers negotiating curves. To further emphasize the curve, some agencies have started using a Sequential Dynamic Chevron Warning System (SDCWS) which uses LED lights within each chevron sign to provide sequential lighted guidance through the curve. The research team evaluated eighteen rural horizontal curves where a SDCWS had been implemented on rural 2-lane curves. Control sites with similar characteristics were selected and included in the study. Models were developed using an EB methodology for non-intersection (total) crashes and injury crashes. Additional countermeasures were present at some of the sites and were included in the model. Using these data, the study developed crash modification factors for SDCWS with a resulting Crash Modification Factor (CMF) of 0.34 for total crashes (non-intersection) and 0.49 for injury crashes.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-01409
Paper Title	A Before-After Evaluation of Left-turn Lane Extension: Considering Injury Severity and Collision Type
Abstract	Left-turn lanes are commonly used to provide space to accommodate vehicle deceleration and provide adequate storage of turning vehicles. The objective of this study is to evaluate the safety effectiveness of extending the length of left-turn lanes at signalized intersection approaches. Five years of collision data including injury severity and collision type from 3 treatment sites and 31 comparison sites in the City of Surrey, Canada were used in the study. A Full Bayesian (FB) before-after analysis was conducted for all collisions, severity levels, and collision types. Multivariate Poisson–lognormal linear intervention (PLNI) models were used. The treatment effectiveness index were calculated to quantitatively measure the effectiveness of the safety treatment. The FB before-after results showed that the treatment-related collisions were reduced by 57.4% following the implementation of extended left-turn lane. The reduction in injuries and fatalities (I+F) collisions (63.8%) was greater than that in property damage only (PDO) collisions (55.7%). The decrease in rear-end collisions (62.8%) was greater than that in sideswipe collisions (58.11%). The findings indicate a remarkable improvement in safety after the length extension of the left-turn lane.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-01888
Paper Title	Comparison of State-of-the-art Observational Before-After Analysis Methods in Traffic Safety: A Case Study of the Red-light-running Program in New Jersey
Abstract	Empirical Bayes (EB) and full Full Bayes (FB) methods are widely used for before-after safety evaluation because they can appropriately estimate the “should-be” crash occurrence in the after period should treatment not implemented. A new before-after method stemmed from the survival analysis was proposed in a recent study by Xie et al. (1), and this method shows its merits when sufficient data from reference sites is unavailable and temporal heterogeneity needs to be captured. On the other hand, two methods originated from the Neyman-Rubin causal framework in statistics, namely propensity score matching (PSM) and the difference-in-difference (DID) is gaining increasing attention in traffic safety research. In this study, we compared all aforementioned methods in terms of their treatment effect estimation after being unified within the Neyman-Rubin causal framework. Multiplicative average treatment effect on the treated was used as the target estimand. The deactivation of the red-light-running (RLR) program in New Jersey was used as the case study to compare treatment effects estimates from different methods. All the methods except the PSM can yield similar crash modification factors (CMFs) that are less than one. It indicates that deactivating RLR counterintuitively led to crash reduction, which may result from the carryover effect of the RLR program. The contradicting outcomes of the PSM was probably due to the overlap and balance assumption violation of the PSM method. The use of the PSM method should be adopted with caution since PSM method may actually increase the bias in treatment effect estimates.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-03859
Paper Title	Estimate of the Safety Effect of All-Way Stop Control Conversion: A Case Study in Washington D.C.
Abstract	This study evaluated safety effects associated with converting Traditional Stop Control (TSC) to All-Way Stop Control (AWSC) at 53 intersections in Washington DC. The study utilized an observational treatment group and a randomly selected comparison group. Multiple linear regression modeling was used to estimate the effect of of AWSC conversion on crash outcomes, controlling for confounding factors and check its statistical significance. The study also examined potential covariates that could influence AWSC crash outcomes, such as the number of legs and functional classification. This study found an overall 36% reduction in all crashes and a 42% reduction in injury crashes associated with converting intersections from TSC to AWSC. In addition, the study revealed a statistically significant reduction in right-angle crashes along with a statistically significant increase in straight hit pedestrian crashes. For all the other collision types, including right turn, left turn, rear end, sideswipes and bicycle crashes, no statistically significant coefficients were found. With many Vision Zero cities considering increased use of AWSC to help achieve their safety goals, it is important to understand and communicate AWSC safety effects.

Authors	Alyssa Ryan, University of Massachusetts, Amherst Michael Knodler, University of Massachusetts, Amherst
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 1357
Session Title	Intersection Safety in Focus
Paper Number	20-04710
Paper Title	Evaluating Crash Type Likelihood at Various Traffic Control Devices: A Multinomial Logistic Regression Approach Using HSIS Data
Abstract	Widespread acceptance of analytical methods outlined in the Highway Safety Manual, including Crash Modification Factors (CMFs), have been developed to measure the safety effectiveness of a particular treatment or design element. Often, these CMFs are developed to target specific crash types, with the goal of reducing that crash type with a specific treatment. Implementing these countermeasures at specified locations can help mitigate preventable crashes. However, a lack of research has been completed analyzing the likelihood of each crash type occurring at various traffic control devices on a large, multi-year scale across the United States. Without this information, the increased need for specific CMFs to be developed cannot yet be fully realized. Certain crash types are often associated with higher severity, which should be targeted in future research. To align with the goal of reducing crashes and reaching zero fatalities, this study provides insight into the relationship between various crash types and traffic control devices on a macro scale for all roadway types. A multinomial logistic regression model and relative risk ratios were utilized in the analysis of Highway Safety Information System (HSIS) data obtained from over 1.8 million crashes occurring in the states of North Carolina and Ohio from 2010 to 2015. The results of this analysis provide both an improved understanding and necessary foundational element for future modeling of the relationships between crash types, and in relation, crash severity, that occur at specific traffic control devices.

Authors	Adrian Sandt, University of Central Florida Haitham Al-Deek, University of Central Florida Md Imrul Kayes, University of Central Florida Patrick Blue, University of Central Florida Valentina Gamero, University of Central Florida
Sponsoring Committee	Standing Committee on Freeway Operations (AHB20)
Session Number	Session 1142
Session Title	Freeway Operations 2020
Paper Number	20-00748
Paper Title	Benefit-Cost Analyses of Rectangular Flashing Beacon Wrong-Way Driving Countermeasures on Toll Road Exit Ramps in Florida
Abstract	In recent years, Rectangular Flashing Beacons (RFBs) and other technologies have been used as wrong-way driving (WWD) countermeasures on limited access facilities. Studies have shown that these devices effectively reduce WWD, but no research has compared the financial benefits and costs of these countermeasures. This paper uses three different methodologies to conduct benefit-cost analyses for RFB WWD countermeasures installed on Central Florida toll road exit ramps. The studied benefits include savings due to reductions in WWD crashes, non-crash events, and injuries, while costs include equipment, installation, and maintenance costs. For the first two methodologies, the reduction in WWD crash risk (WWCR) at the RFB-equipped ramps was determined. This WWCR considers non-crash WWD events, interchange design, and traffic volumes. Different measures of effectiveness (turn around percentage of detected wrong-way vehicles at the RFB ramps and reduction in WWD 911 calls and citations at the RFB interchanges compared to similar comparison interchanges without RFBs) were used in these two methodologies to estimate the WWCR reduction and associated savings. For the third methodology, the relationship between WWD crashes and non-crash events was used to determine the average savings for WWD 911 calls and citations. Before-after analyses were then conducted to determine the individual reductions in WWD 911 calls and citations. Applying these three methods resulted in life-cycle benefit-cost ratios ranging from 2.49 to 4.10 (crash savings) and from 4.77 to 7.20 (injury savings). Other agencies could use these methodologies to determine the benefits of WWD countermeasures or other technologies with limited crash data.

Authors	Abigail Preston, SEPI Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Bicycle Transportation (ANF20)
Session Number	Session 1142
Session Title	Bicycle Research Poster Session
Paper Number	20-05247
Paper Title	Safer for Cycling: Evaluating Operational and Safety Effects of a Protected Intersection Design
Abstract	This research seeks to improve the safety of cyclists at intersections. The focus is primarily to evaluate the operational and safety effects of a protected intersection design (PID) on cyclists' safety at intersections. The PID was modeled and evaluated at the intersection of Tyvola Rd and South Blvd in south Charlotte, North Carolina. Traffic was modeled on the existing and proposed PID using PTV VISSIM microscopic simulation software under conditions of zero percent bikes to fifteen percent bikes. Safety was then analyzed using Surrogate Safety Assessment Model (SSAM), and conflicts were defined as a 1.5-second intersection of two or more trajectories. The results indicate as much as an 80% reduction in bicycle-related crossing-type conflicts. The findings support the hypothesis that the PID significantly reduces conflicts at intersections, and therefore improves safety.

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Sponsoring Committee	Standing Committee on Signing and Marking Materials (AHD55)
Session Number	Session 1256
Session Title	Bicycle Research Poster Session
Paper Number	20-00970
Paper Title	Investigating Potential Benefits and Applicability of Wider Longitudinal Pavement Markings for Applications in Canada
Abstract	In recent years, many road authorities in Canada have been considering the use of wider longitudinal pavement markings (LPM) to enhance road safety and driver comfort. However, conclusive evidence on the safety impacts of this type of intervention has not been available. To address this gap in the literature, this study was conducted to investigate the safety impacts of wider pavement markings. The study adopted the state-of-the-art Full Bayes approach to conduct a “Before” and “After” safety evaluation, using data collected from 38 treatment sites (highway segments) from three Canadian jurisdictions (British Columbia, Alberta, and Quebec). Eight years of collision and traffic data were collected before and after increasing the width of pavement markings of the 38 highway segments. In addition, collision and traffic data were also collected from 170 comparison sites in order to control for the confounding factors, such as maturation and unrelated effects. The results showed an overall significant reduction in both total collisions and target collisions (run-off-the-road collisions) by 12.3% and 19.0%, respectively, after applying the wider pavement markings. The Total collisions were reduced by 11.1%, 27.5%, and 1.1% in Alberta, British Columbia, and Quebec, respectively. In addition, a reduction that varies between 22.7% and 28.9% were observed in the run-off-the-road collisions in the three jurisdictions. The results suggest that wider longitudinal pavement markings are likely to provide a reduction in collisions. As such, road authorities should consider using this intervention to improve road safety, particularly, at locations that experience a high frequency of run-off-the-road collisions.

7 Surrogate Measures of Safety

Nicolas Saunier and Bismarck Ledezma-Navarro, Polytechnique Montreal

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

From the review, the studies can be classified in four main topics: **Intersections and interchanges**, **pedestrians and non-motorized users**, **real-time safety analysis** and **safety tool development** (implementing the actual measures or proposing frameworks). Nine papers involved safety at **intersections and interchanges** (Hu et al., 20-00229; Essa & Sayed, 20-00438; Borsos et al., 20-00691; Fu et al., 20-01525; Bocktor et al., 20-02363; Scholl et al., 20-03490; Ledezma-Navarro et al., 20-03499; Goyani et al., 20-04461; Mukherjee & Mitra, 20-05873). Likewise, **pedestrians and non-motorized users** were investigated in seven papers (Fu et al., 20-01525; Scholl et al., 20-03490; Ledezma-Navarro et al., 20-03499; Golakiya & Dhamaniya, 20-03513; Russo et al., 20-05024; Nassereddine et al., 20-05550; Mukherjee & Mitra, 20-05873). **Real-time safety analysis** was investigated in four papers (Wang et al., 20-02474; Bao et al., 20-02682; Osman & Hajij, 20-04962; Azizi et al., 20-04969). Different **speed measures** such as acceleration, deceleration, braking, etc. were the main indicator or a complementary in seven articles (Fu et al., 20-01525; Cai et al., 20-02105; Bocktor et al., 20-02363; Bao et al., 20-02682; Wang., 20-03236; Scholl et al., 20-03490; Ledezma-Navarro et al., 20-03499), while **safety tool development** was addressed in six papers (Cai et al., 20-02105; Keung et al., 20-02239; Raju et al., 20-03089; Wang, 20-03236; Liu et al., 20-03472; Janvier & Saunier, 20-06071).

Related to the surrogate measures of safety, **traffic conflicts** were used in six papers (Hu et al., 20-00229; Essa & Sayed, 20-00438; Tarko & Lizarazo Jimenez, 20-01358; Stipancic et al., 20-01391; Keung et al., 20-02239; Nassereddine et al., 20-05550). As main traffic conflict indicator, **time-to-collision (TTC)** and **post-encroachment time (PET)** were used in thirteen articles. In two papers, the **TTC and PET** were used together as evaluation measures (Russo et al., 20-05024; Janvier & Saunier, 20-06071), in six papers the **TTC** value was used as main safety measure (Li et al., 20-00665; Borsos et al., 20-00691; Wang et al., 20-02474; Liu et al., 20-03472; Golakiya & Dhamaniya., 20-03513; Azizi et al., 20-04969), while **PET** was used alone or as a complementary measure in five articles (Fu et al., 20-01525; Scholl et al., 20-03490; Ledezma-Navarro et al., 20-03499; Goyani et al., 20-04461; Mukherjee & Mitra, 20-05873).

Regarding to the input data, eight papers had **video data** as primary source (Essa & Sayed, 20-00438; Li et al., 20-00665; Fu et al., 20-01525; Bocktor et al., 20-02363; Scholl et al., 20-03490; Ledezma-Navarro et al., 20-03499; Golakiya & Dhamaniya., 20-03513; Nassereddine et al., 20-05550). **Simulation trajectories** were used as main source of information in four articles (Essa & Sayed, 20-00438; Raju et al., 20-03089; Russo et al., 20-05024; Janvier & Saunier, 20-06071). **Vehicles trajectories** were used in three articles (Cai et al., 20-02105; Osman & Hajij, 20-04962; Azizi et al., 20-04969). Information from **user trajectories** is used in three papers (Raju et al., 20-03089; Wang., 20-03236; Liu et al., 20-03472). **Naturalistic driving data** was the input of two articles (Tarko & Lizarazo Jimenez, 20-01358; Bao et al., 20-02682). **GPS and smartphone** data were utilized by Stipancic et al., 20-01391.

In terms of the data analysis, **statistical regression models** were used in eleven articles (Hu et al., 20-00229; Stipancic et al., 20-01391; Keung et al., 20-02239; Bocktor et al., 20-02363; Liu et al., 20-03472; Scholl et al., 20-03490; Ledezma-Navarro et al., 20-03499; Golakiya & Dhamaniya., 20-03513; Azizi et al., 20-04969; Nassereddine et al., 20-05550; Janvier & Saunier, 20-06071). **Machine learning algorithms** were implemented in two papers (Bao et al., 20-02682 and Wang., 20-03236), while empirical analysis was used by Wang et al., 20-02474.

Finally, it is important to mention that the **crash risk** was predicted in six papers (Cai et al., 20-02105; Wang., 20-03236; Liu et al., 20-03472; Scholl et al., 20-03490; Goyani et al., 20-04461; Osman & Hajij, 20-04962).

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

Authors	Minqi Hu, Southeast University Qiaojun Xiang, Southeast University Zhanji Zheng, Southeast University Xuhua Zhang, Southeast University Yan Li, Minisry of Public Security
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-00229
Paper Title	Correlation Analysis of Traffic Conflicts and Driving Behaviors at Interchange Diverging Areas
Abstract	Driving Behaviors (e.g., lane-changing, acceleration/deceleration) might be the most possible reasons for traffic conflicts at freeway interchange diverging areas. This study aims to investigate the correlation between traffic conflicts and driving behaviors which include vehicle acceleration/deceleration and lane changing characters at diverging area based on Chinese cases. Principal component analysis was used to make a dimension reduction of the parameters which would influence traffic conflicts. The Bayesian network was used to construct a correlation model between relevant parameters and traffic conflicts at diverging area. Results showed that there is a significant correlation between the lane-changing position and the traffic conflicts, which were located within 600m from the beginning of the diverging area and the first 60m of the deceleration area. A representative correlation was found exist between acceleration/deceleration and the traffic conflict. Vehicle acceleration/deceleration and lane changing behaviors are the main factors affect traffic conflicts. The research could provide useful advices for driver training programs to reduce casualties and also put forward a basis for the active prevention of traffic crashes.

Authors	Mohamed Essa, The University of British Columbia Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-00438
Paper Title	A Comparison between SSAM and Real-Time Safety Models in Predicting Field-Measured Conflicts at Signalized Intersections
Abstract	Traffic simulation models are frequently being used to evaluate safety of signalized intersections, especially when testing unconventional designs or investigating effects of emerging technologies such as connected and autonomous vehicles. In this approach, vehicle trajectories extracted from traffic simulation are usually analyzed using the Surrogate Safety Assessment Model (SSAM) to estimate the number and severity of traffic conflicts. However, recent research showed that evaluating safety using SSAM is associated with several limitations. First, a rigorous calibration procedure must be applied to the simulation model to obtain reliable conflict results. Second, simulation models, in many cases, do not accurately represent the actual driving behavior. Subsequently, they often fail to capture the actual mechanism generating near misses. This paper presents a new procedure, alternative to SSAM, for evaluating the safety of signalized intersections. The procedure combines simulated vehicle trajectories with real-time safety models to predict rear-end conflicts. The conflict prediction is based on dynamic traffic parameters, such as traffic volume and shock wave characteristics, repeatedly measured over a short time interval (a few seconds). To validate the proposed procedure, we investigated its performance in predicting traffic conflicts extracted from 54 hours of real-world video data at two signalized intersections in the City of Surrey, British Columbia. The predicted conflict results were compared with SSAM. Overall, the results showed that the proposed procedure outperforms SSAM in terms of the conflict prediction accuracy. Lastly, we presented a case study of using the proposed procedure in evaluating the safety impact of a recently-developed connected-vehicles application.

Authors	Ye Li, Central South University Qing Cai, University of Central Florida Zhibin Chen, New York University Shanghai
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-00665
Paper Title	Longitudinal Safety Evaluation of Regular Vehicle and Connected and Automated Vehicle (CAV) via In-Depth Analysis of Trajectory Data
Abstract	With the advancement of traffic video surveillance and data collection, micro-level trajectory data has become available for traffic safety analysis. Surrogate safety measures could be applied to establish the relationship between trajectories and conflicts, but it is difficult to verify the validity of the relationship due to the deficiency of pre-crash data in practice. This study investigated the related issues by in-depth analysis of vehicle trajectory data. Taking the time-to-collision (TTC) index as an example, this study proposed an indirect method to analyze the TTC values based on the well-known Heinrich's pyramid. Further, potentially dangerous durations and three types of critical durations were developed for revealing inherent impacts of micro-level driving behaviors on safety. Finally, the proposed methods were employed for the adaptive cruise control (ACC) and connected and automated vehicle (CAV) systems for safety evaluations. Results indicate the utilization of critical durations provides more information for longitudinal risks. For manually driven vehicles (denoted as regular vehicles, RVs), type 3 duration has the highest risks due to the combined effect. The CAV system is safer than ACC as the CAV has the smaller time delay but with the larger TTC distribution. The CAV system will not cause risks by accelerating actively. The initial critical duration type of RVs, the mean and standard deviation of leading vehicle speeds have significantly impacts on longitudinal safety for ACC and CAV systems. Results of this study could provide useful information for the safety improvement of advanced vehicle systems in the future.

Authors	Attila Borsos, Széchenyi István University Haneen Farah, Delft University of Technology Aliaksei Laureshyn, Lund University Marjan Hagenzieker, Delft University of Technology
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-00691
Paper Title	Are Collision and Crossing Course Surrogate Safety Indicators Transferable? A Probability Based Approach Using Extreme Value Theory
Abstract	In order to overcome the shortcomings of crash data a number of Surrogate Measures of Safety have been developed and proposed by various researchers. One of the most widely used temporal indicators is Time-to-Collision (TTC) which requires the road users to be on a collision course. Road users that are strictly speaking not on a collision course actually might behave and take evasive actions as if they were, thus indicating that such near-miss situations might also be relevant for safety analysis. Taking that into account, a more flexible indicator T_2, which does not require the two vehicles to be on a collision course, describes the expected time for the second road user to arrive at the conflict point. Recently Extreme Value Theory (EVT) offering two approaches, Block Maxima (BM) and Peak-over-Threshold (POT), has been applied in combination with surrogate indicators to estimate crash probabilities. Most of this research has focused on testing BM and POT as well as validating various surrogate safety indicators by comparing model estimates to actual crash frequencies. The comparison of collision course indicators with indicators including crossing course interactions and their performance using EVT has not been investigated yet. In this study we are seeking answers to under what conditions these indicators perform better and whether they are transferable. Using data gathered at a signalized intersection focusing on left-turning and straight moving vehicle interactions our analysis concluded that the two indicators are transferable with stricter threshold values for T_2 and that POT gives more reasonable results.

Authors	Andrew Tarko, Purdue University Cristhian Lizarazo Jimenez, Purdue University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-01358
Paper Title	Estimating the Expected Number of Crashes with Traffic Conflicts Observed in Naturalistic Driving Studies
Abstract	Although the frequency and severity of crashes are direct measures of road safety, crash data are typically of low quality and they require long time to collect for conclusive analyses. Surrogates of crashes that allow a quick and accurate estimation of safety have been an active topic for years. Among multiple alternatives, traffic conflicts are most promising. This paper is aimed to demonstrate the validity of the recently proposed Lomax-based method of applying traffic conflicts to evaluate traffic safety. The data collected in the recent naturalistic driving study, the Strategic Highway Research Program 2 (SHRP2) were used in the validation task. The rear-end crashes recorded during the SHRP2 program and detected corresponding rear-end traffic interactions were analyzed for three category of drivers: young male, mature male, and mature female. These three categories of drives have distinctively different proneness to involvement in crashes. Out of all rear-end traffic conflicts, 1.7 % of them was used to estimate the crash frequencies and rates for each type of drivers by applying the Lomax distribution within the counterfactual approach. Then, the conflict-based crash rate estimates were compared to the crash rates of the studied types of drivers calculated from all the rear-end crashes observed in the SHRP2 study period. The conflict-based rate estimates followed well the crash-based rates and the existing knowledge about the safety performance of the studied drivers. The results confirmed the over-representation of young male drivers in crashes. It was also confirmed that mature male drivers are involved in rear-end crashes more frequently than mature female drivers. The results demonstrate both the validity of the Lomax-based analysis of traffic conflicts and the benefit of reducing the data-collection time by factor 60.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1338
Session Title	Safety Data, Analysis, and Evaluation, Act I: GPS, Naturalistic Driving, Toll, and Other Emerging Data Sources
Paper Number	20-01391
Paper Title	Relating Traffic Flow to Crashes Using Massive GPS Data: Smartphones and Usage-Based Insurance Data Agree
Abstract	Mobile sensors are a powerful data source with applications in several transportation fields. Though cost of collection, transmission, and storage has practically limited studies on driving data and safety, this can be overcome through Usage Based Insurance (UBI). UBI programs track drivers to adjust their premiums based on driver-level surrogate safety measures (SSMs) related to exposure and driving style. Link-level SSMs (volume, speed, or density) could further improve discount calibration. This study quantifies relationships between traffic flow SSMs and historical crashes and includes the validation of previous results (using smartphone-collected data from Quebec City, Canada) and the comparison of three Canadian cities (using UBI data from Quebec City, Montreal, and Ottawa). Extracted SSMs were compared to large volumes of historical crash data using Spearman's Rank Correlation Coefficient and pairwise Kolmogorov-Smirnov tests to determine relationships with crash frequency and severity respectively. Results from the UBI data generally matched those from the previous study. With respect to crash frequency, observed correlations mirrored previous results in direction (congestion and speed variation are positively associated with crashes while mean speed is negatively associated with crashes) while correlation strength was slightly higher. Comparing cities, congestion appears to be a much weaker determinant of crashes in Montreal. Considering crash severity, the previously observed relationships were mostly validated: higher levels of speed variation are attributed to more severe crashes. The significant relationships between link-level SSMs and historical crashes clearly demonstrate the benefit for insurers, municipalities, and other agencies in predicting the likelihood and severity of crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-01525
Paper Title	Impact of Right-turn Channelization on Pedestrian Safety at Signalized Intersections
Abstract	Channelized right turns or slip lanes have been widely implemented as an effective countermeasure of reducing traffic delay and number of conflicts between vehicles at signalized intersections. However, few studies have investigated the impact of channelized right turns (in left-band driving countries) on pedestrian safety. Channelized right turns may increase the risks for the crossing pedestrians since it brings all pedestrian-vehicle interactions in a fully non-signalized environment. Besides, the increased radius at channelized right turns can lead to higher vehicle speeds. This paper investigates the impact of channelized right turns on pedestrian safety based on surrogate safety and behavior measures. For this purpose, video data were collected from twelve signalized intersections in Zunyi, China, involving three main types of right-turn lane designs: 1) non-channelized right-only lane, 2) non-channelized right-through lane, and 3) channelized right-turn lane. Different measures are used including interaction and behavior measures based on a recent-proposed Distance-Velocity model, PET measurements, speed measurements (average crossing speed during interactions and interaction-free speed), and observations of failures in interactions (retreats and evasive maneuvers). Results indicate that the design of channelized right-turn lane increases pedestrian risks from different dimensions of safety. The impact of the nighttime condition on pedestrian safety was also compared. Results show that drivers pay more attention to pedestrians at non-channelized right-turn locations by reducing their speeds at nighttime.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-02105
Paper Title	Road Traffic Safety Risk Estimation Method Based on Vehicle Onboard Diagnostic Data
Abstract	Currently, research on road traffic safety is mostly focused on traffic safety evaluations based on statistical indices for accidents. There is still a need for in-depth investigation on preaccident identification of safety risks. In this study, the correlations between high-incidence locations for aberrant driving behaviors and locations of road traffic accidents are analyzed based on vehicle OBD data. A road traffic safety risk estimation index system with road safety entropy as the primary index and rapid acceleration frequency, rapid deceleration frequency, rapid turning frequency, speeding frequency and high-speed neutral coasting frequency as secondary indices is established. A road safety entropy calculation method is proposed based on an improved entropy weight method. This method involves three aspects, namely, optimization of the base of the logarithm, processing of zero-value secondary indices and piecewise calculation of the weight of each index. Additionally, a safety risk level determination method based on two-step clustering (density and k-means clustering) is also proposed, which prevents isolated data points from affecting safety risk classification. A risk classification threshold calculation method is formulated based on k-mean clustering. The results show that high-incidence locations for aberrant driving behaviors are consistent with the locations of traffic accidents. The proposed methods are validated through a case study on four roads in Chongqing with a total length of approximately 3 8 km. The results show that the road traffic safety trends characterized by road safety entropy and traffic accidents are consistent.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-02239
Paper Title	A Comprehensive Framework for Determining the Optimal Sample Size for Conflict-based Traffic Safety Analysis
Abstract	Conflict-based traffic safety analysis is a burgeoning field but many studies have failed to determine the optimal sample size before conducting their study. Power analysis is a well-established statistical tool used in many different scientific fields, is generalizable to many studies, and can be used to determine an appropriate sample size. The power analysis exploits the significance criterion (α), power (1-β), and effect size (ES) such that the sample size is large enough to protect investigators from Type I and Type II errors to conventional thresholds of 95% and 80%, respectively. This paper proposes a comprehensive framework for road safety researchers and practitioners based on power analysis to determine the minimum sample size required for a conflict analysis study. Three case studies are investigated to illustrate how power analysis can be conducted for different types of conflict analysis study specifications, using the corresponding statistical tests. The minimum sample size is also the optimal sample size because it minimizes the observation period while maintaining acceptable protection from Type I and Type II errors. The proposed framework was found to be valuable in the planning of a current conflict-based safety study and is recommended to be used in future conflict-based traffic safety analyses.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	1253
Session Title	Up to Speed: Safety and Operational Effects of Road Design
Paper Number	20-02363
Paper Title	The Effect of The Geometric Turning Radius on Vehicle Speeds at Urban Non-signalized Intersections as a Safety Indicator
Abstract	Turning maneuvers (left or right) and related treatments have been studied given their safety implications. However, a few studies have examined the effects of the designed curb turning radius. With the help of modern data collection techniques, this study aims to fill the gap presented in the literature on the investigation of the safety of local urban non-signalized intersections using the operating vehicle speed measures derived from observed video trajectory data. Using 35 non-signalized intersections in Montreal with turning radii less than 10.0 meters, video data was collected and processed using commercial software to obtain speed measures. The software utilizes computer vision and deep learning techniques to obtain the trajectories of all users. Over 75,000 users (motorists, cyclists and pedestrians) were detected and motorized vehicles (6906 cars, buses and trucks) were used for the purpose of this study. A random effects linear regression model was run on the speed data and the geometric measures, with an error factor on the intersection level in an aggregated and disaggregated approach. A significant statistical association between radius and speeds observed for aggregated data. For an increase of 1 meter in the turning radius, an increase of 0.775 kph for the 85th speed and 1.208 kph for the median speed for all turns, thus, decreasing the safety of the intersection. However, the turning radius was not of significance for the 85th speed of right turning vehicles which implies further investigation is required.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-02474
Paper Title	Time-to-Collision (TTC) Based Crash Risk Model Incorporating the Effect of Vehicle Weight
Abstract	Collision Avoidance System (CAS) is one of an emerging feature in advanced driver assistant system. To estimate the rear-end crash risk of the subject vehicle, relative to that of a leading vehicle, Time-To-Collision (TTC) has been one of the most commonly adopted indicator for CAS. It is necessary to modify the estimation of TTC by incorporating the information on vehicle weight (based on the information on vehicle classes, vehicle weight, overweight and speeding) for the estimation of local crash risk (between a leading and following vehicles). In this study, an emerging weight-based traffic counting technology - Weigh-in-Motion (WIM) - is applied to collect the required real-time traffic flow characteristics and vehicle weight, for the estimation of real-time TTC. An empirical analysis is conducted based on the WIM data collected from the freeways in China. Results indicated that, distribution of TTC values are correlated to speed differences , standard deviation of speed , vehicle classes, and presence of overweight and speeding. In particular, present of overweight can increase the risk probability of collision when light vehicles are prevalent. Favorably, collision risk would reduce when heavy vehicles involve. Furthermore, presence of speeding of following vehicle leads to significant risk probability gains. Such findings are indicative to the design and development of CAS, since the TTC estimation also depends on the classes and weight of subject vehicle and surrounding vehicles, and more robust collision warning could be provided.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-02682
Paper Title	Real-time Prediction of Hard-Braking Behavior when Following: A Hybrid SVM-Based Method
Abstract	Car-following models are an important tool in understanding and predicting the behavior of the following vehicle with respect to the lead vehicle behaviors under different scenarios. These models are critical in the current automated vehicle technology designs for simulation and testing purposes. However, there is a lack of literature in the area of real-time car-following behavior prediction algorithms, especially for those behavior of safety concerns such as hard-braking. The objective of this research is to fill in the research gap by developing models to predict real-time hard-braking behavior when following other vehicles on highways hard-braking. Naturalistic driving study data was used with a total of 245 hard-braking events extracted and used in the models. A hybrid SVM-based method including two modules were proposed in this paper, support vector machine classifier (SVM) and support vector regression (SVR). This method uses hard-braking SVM classifier to predict vehicle next time point acceleration or deceleration values. Input variables in the model include acceleration or deceleration values up to current time point, velocity, following distance and relative velocity to the lead vehicle. Results showed this hybrid method is better than each single machine learning method. The prediction accuracy is 98.7% for normal driving only data, 85.1% for hard-braking time points only data, and 98.2% for mixed data with both normal driving and hard braking events. The mean absolute deviation of the prediction is 0.297 and mean squared predictor error is 0.349 . The proposed method in this study provides a promising way to model and predict car-following behavior.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-03089
Paper Title	Empirical Approach for Identifying Potential Rear-End Collisions Using Trajectory Data
Abstract	This paper proposes a novel approach for examining rear-end collisions between successive vehicles in a traffic stream. In this approach, a new safety measure of the attentiveness of the follower driver is proposed, referred to herein as instantaneous heeding time (IHT), which reflects the heeding nature of the subject follower with respect to its leader. A safety framework that integrates the IHT with the distance gap and the instantaneous follower's speed is presented. The applicability of the framework is demonstrated using a mixed-traffic trajectory database (developed in this study) and the homogeneous traffic database of the next generation simulation (NGSIM) project developed in the United States (U.S.). Five study sections in India and two study sections in the U.S. are analyzed for three traffic-flow levels. For mixed traffic, the results show that the presence of motorized two-wheelers (MTW) has degraded road safety due to the unrestrained lateral crisscross movements. Due to the presence of MTW, mixed-traffic stream operates in a disorderly fashion, thereby increasing the probability of rear-end collisions with other vehicle classes. Further, the importance of implementing cautioning measures for drivers, that reduce the probability of collisions, is clearly demonstrated. In addition, the NGSIM application results confirmed the applicability of the proposed framework to both mixed and homogeneous traffic conditions. In practice, the proposed framework can be used in real-time to monitor driver's aggressive instincts.

Authors	Ke Wang, Tongji University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-03236
Paper Title	Identification of Aggressive Driver using Collision Surrogate and Imbalanced Class Boosting Algorithms
Abstract	Machine learning algorithms are wildly applied in the recognition of risky driving behavior and dangerous drivers. Since the proportion of risky behavior or drivers in real traffic is very low, common machine learning algorithms prone to better recognize normal sample rather than risky sample, which is our real interest. This paper aims to use imbalanced class boosting algorithms to identify driver's driving style (normal vs. aggressive) using vehicle trajectory data, including speed, gap and acceleration. First, a surrogate measurement of collision risk is proposed to calculate vehicle's crash risk based on how driver response in car-following process. Then, the driver's driving style is determined by his average crash risk. Using the determined driving style information and vehicle trajectory data, we can train a classification model to identify aggressive drivers. Among all imbalanced class boosting algorithms we test, SMOTEBoost achieves the best performance. This paper uses Montanino and Punzo' reconstructed NGSIM dataset for aggressive driver identification and focuses on 299 leader-follower vehicle pairs on I-80 HOV lane that was not interrupted by lane-changing. This paper also finds that in a car-following process, the driving styles of the leading and following drivers are independent.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1339
Session Title	Safety Data, Analysis, and Evaluation, Act II: Deep Learning, Induced Exposure, and Other Sophisticated Methods
Paper Number	20-03472
Paper Title	Using Empirical Traffic Trajectory Data for Crash Risk Evaluation under Three-Phase Traffic Theory Framework
Abstract	This paper employed traffic conflict techniques to evaluate the crash risk in different traffic phases defined by three-phase theory. The analysis was based on empirical trajectory data extracted from two freeways, one is Interstate 80 in California, USA, the other is Yingtian Expressway in Jiangsu, China. First, the traffic phases were identified based on values of traffic flow variables and their correlations. Then, two advanced crash risk indexes based on time-to-collision were conducted to estimate the safety performance in each traffic phase. The effect of various traffic flow variables (e.g. flow rate, average speed) on crash risk were explored based on speed-density plane, speed-flow plane and flow-density plane. Three regression models were developed to quantify the effect of traffic flow variable and traffic phases. The results indicated significant disparity of safety performance among different traffic phases. High density and low speed were associated with high crash risk. In addition, the model only integrating different traffic phases had better fitness (R2=0.726) than that only integrating macroscopic traffic parameters (R2=0.545), and a better performance could be achieved when integrating both of them (R2=0.757).This study directly establishes the relationship between macroscopic traffic flow phase and microscopic traffic safety performance. The study also proposes a safety perspective that can be added to the three-phase traffic theory.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-03490
Paper Title	A Surrogate Video-Based Safety Methodology for Diagnosis and Evaluation of Pedestrian-Safety Low-Cost Countermeasures: The Case of Cochabamba, Bolivia
Abstract	Due to a lack of reliable data collection systems, traffic fatalities and injuries are often under-reported in developing countries. Recent developments in surrogate road safety methods and video analytics tools offer an alternative approach that can be lower cost and more time-efficient when crash data is incomplete or missing. However, very few studies investigating pedestrian road safety in developing countries using these approaches exist. We use an automated video analytics tool to develop and analyze surrogate traffic safety measures and to evaluate the effectiveness of temporary low-cost countermeasures at selected pedestrian crossings at risky intersections in the city of Cochabamba, Bolivia. Specialized computer vision software is used to process hundreds of hours of video data and generate data on road users speed and trajectories. We find that motorcycles, turning movements, and roundabouts, are among the key factors related to pedestrian crash risk and that the implemented treatments were effective at four-leg intersections but not at traditional-design traffic circles. This study demonstrates the applicability of the surrogate methodology based on automated video analytics in the Latin American context, where traditional methods are challenging to implement. The methodology could serve as a tool to rapidly evaluate temporary treatments before they are permanently implemented and replicated.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-03499
Paper Title	Does Stop-Signs Improve Safety For All Road Users? A Before-After Study On Stop-Controlled Intersections Using Video Trajectory And Surrogate Methods
Abstract	The conversion of minor-approach-only stop (MAS) intersections to all-way-stops (AWS) intersections are a common safety countermeasure in North America in residential areas. Although there is a positive perception by the general population of the installation of stop-signs in residential areas, there is little research that has looked at the impact of AWS on road safety and road users behaviour. This paper aims at investigating the safety effect of converting MAS to AWS intersections using an observational before and after approach and alternative surrogate measures of safety (SMoS). More specifically, the impact of AWS conversion is investigated using multiple indicators including vehicle and bicycle speed measures, vehicle-pedestrian and vehicle-cyclist conflicts as well as yielding rates. To determine the effect of stop signs, a multilevel regression approach is adopted in order to control for built environment, traffic exposure and intersection geometry factors. In this study, a unique sample of 40 treated intersections is used from which data was collected before and after the implementation of AWS. Using automated video processing and computer vision software, 248 hours of video were processed and corrected; more than 62,000 (32,208 before and 30,127 after treatment) road users' trajectories were obtained from 110 approaches. Results show that the implementation of AWS has a statistically significant effect on the speed reduction of vehicles and cyclist. However, it is observed a small variation after the AWS implementation on the post-encroachment time (PET) values. The DV analysis shows that there is a better performance from the behavioural aspect, having more yielding compliances after the treatment. Future work would investigate the poor fit of the PET and evaluate cyclist behaviour deeply.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-03513
Paper Title	Pedestrian Safety Analysis at Urban Midblock Sections under Mixed Traffic Conditions Using Time to Collision as Surrogate Safety Measure
Abstract	Pedestrians are the most vulnerable road users, and pedestrian safety has become a major concern of researches in recent years due to increasing number of fatalities on roads. Conflict analysis using surrogate safety measures are hence a useful technique to study pedestrian safety, as there are many issues with collision data. Moreover, it is a cost-effective technique as compared to the historical crash data analysis. The present paper deals with analyzing pedestrian safety at urban midblock crosswalk using Time to Collision (TTC) as a surrogate safety measure. The data for the present study has been collected from four different midblock pedestrian crossing locations in four different cities located in western parts of India using the video-graphic technique. The trajectory of pedestrians and vehicles are extracted for micro-level analysis of pedestrian-vehicle interactions. The trajectory data are further used for calculating TTC at regular time interval during the interaction of pedestrian and vehicles. Two different types of pedestrian road crossing behavior known as vehicle-pass-first and pedestrian-pass-first are identified, and the analysis of TTC has been done differently for each scenario. The variation of TTC based on gender and vehicle category is analyzed to evaluate the influence of such parameters on pedestrian safety. Generalized linear mixed models approach used for developing linear regression models for TTC based on the empirical data. The threshold values for TTC are used to define various safety level of pedestrians using a clustering approach.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1357
Session Title	Intersection Safety in Focus
Paper Number	20-04461
Paper Title	Post Encroachment Time based Risk Characterization at Un-Signalized T-Intersections Operating under Mixed Traffic Conditions
Abstract	Post Encroachment Time (PET) is the most acceptable Surrogate Safety Measure (SSM) for analysing traffic conflicts, where crash data is limited. The present study evaluate traffic conflicts at un-signalized T-intersections using PET as a SSM. Five un-signalized T-intersections from different cities of India with varying geometry and traffic flow characteristics were selected for the present study. The results revealed that vehicle category significantly affected crash probability of the drivers, where smaller size vehicles showed higher safety implications at the intersection. It was observed that volume and traffic composition of the conflicting stream significantly affected crash probability. Intersection geometry has a substantial effect on safety. Crash probability was observed to be higher (10-15%) at intersection without central island compared to intersection with central island. Thereafter, PET dataset is extended to characterize risk at four levels of severity: fatal, grievous injury, minor injury, and non-injury crashes, respectively. The developed risk thresholds were validated using field crash data and were found to be in close approximation with each other. The main contribution of the current study is the development of severity-based probability of crash prediction model using generalized linear modelling (GLM) technique. Four different GLM models according to the level of severity were developed. These models can facilitate the engineers and planners to compute crash probabilities at intersections based on location, intersection control, traffic volume, and time of day (peak-off-peak hours), which can then enable development of safety measures.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-04962
Paper Title	Crash Prediction Based on Vehicle Kinematics Profile Similarity
Abstract	This study introduces a crash prediction model based on vehicle kinematics profile similarity (VKPS). A support vector machine (SVM) model was developed to predict crashes using the SHRP2 NDS vehicle kinematics data (speed, longitudinal acceleration, lateral acceleration, yaw rate, and pedal position). The study builds on the Osman et al.'s study (1) that any safety critical events are preceded by turbulence in the vehicle kinematics that leads to those events. Building on that hypothesis, which was proved to be true in Osman et al.'s study, the study herein applies a Gaussian function to the vehicle kinematics data to identify similarities between vehicle kinematics time series profiles and help detect crash-related turbulence in vehicle kinematics. To develop the SVM prediction model, the data was split into 80% for training and 20% for testing. To identify the optimal turbulence horizon (the time period during which crash related changes in vehicle kinematics take place) and prediction horizon (the time period before the occurrence of a crash), a sensitivity analysis was performed. The results showed that the crashes can be predicted with an outstanding accuracy 1-second before the crashes take place. This indicates that the vehicle kinematics turbulence increase significantly shortly before the crash occurrence. The results also showed that the best model performance (overall accuracy =99%) is achieved for a 6-seconds turbulence horizon, indicating that the VKPS approach can help early detect crash-related turbulences in vehicle kinematics. This performance is promising for crash avoidance systems in the emerging autonomous vehicle technology.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-04969
Paper Title	Estimation of Freeway Traffic Safety Utilizing Disturbance Metrics Based on Trajectory Data
Abstract	There have been limited efforts to investigate the potential of using detailed trajectory data obtained from connected vehicles and/or other sensors in deriving metrics for use in real-time assessment of traffic safety and the activation of management strategies based on this assessment. This study investigates utilizing disturbance metrics for this purpose. The utilized disturbance metrics are the number of oscillations and a measure of disturbance durations in terms of the time exposed time to collisions index (TETIndex). TET has been widely used as a safety surrogate measure, however, to the best of authors knowledge, there is no study on the identification of its thresholds to justify activating plans to mitigate unsafe conditions in real-time operations. Since the TETIndex estimation requires the location and speed of both the leading and following vehicles and therefore cannot be measured accurately with low sample sizes of vehicle trajectories, this study derived regression model to estimate it based on speed parameters. The developed model was tested using real-world trajectory data from two locations that were not used in the development of the model. It was found that the TETIndex can be estimated based on speed parameters with an error of around 15%-20%. The study also found that the investigated disturbance metrics and associated models are significantly related to crash occurrence and thus can be used in the activation of transportation management strategies to reduce the probability of unsafe traffic and ease traffic disturbances that have adverse impact on traffic safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05024
Paper Title	An Exploratory Parameter Sensitivity Analysis of Bicycle-Vehicle Conflicts Using the Surrogate Safety Assessment Model
Abstract	The use of traffic microsimulation software has been an invaluable tool for analysis of operational performance at signalized intersections in recent decades. Microsimulation also offers opportunities to examine the safety performance of an intersection through analysis of surrogate measures of safety such as conflicts identified using post encroachment time (PET) or time to collision (TTC). The use of microsimulation and surrogate measures of safety provides a very promising avenue for analysis of the safety impacts of treatments aimed at improving bicyclist safety, particularly for new and/or developing treatments given the absence of police-reported crash data. However, the use of these tools for the analysis of bicycle-vehicle conflicts is lacking. To fill this gap, the following to objectives were addressed in this study: 1) perform a sensitivity analysis on the impacts of behavioral parameters in microsimulation on the frequency and severity of bicycle-vehicle conflict outputs from Surrogate Safety Assessment Model (SSAM) at a signalized intersection, and 2) perform a qualitative analysis on the ability of microsimulation to emulate realistic interactions between motor vehicles and bicycles. The results indicated that some behavioral parameters had no effect on conflict outputs, while some did have effects with varying consistency and magnitude. The qualitative analysis revealed instances of unrealistic interactions between bicycles and vehicles, and further refinement of these models is needed. Ultimately, this study adds to the literature by providing an exploratory step forward in fine-tuning the use of microsimulation/SSAM to analyze bicycle-vehicle conflicts.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05550
Paper Title	Modeling Vehicle-Pedestrian Interactions Using a Non-Probabilistic Regression Approach
Abstract	Understanding how vehicle drivers and pedestrians interact is key to identifying countermeasures to improve the safety of these interactions. Furthermore, there is a need to identify techniques that can be used to evaluate the effectiveness of safety countermeasures and traffic control devices without the need to wait for crash data. Using video, interactions between right-turning vehicles and conflicting pedestrians were documented by logging the timestamps associated with key vehicle positions during right turn maneuvers and corresponding key conflicting pedestrian positions. Interactions documented were purposely limited and narrow in scope to provide a controlled dataset. Logged timestamps enabled the calculation of values such as time to complete a right turn and time for a pedestrian to reach a critical conflict point when a vehicle initiated a right turn. A non-probabilistic regression model explaining the relationship between the calculated values was created. The model described the expected right turning behavior: when drivers perceive the possibility of pedestrian reaching a critical conflict point at the same time as them, they will modify their behavior even if not coming to a stop. The behavior is not a surprise and has been previously documented in the literature. The main contribution of this paper is demonstrating that by analyzing a narrow set of interactions, a clean and simple model that explains the interaction of right-turning vehicles and pedestrians can be developed using a non-probabilistic regression approach. An argument is made that the model parameters can be used to evaluate the effectiveness of traffic control devices.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1358
Session Title	Focus on Pedestrian and Bicycle Safety
Paper Number	20-05873
Paper Title	Pedestrian Safety Analysis of Urban Intersections in Kolkata, India Using a Combined Proactive and Reactive Approach
Abstract	Assessment of pedestrian safety is often conducted in a reactive way by analyzing pedestrian crash data. However, in a developing country, the availability of reliable crash data is a major challenge. Therefore, without relying solely on reactive approach, it is essential to combine some methods that can proactively assess pedestrian safety. In this background, the present study proposed a methodology combining both reactive and proactive approach to assess pedestrian safety at urban intersections in Kolkata, India. The method developed in the present study utilizes a combination of the historical crash data analysis, the analysis of pedestrian-vehicular conflict (i.e., pedestrian-vehicular post-encroachment time), along with pedestrians' risk perception towards the built environment and traffic parameters, to identify potential risk-prone intersections in Kolkata. Based on the combined reactive and proactive assessments, there is evidence that the high traffic volume, pedestrian-vehicular interaction captured through pedestrian and vehicle volume ratio, the absence of police personnel, high approaching speed, the presence of commercial area, inadequate sight distance, the presence of slum population, and a high population density near the intersection significantly increase the risk of pedestrian crashes. Finally, using this combined proactive-reactive approach, the present study also identifies and ranks 25 high risk-prone intersections for pedestrians. This is a significant step towards scientific decision making and allowing use of information beyond historical crash records.

Authors	Lionel Nebot Janvier, Ecole Polytechnique de Montreal Nicolas Saunier, Ecole Polytechnique de Montreal
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1340
Session Title	Safety Data, Analysis, and Evaluation, Act III: Time to Collision, Conflicts, and Other Safety Surrogates
Paper Number	20-06071
Paper Title	An Open-Source Minimal Micro-Simulation Tool for Safety Analysis
Abstract	Surrogate measures of safety (SMoS) have been developed in order to address the shortcomings of safety diagnosis methods based on historical crash records. They rely on the observations of traffic events or interactions that do not end up as crashes, and the evaluation of their severity through temporal and spatial indicators of proximity. This paper aims to investigate the distributions of interaction severity indicators via the development of a minimal microscopic traffic simulation tool under an open source license. It relies on a simple car-following model at constant velocity and a simple behavior model at traffic control devices based on gap acceptance theory for yield and stop signs. There simulation parameters are the parameters of six probability distributions, as well as the distributions of the headway of generated users. The tool is analyzed through a sensitivity analysis of the minimum distance and time-to-collision (TTC) per category of interaction (rear-end and side) and of post-encroachment time (PET) at a simple intersection of two unidirectional roads. It is further demonstrated on two case studies about the impacts of the zone of analysis (the size of the zone where interactions are observed) and the impacts of stop and yield signs. Results show that the distribution of the side minimum TTC depends on the size of the analysis zone, which warrants further scrutiny in simulation and field studies. The second case study shows that different traffic control devices change the shape of the distributions of some indicators, PET in this case.

8 Transportation Safety Management

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

Thirty-three papers describing different aspects of transportation safety management will be presented at the 2020 TRB Annual Meeting, which are briefly discussed below.

Eight papers will be presented in Hybrid Session 1316 titled, ***Safety Management in a World of Connected and Automated Vehicles***, discussing safety assessments of highly automated driving systems, harnessing the data generated by connected vehicles to monitor safety performance, and information on traffic collisions involving these vehicles. Feng et al. (20-01530) propose a new framework for closed-facility testing, which can quantitatively and efficiently assess the safety of highly automated driving systems in a cost-effective fashion. Arvin and Khattak (20-02457) develop a conceptual framework to harness big data generated by connected vehicles to monitor the safety performance of the system by incorporating human behavior to identify high risk locations. Das et al. (20-05173) demonstrate a variational inference algorithm for Bayesian latent class models, providing an in-depth exploratory analysis of the critical variables in AV crashes. Zhong et al. (20-00285) used meta-analysis to evaluate the safety effectiveness of eight common and important CV or AV technologies, and tested the safety effectiveness of these technologies for six countries. Rahman and Abdel-Aty (20-03349) analyze the effectiveness of CAVs at the network level by utilizing both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technologies. Pan et al. (20-03409) develop a methodology to evaluate the efficiency and safety performance of signalized intersections under the conditions of AV mixed flows. Alambeigi et al. (20-05062) analyze automated vehicle crash narratives from the California Department of Motor Vehicles automated vehicle crash database to identify safety concerns and gaps between crash types and current areas of focus in the current research. Bin-Nun et al. (20-05778) consider whether Heinrich's Triangle applies to human driving safety, using several insurance claim datasets to examine whether there is a similar relationship between the frequency of milder and more severe crashes across the datasets.

Three papers will be presented in Lectern Session 1702, ***Moving Transportation Safety Research into Practice***. Goddard et al. (20-03189) conduct an experiment to explore efforts to change public perceptions of road safety by focusing on editorial patterns in traffic crash reporting. Albitres et al. (20-03668) describe a framework for incorporating vulnerable road user safety into the transportation asset management decision-making process. Claros et al. (20-04134) provide guidance for development of jurisdiction-specific crash prediction models, integration of pedestrian and cyclist crashes, application of EPDO and LOSS performance measures, and selection of sites with promise through an incremental optimization process for a given budget in a small jurisdiction.

The remaining papers will be presented in Poster Session 1284, *Transportation Safety Management from Start to Finish.* The following is a brief overview of these papers.

Nine papers discuss **advanced modeling approaches to support system planning and network screening**. Farhan et al. (20-01034) develop Network-based Collision Prediction Models that can be integrated with Regional Transportation Models (RTM) as a fifth step of the traditional four-step RTM modeling concept. Dadvar et al. (20-01983) propose a calibration methodology that incorporates multiple calibration factors for different components of the Highway Safety Manual (HSM) predictive method rather than a single calibration factor, as recommended by the HSM first edition. Yuan et al. (20-02847) develop a model to capture the individual-specific heterogeneity across crash records for four significant factors and show that the model specification is generally not temporally stable for driver injury severity, especially for longer periods. Matthews et al. (20-02863) demonstrate a new method for making the most efficient use of a candidate comparison group by weighting the safety performance function (SPF) according to propensity score similarity, known as propensity score weighted regression (PSWR). Wang et al. (20-02889) propose a novel meso-level approach applying Full Bayesian method (FB) and potential for safety improvement (PSI) to identify hotspots for suburban arterials. Yang et al. (20-02893) updated a macro-level safety model for 263 traffic analysis zones (TAZs) within the urban area of Shanghai to help formulate informative priors for independent variables in macro-level traffic safety studies. Rahmani et al. (20-03791) demonstrate the challenges with traditional approaches and propose an alternative structure using a cross-comparison framework that not only compares the raw counts from crash data but also compares a focus county's crash percentage and ranking to other similar counties or jurisdictions. Roy et al. (20-05301) studied the safety of urban expressways using dynamic Bayesian network-based real-time crash prediction model (RTCPM) and deep Q-network-based intervention. Herrera (20-05787) presents a crash analysis methodology utilized by the Maricopa Association of Governments (MAG) to identify intersections with the best potential of benefitting from safety improvements related to creating positive offset.

Eight papers explored the **safety effects of factors such as operations, environment, economics, vehicles, driver behavior, and demographics**. Lee et al. (20-01355) propose a hierarchical approach to investigate traffic safety (crashes and violations) with diverse perspectives using traffic, commuter, roadway, industry, socio-economic, and demographic data collected from multiple sources. Marshall and Ferenchak (20-02218) propose a proactive assessment approach for identifying child pedestrian and bicyclist road safety concerns, allowing for the prioritization of issues before a crash occurs. Jalayer et al. (20-04157) investigate wrong-way driving incidents, using a web-based survey to gauge the level of familiarity amongst drivers of different ages and experience. Martin et al. (20-04603) linked household travel survey demographic information and global positioning system (GPS) traces to HERE network speed limit to study the impact of vehicle occupancy on speeding. Shimu et al. (20-04761) investigated the factors that contributed to the large reduction and subsequent increase in roadway fatalities in the United States between 2005 and 2016. Torres et al. (20-04917) used structural equation models to study the relationship between the Road Safety Pillars, including the influence of 48 road safety performance indicators, on mortality rate in 175 WHO Member States. Taylor and Hwang (20-05268) take a historical look at crowdsourcing speed limits and the question of safety. Zhang et al. (20-05512) applied a linear Poisson autoregressive (PAR) model to analyze the dynamic impact of traffic laws on the frequency of fatal traffic crashes from 1975 to 2016.

Two papers address **data collection, data integration, and data management**. Bianchi et al. (20-03374) performed a record linkage comparison between deterministic and probabilistic approach using attributes matching techniques with numerical distance and weight pattern under the Fellegi-Sunter

approach. Burdett et al. (20-05134) assessed the accuracy of "Serious Injury" reporting with the implementation of the new KABCO definition in the Model Minimum Uniform Crash Criteria (MMUCC).

Two papers address the topic of **emergency response**. Cruz and Ferenchak (20-04196) study the change in emergency response times over the last few decades, using data from the Fatality Analysis Reporting System (FARS) to identify the national trend in emergency response times from 1975 through 2017. Nie et al. (20-05447) performed a comparative analysis for crashes that caused different damages to uncover correlates of EMS requests with a focus on the role of auto insurance.

A single paper by Eslamifard and Gonzales (20-04939) addresses the topic of **school transportation safety**. They used school data to determine the potential to start high school classes as late as possible in the day and minimize the cost of busing.

A single paper by Archibald et al. (20-05231) explored **other safety management issues**. They developed a definition of a road safety focusing event (a term derived from the policy science field) and proposed a method to determine if a road safety incident is a focusing event or not.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-01530
Paper Title	Safety Assessment of Highly Automated Driving Systems: A New Framework
Abstract	Safety assessment is critical in the development and deployment of highly automated driving systems (ADS). In this paper, a new framework is proposed for closed-facility testing, which can quantitatively, accurately, and efficiently assess the safety of highly ADS in a cost-effective fashion. To this end, two major problems of closed-facility testing approach are resolved by two pillars of the framework. First, an augmented reality (AR) testing platform is constructed to augment the real ADS interacting with simulated background traffic. Second, a testing scenario library generation (TSLG) method is designed to systematically generate a set of critical scenarios for each operational design domain (ODD). Four research questions are identified as scenario description, metric design, library generation, and ADS evaluation. By the important sampling theory, generating a library is transformed as constructing an importance function. A new definition of criticality and critical scenario searching methods are proposed. The framework is implemented in the Mcity test facility at the University of Michigan. Field test results validate the accuracy and efficiency of the proposed framework. In the cut-in case study, the proposed framework can accelerate the safety assessment process by 9.87×10 4 times faster than the public-road testing approach.

Authors	Ramin Arvin, University of Tennessee Knoxville Asad Khattak, University of Tennessee
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-02457
Paper Title	Harnessing Big Data Generated by Connected Vehicles to Monitor Safety Performance: Application of Geographically Weighted Negative Binomial Regression
Abstract	Emergence of high-resolution big data generated by connected and automated vehicles provides promising opportunity to monitor and evaluate the performance of the transportation system. This study develops a conceptual framework to harness big data generated by connected vehicles to monitor the safety performance of the system by incorporating human behavior to identify high risk locations. The main advantage of this method is proactively monitoring the system safety performance compared to traditional methods that reactively identify high risk locations. The Safety Pilot Model Deployment data collected in Ann Arbor, MI, is utilized. More than 2.2 billion Basic Safety Messages transmitted between more than 2800 connected vehicles are processed, analyzed and linked with crash data. This study captures the temporal dimension of driving volatility by quantifying variations in instantaneous driving decisions. Several volatility measures are applied to vehicular speed, longitudinal, and lateral accelerations of vehicles, and their correlations with crash frequency are explored. To address unobserved heterogeneity in safety performance and spatial correlations, Geographically Weighted Poisson and Negative Binomial models are estimated. Results reveal that driving volatility is positively and significantly correlated with crash frequency, and these associations vary substantially across space. Variations in longitudinal and lateral vehicle movements are associated with higher crash frequencies. In order to identify hotspot locations where driving volatility is high while crash frequency is low, k-means clustering is performed. Given the hotspot locations, further research is needed to identify reasons that drivers exhibit volatile behavior and explore countermeasures to reduce driving volatility to decrease crash risk.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-05173
Paper Title	Traffic Collisions Involving Autonomous Vehicles in California: Bayesian Model Based Clustering
Abstract	The emerging technology of autonomous vehicles (AV) has been rapidly advancing. This new technology is accompanied by various positive and negative potentials. It is expected to affect the costs mainly by reducing the number of crashes and travel time, as well as improving fuel efficiency and parking benefits. On the other hand, safety outcomes from AV deployment is a critical issue. Ensuring safety of AVs requires a multi-disciplinary approach which monitors every aspect of these vehicles. To promote safety, the California Department of Motor Vehicles has mandated that autonomous car crash reports be made public in recent years. This study collected all crash reports filed by different manufacturers that are testing autonomous vehicles in California (September 2014 to May 2019). The data provides important information on autonomous vehicles crash frequencies and associated contributing factors. This study provides an in-depth exploratory analysis of the critical variables. The research team demonstrated a variational inference algorithm for Bayesian latent class models. The Bayesian latent class model identified six classes of collision patterns. Classes associated with turning, multi-vehicle collisions, dark lighting conditions with streetlights, and sideswipe and rear-end collisions, were also associated with a higher proportion of injury severity level. The authors anticipate that these results will provide a significant contribution to the area of AV and safety outcomes.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-00285
Paper Title	Safety Benefit Analysis of Connected and Automated Vehicle Technologies Based on Meta-analysis
Abstract	The connected and automated vehicle (CAV) technologies have made great progresses. It has been commonly accepted that CAV technologies would reduce human errors in driving and benefit traffic safety. However, the answer of how many crashes can be prevented because of CAV technologies has not reached a consistent conclusion. In order to quantitatively answer this question, this study used meta-analysis to evaluate the safety effectiveness of eight common and important CV or AV technologies, and tested the safety effectiveness of these technologies for six countries. First, 73 studies about the safety impact of these technologies were filtered out from 826 CAV-related papers or reports. Second, in the meta-analysis, the random effect model was used to evaluate the safety effectiveness, and the funnel plots and trim-and-fill method were used to evaluate and adjust publication bias, so as to objectively evaluate the safety effectiveness of each technology. Then, according to the crash data of six countries, the comprehensive safety effectiveness and compilation of safety effectiveness of the above technologies were calculated. The results show that if these technologies were implemented in the six countries, the average number of crashes could be reduced by 2.79 million, among which the USA would reduce the most (40.53%). Additionally, different countries should develop different development strategies, e.g., USA should prioritize the development of the emergency action technologies. Overall, this study provides comprehensive and quantitative understating of the safety effectiveness and would contribute to government, vehicle companies, and agencies in deciding the development priority of CAV technologies.

Authors	Md Hasibur Rahman, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-03349
Paper Title	Application of Connected and Automated Vehicles in a Large-Scale Network by Considering V2V and V2I Technology
Abstract	Application of connected and automated vehicles (CAVs) are expected to have a significant impact on traffic safety and mobility. Although several studies evaluated the effectiveness of CAVs in a small roadway network, there is a lack of studies analyzing the impact of CAVs in a large scale network by considering both freeways and arterials. The objective of this study is to analyze the effectiveness of CAVs at the network level by utilizing both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technologies. Also, the study proposed a new signal control algorithm through V2I technology in order to elevate the performance of CAVs at intersections. This study considered a car-following model (CACC) in order to approximate the driving behavior of CAVs in the Aimsun microsimulation environment. For the testbed, the research team selected Orlando CBD (central business district) area in Florida. To this end, the impacts of CAVs were evaluated based on traffic efficiency (e.g., travel time rate (TTR), and average approach delay, etc.) and safety (e.g., standard deviation of speed, real-time crash-risk models for freeways and arterials). The results showed that the application of CAVs reduced TTR significantly compared with the base condition even with the low market penetration level. Also, the proposed signal control algorithm reduced the approach delay for 94% of the total intersections present in the network. Moreover, safety evaluation results showed a significant improvement of traffic safety in the freeways and arterials under CAV condition with different market penetration rates.

Authors	Ang Pan, Xin Zhang, Hideki Nakamura, Wael Alhajyaseen
Sponsoring Committee	ANB10
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-03409
Paper Title	An Analysis of the Efficiency and Safety of Signalized Intersections under Conditions of Autonomous Vehicle Mixed Flows
Abstract	Field experiments of autonomous driving systems have already been started in several countries around the world. However, investigations on the performance of signalized intersections under the mixed flow condition of autonomous vehicle (AV) and human driven vehicle (HDV) is still very limited, especially in terms of considering the interaction between vehicles. This study aims at developing a methodology to evaluate the efficiency and safety performance of signalized intersections under the conditions of AV mixed flows. If AVs are set aggressively such as small critical gap acceptance thresholds, approach capacity of signalized intersections may increase. However, the aggressive driving maneuver and the misjudgment by human drivers to AV may lead to some potential safety risks. On the other hand, if AVs are set conservatively to ensure large safety margins, for example by setting large critical gap thresholds or a longer following headway, a significant drop in the capacity is expected while the safety improvements may not be insured since extra delays will be imposed on HDVs which may induce risky behaviors. This study finds that AV with either excessively aggressive or conservative settings will lead to waste of capacity or potential safety hazard.

Authors	Hananeh Alambeigi, MBA, Texas A&M University College Station Anthony D. McDonald, Ph.D., Texas A&M University College Station Srinivas Tankasala, Texas A&M University College Station
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-05062
Paper Title	Crash Themes in Automated Vehicles: A Topic Modeling Analysis of the California Department of Motor Vehicles Automated Vehicle Crash Database
Abstract	Automated vehicle technology promises to reduce the societal impact of traffic crashes. Early investigations of this technology suggest that significant safety issues remain during control transfers between the automation and human drivers and automation interactions with the transportation system. In order to address these issues, it is critical to understand both the behavior of human drivers during these events and the environments where they occur. This article analyzes automated vehicle crash narratives from the California Department of Motor Vehicles automated vehicle crash database to identify safety concerns and gaps between crash types and current areas of focus in the current research. The database was analyzed using probabilistic topic modeling of open-ended crash narratives. Topic modeling analysis identified five themes in the database: driver-initiated transition crashes, sideswipe crashes during left-side overtakes, and rear-end collisions while the vehicle was stopped at an intersection, in a turn lane, and when the crash involved oncoming traffic. Many crashes represented by the driver-initiated transitions topic were also associated with the side-swipe collisions. A substantial portion of the side-swipe collisions also involved motorcycles. These findings highlight previously raised safety concerns with transitions of control and interactions between vehicles in automated mode and the transportation social network. In response to these findings, future empirical work should focus on driver-initiated transitions, overtakes, silent failures, complex traffic situations, and adverse driving environments. Beyond this future work, the topic modeling analysis method may be used as a tool to monitor emergent safety issues.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1316
Session Title	Safety Management in a World of Connected and Automated Vehicles—Hybrid Session
Paper Number	20-05778
Paper Title	Heinrich's Triangle, Heavy-Tailed Distributions, and Autonomous Vehicle Safety
Abstract	Road safety is a leading public health issue with over 1.35 million global road traffic fatalities in 2016. Automated Vehicles (AVs) may improve road safety. While considerable effort focuses on building AV systems according to strong engineering principles, measuring the safety of AV systems in the real world presents challenges. Severe crashes, while common in aggregate on public roads, occur at relatively low rates compared to the distance driven by a single driver. This paper examines the application of the Heinrich's triangle framework (HT) to human and autonomous driving. HT posits that severe incidents with injuries and fatalities share causal mechanisms with less severe incidents, near-misses, and even minor safety conflicts. This manuscript considers whether HT applies to human driving safety. We use several insurance claims data sets to examine whether there is a similar relationship between the frequency of milder and more severe crashes across the datasets. We offer evidence that human crash frequency-severity follows a heavy-tailed distribution, with the lognormal distribution generally providing a good fit. We further provide evidence that "leading indicators" such as near-crashes can help evaluate human driving safety. Finally, we discuss whether AVs may follow a similar crash frequency-severity distribution and whether examining rates of near-crashes or "safety envelope violations" could effectively evaluate AV safety using relatively small sample sizes We outline further research directions to evaluate this possibility.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1702
Session Title	Moving Transportation Safety Research into Practice
Paper Number	20-03189
Paper Title	Does News Coverage of Traffic Crashes Affect Perceived Blame and Preferred Solutions? Evidence from an Experiment
Abstract	Traffic crashes are one of the leading causes of preventable death in the United States. Nearly twenty percent of these roadway fatalities are people who were hit and killed while walking or bicycling. Pedestrian deaths increased by 46% between 2009 and 2016. Despite these troubling statistics, there has not been a sustained and widespread public call to action to improve road safety. Researchers and advocates are increasingly focused how traffic crashes are reported in the media, and whether existing editorial patterns contribute to victim-blaming and distract from systems-level solutions. However, no previous study has examined whether editorial patterns in traffic crash coverage actually influence perceptions. This study conducted an experiment in which subjects were randomly assigned to read one of three versions of a news article describing a traffic crash involving a pedestrian. After reading the description, subjects were asked to apportion blame, identify an appropriate punishment for the driver, and assess various approaches for improving road safety. In comparing the three groups, even relatively subtle differences in editorial patterns significantly affected readers' interpretation of both what happened and what to do about it on nearly every measure. Shifting from pedestrian-focused to driver-focused language reduced victim-blaming and increased perceived blame for the driver. A thematic frame significantly increased support for infrastructure improvements. This study provides compelling evidence that efforts to change public perceptions of road safety should include a focus on improving editorial patterns in traffic crash reporting.

Authors	Carlos Chang Albitres, Marketa Vavrova, Edgar Rodriguez
Sponsoring Committee	ABG30, ANB10
Session Number	1702
Session Title	Moving Transportation Safety Research into Practice
Paper Number	20-03668
Paper Title	Incorporating Vulnerable Road User Safety into the Transportation Asset Management Decision-Making Process to Mitigate Pedestrian Fatalities
Abstract	Safety is a major concern for transportation agencies due to the increase in the number of fatalities, in particular for Vulnerable Road Users (VRUs). Pedestrians, bicyclists, and motorcyclists are VRUs and their safety is a priority. Traditionally, transportation agencies have adopted Transportation Asset Management (TAM) practices to manage infrastructure assets based on performance measures expressed in terms of the physical condition of the assets. This paper describes a framework for incorporating VRU's safety into the TAM decision-making process. The VRU-TAM framework is composed of four phases: Assessment, Prioritization, Scenario Analysis, and Results. It includes a methodology for prioritization based on a Safety Weighted Effectiveness Ratio (SWER) which considers pedestrian's safety. Factors influencing pedestrian safety are also discussed including: driver factors; demographic, cultural, and social factors; pedestrian factors; infrastructure factors; and policy factors. The importance of preserving safe infrastructure assets for pedestrians is emphasized by using SWER in combination with the Dynamic Bubble Up (DBU) technique for budget allocation. The main objective of the VRU-TAM framework is to mitigate pedestrian fatalities by improving the decision-making process at the strategic level. The decision-making criteria considers the asset importance, location, pedestrian safety risk, costs, and remaining life in the process. A case study is presented for pedestrians using crosswalks as an example to demonstrate the applicability of the methodology under different budget scenarios.

Authors	Boris Claros, Madhav Chitturi, Andrea Bill, David Noyce
Sponsoring Committee	ABG30, ANB10
Session Number	1702
Session Title	Moving Transportation Safety Research into Practice
Paper Number	20-04134
Paper Title	Roadway Safety Management in Small Municipalities
Abstract	Roadway safety management consists of network screening, diagnosis, countermeasure selection, economic appraisal, prioritization, and safety effectiveness. Applications of the safety management process is limited in small municipalities due to data, statistical expertise, and resources required. This paper addresses the challenges faced by small jurisdictions and implementation of the safety management process for Madison metropolitan area in Wisconsin. Jurisdiction specific crash prediction models were developed by intersection type using data from over 4,000 intersections. Performance measures included the Equivalent Property Damage Only (EPDO) average crash frequency with Empirical Bayes adjustments and the Level of Service of Safety (LOSS). Wisconsin Crash Outcome Data Evaluation System (CODES) data was used to estimate local crash costs by severity and type. Sites were provisionally ranked in network screening, and diagnosis was conducted based on intersection observed crash types and distributions. Treatments were selected for each intersection and costs of treatments were obtained from local estimates and available literature. Crash cost benefit and treatment cost were used to estimate benefit-cost ratio by site. A combination of sites that had the greatest overall cost

effective safety benefit on the network were selected through an incremental optimization process. This paper contributes to exiting literature by providing guidance for development of jurisdiction specific crash prediction models, integration of pedestrian and cyclist crashes, application of EPDO and LOSS performance measures, and selection of sites with promise through an incremental optimization process for a given budget in a small jurisdiction.

Authors	Ali Farhan, University of Calgary Lina Kattan, University of Calgary Richard Tay, "RMIT University"
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-01034
Paper Title	Integrated Regional Transportation Model (RTM)-Network-based Collision Prediction Model (NCPM) Framework
Abstract	Road safety is rarely considered in the transportation planning process. Instead, each effort is typically conducted individually. For decades, transportation planners have used Regional Transportation Models (RTMs) to analyse and evaluate future transportation policies, road and transit network expansion and design options, and land use scenarios. Examples of an RTM's outputs include future trips by transportation mode, transit ridership, and traffic patterns, volume, speed and congestion indices on road segments. Road safety is conventionally evaluated separately via statistical models that use estimated collision numbers based on historical collision data as dependent variables and that explore a variety of independent explanatory variables. Some explanatory variables are exposure variables that can be extracted from RTM models for base and future horizons, but most current Network-based Collision Prediction Models (NCPMs) are standalone models that do not interact with RTMs. The primary objective of this study is to advance transportation planning and road safety research by developing a NCPM that can be integrated with an RTM as a fifth step of the traditional four-step RTM modeling concept. The integrated RTM-NCPM framework provides estimates on both traffic demand and the number of collisions for base and future planning horizons. The City of Calgary's RTM model is used as a case study to test various scenarios and to examine the safety implications of changes in transportation policies related to fuel price, parking fees, transit fare, and transit frequency. The results of the scenario analysis clearly show the expected reduction in collision frequency at mid-blocks and intersections upon implementation of policies designed to shift travellers' mode choices from auto to transit. These collision-reduction policies include both incentives to encourage transit use and disincentives to discourage auto use. This study thus demonstrates how the integrated RTM-NCPM framework can help transportation planners and policy makers to incorporate a safety impact assessment as part of transportation planning process.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-01355
Paper Title	Hierarchical Analysis of Traffic Violations and Crashes: A Macroscopic Safety Analysis
Abstract	Traffic safety has been one of the most important topics in the transportation field. Most previous safety studies have focused on analyzing traffic crash data. Crash data has been analyzed to determine the level of traffic safety along with possible candidate contributory factors. Another way to examine the safety level is to analyze traffic violations. Traffic violation and crash data of five years (2013-2017) were collected from Montgomery County, Maryland. The numbers of non-crash violations and crashes during the five years are 954,428 and 22,563, respectively. (Approximately 42:1 ratio). Using traffic, commuter, roadway, industry, socio-economic, and demographic data collected from multiple sources, three different modeling frameworks are applied to explore violations and crashes. Each framework has two components: Bayesian Poisson lognormal models for violations and crashes. The first scenario has a hierarchical structure by using the expected number of violations from the first component as the

exposure variable of the crash model. The second scenario's crash model uses the observed number of violations as the exposure. The third scenario's crash model uses the daily miles-traveled as the exposure. The first modeling scenario shows the best performance, in terms of deviance information criterion (DIC), it is followed by the second scenario, and the third scenario performs the worst. Subsequently, hot zone identification analysis was conducted, and revealed the areas with particular problems with respect to violations and crashes. It is expected that the proposed hierarchical approach will be a useful tool to investigate traffic safety with diverse perspectives.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-01983
Paper Title	Development and Application of Roadway Safety Data Integrator (RSDI) Tool for Highway Safety Information System (HSIS) Data
Abstract	The Highway Safety Information System (HSIS) is a database that maintains crash data, roadway inventory, and traffic volume data for several US states. It is an excellent source of data to highway safety research and can be used to investigate many research questions. However, to prepare a roadway safety dataset based on the HSIS or any databases that store the data in multiple different subsets and follows linear referencing, the researchers should combine multiple datasets, merge or unmerge and remove certain inconsistent records, and finally clean the dataset. The HSIS staffs are usually accommodating and eager to help, but sometimes the nature of data needs is complicated and laborious. A tool named Roadway Safety Data Integrator (RSDI) was developed for combining, segmentation, and selection of homogeneous HSIS roadway segments and also crash assignment by desired crash fields (e.g., crash severity or type). This study utilized the RSDI to enhance the study on investigation of an alternative calibration method for the Highway Safety Manual (HSM). The results of a preliminary analysis based on sample data from Maryland were validated and complemented by statewide data from Illinois and Washington. The proposed calibration methodology incorporates multiple calibration factors for different components of the HSM predictive method rather than a single calibration factor, as recommended by the HSM that only calibrates at the aggregate level. In the proposed method, the application of calibration factors expressed in both weight and power function reflects better the local conditions while still ensuring calibration at the aggregate level.

Authors	Wesley Marshall, University of Colorado, Denver Nicholas Ferenchak, University of New Mexico
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02218
Paper Title	Implementing Vision Zero: A Proactive Methodology for Building Communities for Kids
Abstract	With communities across North America taking the Vision Zero pledge, fresh attention and energy is being focused on improving road safety. While the goal of reducing the number of traffic fatalities and severe injuries to zero is an admirable aim, the way in which communities are attempting to reach that goal is often unfocussed and thus far, inadequate. To realize Vision Zero, we need to first accommodate our vulnerable road users; we can start by better designing communities for kids. The proactive assessment approach proposed in this paper provides a method for doing just that. By proactively identifying child pedestrian and bicyclist road safety concerns, this methodology allows for the prioritization of issues before a crash occurs. We first identify roadway characteristics that most suppress children's walking and biking trips. We then use GIS network analyses to determine which barriers cause the most trip suppression and deserve the most attention. This approach allows us to not only reduce fatalities and injuries where children are currently walking and biking, but to also help ensure safe and comfortable mobility where children want to walk and bike. The same methods can also be applied to school siting scenario analyses. The accompanying GIS tool can be downloaded and applied to any U.S. community that is looking to provide safe, healthy, and equitable active transport for all.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02847
Paper Title	Investigate Factors Affecting Driver Injury Severity in Snow-Related Rural Single-Vehicle Crashes
Abstract	Snow weather is consistently considered as a hazardous factor due to its potential leading to severe fatal crashes. A seven-year crash dataset including all the snow-related rural highway single vehicle crashes from 2010 to 2016 in Washington state is applied in the present study. Pseudo elasticity analysis is conducted to investigate significant impact factors and the temporal stability of model specifications is tested via a likelihood ratio test. The proposed model based on the seven-year dataset is able to capture the individual-specific heterogeneity across crash records for four significant factors, i.e., male, not impaired and no insurance for minor injury, and not impaired for serious injury and fatality. Their estimated parameters were found to be normal distribution instead of fixed value over the observations. Other significant impact factors with fixed effects are: traffic object, animal, overturn, out-of-control, snow surface, smoke surface, sleet surface, curve horizontal design, medium and high-speed limits, young and old aged, impaired condition, no belt usage, pickup car type, airbag deployment. The results of temporal stability test show that the model specification is generally not temporally stable for driver injury severity model based on the years of crash data that were used, especially for longer period (more than 3-year dataset). Models that allow the explanatory variables to track temporal heterogeneity, are of great interest and can be explored in future research.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02863
Paper Title	The Problem of, and a Possible Solution to, Comparison Site Selection in Scheme Evaluation
Abstract	Before-and-after studies provide by far the most common method for evaluating the treatment effect of a road safety scheme. The most common among these remain Bayesian methods, which are popular among researchers and practitioners due to their ability to account for the Regression To the Mean (RTM) effect, by using a Safety Performance Function (SPF) built from untreated comparison sites. Failing to accurately estimate the RTM effect immediately leads to a biased estimate of the treatment effect, and so ensuring a well-fitting SPF is vital. It is commonly accepted that an important part of this process is ensuring the comparison sites used to build the SPF are sufficiently similar, or exchangeable, with the treated sites being analysed. Whilst this has been accepted by many authors as intuitively true, no work has been done to numerically demonstrate the consequences of using a non-exchangeable comparison pool in a before-and after study. In this paper we use simulated data to objectively demonstrate that using non-exchangeable comparison sites directly leads to an increase in bias of RTM estimates (and hence of the treatment effect). We investigate methods of comparison site selection using categorical subsetting and propensity score matching (PSM) based methods. We finally demonstrate a new method for making most efficient use of a candidate comparison pool by weighting the SPF according to propensity score similarity, known as propensity score weighted regression (PSWR).

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02889
Paper Title	Meso-Level Hotspot Identification for Suburban Arterials
Abstract	Accurate identification of hotspot as well as the relationship between crashes and the influencing factors contribute to safety improvement on suburban arterials. Micro-level hotspot identification studies treat road segments and intersections as isolated units. It is not consistent with field practices because police department usually identify hotspot based on arterial-level, which consists of multiple segments and intersections. Moreover, dense access density deteriorates traffic safety on both segments and intersections, but the overall safety impact may be underestimated by analyzing segments and intersections separately. In addition, either micro-level or macro-level studies cannot capture the specific impact of road network pattern adjacent to the arterials. This study proposed a novel meso-level approach applying Full Bayesian method (FB) and potential for safety improvement (PSI) to identify hotspots for suburban arterials. In order to reduce the effect of spatial correlation, meso-level analysis units were obtained by combining intersections and their adjacent segments according to the spatial distribution of crashes. Bayesian Poisson-lognormal conditional autoregressive model (PLN-CAR) was selected as prediction model due to its strength in accounting for the spatial correlation among analysis units. The PSI value of each unit was calculated and compared with crash frequency. Results show that 1) meso-level hotspot identification can provide a reasonable reference for police department to improve traffic safety; 2) arterials with more parallel roads and less access density were associated with fewer crashes. The meso-level hotspot identification method proposed in this study are expected to be useful in field application of safety improvement on suburban arterials.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-02893
Paper Title	Macro-Level Traffic Safety Analysis and Model Updating in Shanghai, China
Abstract	Macro-level traffic crash analyses and modeling are prevalent in many countries in order to incorporate traffic safety into long-term transportation planning. Due to the burgeoning urban development and hysteretic nature of data collection, however, many existing studies might be outdated and poorly adaptable. To address the problem, this study updated a macro-level safety model for 263 traffic analysis zones (TAZs) within the urban area of Shanghai. Independent variables for 2009 and 2016 from four categories were investigated to identify specific contributing factors for traffic crashes: socio-economic factors, traffic patterns, road characteristics, and land use features. A Bayesian conditional autoregressive negative binomial (CAR-NB) model was estimated to account for the spatial correlations among TAZs. The 2016 model was developed by using the two-stage Bayesian updating method to provide informative priors for 2009 model. Results show that higher crash frequency is associated with greater population, total length of major and minor arterials, trip frequencies, and shorter intersection spacing. The fact that most variables have similar significance for the two years is indicative of the good flexibility and interpretability of Bayesian CAR-NB model. Additionally, the informative priors are capable of providing theoretically based expectations without losing flexibility. This study helps to fill the gap in formulating informative priors for independent variables in macro-level traffic safety studies. Moreover, urban policy decision makers and traffic police can benefit from this study and implement area-wide engineering, education, and enforcement countermeasures to enhance regional traffic safety.

Authors	Josie Bianchi, Didier Valdés, Héctor Colón
Sponsoring Committee	ANB10
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-03374
Paper Title	Record Linkage of Crashes with Injuries and Medical Cost: Case Study of Puerto Rico
Abstract	Cost considerations are critical in the analysis and prevention of traffic crashes. Integration of cost data to crash datasets facilitates the crash-cost analyses with all their related attributes, but also, is a challenging task due to the availability of unique identifiers across the databases, and the privacy and confidentiality regulations. This study performed a record linkage comparison between deterministic and probabilistic approach using attributes matching techniques with numerical distance and weight pattern under the Fellegi-Sunter approach. As a result, the deterministic algorithm developed using the exact match of the 14-digit police accident record number had an overall matching performance of 52.38% of real matched records while the probabilistic algorithm had an overall matching performance of 70.41% with a quality measurement of Sensitivity of 99.99%. The deterministic approach was outperformed by the probabilistic approach by approximately 20% more of records matched. The probabilistic matching with numerical variables seems to be a good matching strategy supported by quality variables. For the proportion of non-matched records, a cost imputation was performed by regressing the personal injury insurance cost data against weekday, time and municipality of a crash, and number of claimants in the personal injury insurance records. After the record matching, a multivariate regression model was developed to estimate and identify the crash circumstances that increase the medical cost of the crash injured claimants in Puerto Rico.

Authors	Roozbeh Rahmani, Nithin Agarwal, Sivaramakrishnan Srinivasan, Ilir Bejleri, Xingjing Xu, Jia Fang
Sponsoring Committee	ANB10
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-03791
Paper Title	Cross-Comparison and Objective-Based Crash Tree Development and Analysis for Small Counties in Florida
Abstract	The Federal Highway Administration (FHWA) developed the Systemic Safety Project Selection Tool that lists six steps to integrate existing safety management practices and safety analysis tools. The first step is to identify and understand the risk factors commonly associated with the focus crash types. Crash trees have been adopted by agencies to identify the focus facility types and crash types. For most organizations and departments of transportation (DOTs), the concept behind developing a crash tree is a stepwise elimination process where higher value in the crash tree is retained and the rest of the branch is eliminated. This paper demonstrates some of the challenges with the conclusions of this traditional approach and proposes an alternative structure using a cross-comparison framework that not only compares the raw counts from the crash data but also compares focus county's crash percentage and ranking to other similar counties or jurisdictions. This approach assists the decision-makers in understanding the intensity of overrepresentation. This study developed a tool that applied the cross-comparison crash tree approach for 27 small rural counties in Florida to determine the percentage and

crash severity ranking. The results demonstrated the benefits of this approach by prioritizing the focus areas and the counties by normalizing the counts and the intensity of the overrepresentation.

Authors	Mohammad Jalayer, Kevin Takacs, Jason Roberts
Sponsoring Committee	ANB10
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04157
Paper Title	Improving Driver's Education Regarding Wrong-Way Driving Incidents
Abstract	Wrong-way driving (WWD) occurs when a driver, either inadvertently or deliberately, drives in the opposing direction of traffic along a high-speed, physically divided highway or its access ramp. The nature of WWD crashes, which often tend to be head-on collisions, has drawn the attention of transportation engineers over the past few decades. Several state departments of transportation have adopted three key points of interest—engineering, education, and enforcement—to mitigate this crash type. We note that numerous previous studies focused on engineering and enforcement components; however, in most cases, the education component has been underrepresented. The goal of this study is to contribute to the current research by expanding upon the education and knowledge of drivers regarding WWD incidents. Specifically, a web-based survey was designed and distributed to the Rowan University community to gauge the level of familiarity amongst drivers of different ages and experience. The results of the survey indicate that WWD incidents occur much more frequently than are reported. It is evident from the responses that drivers are much less aware of WWD incidents than other issues such as driving under the influence or distracted driving. Communities throughout the state of New Jersey should consider increasing the number of precautionary messages that highlight the dangers of WWD and consider introducing further education campaigns. These programs should then be evaluated to determine their effectiveness. Overall, these results provide valuable information for policymakers, engineers, and researchers to improve overall road safety by reducing WWD incident frequency.

Authors	Maria Cruz, Nicholas Ferenchak
Sponsoring Committee	ANB10
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04196
Paper Title	Invited Student Paper: Emergency Response Times for Fatal Motor Vehicle Crashes, 1975-2017
Abstract	Emergency response times are an important component of road safety outcomes. While a safety analysis may identify a decrease in traffic fatalities, that decrease may be a result of improved road safety or it may simply reflect improved emergency response times. However, it is currently unclear how emergency response times have changed over the last few decades. With data from the Fatality Analysis Reporting System (FARS), we identify the national trend in emergency response times from 1975 through 2017. Results suggest that emergency response times have improved by approximately 50% over this timeframe. Findings have important implications for fatality-based traffic safety analyses.

Authors	Michael Martin, Lisa Green, Byron Chigoy, Eva Shipp, Rahul Mars
Sponsoring Committee	ANB10
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04603
Paper Title	Vehicle Occupants and Driver Behavior An Assessment of Vulnerable User Groups
Abstract	The question of whether driver behavior, and speeding in particular, differs based on vehicle occupancy requires the use of large amounts of data—some of which may be difficult to accurately obtain. Traditional methods of obtaining information on driver behavior either lack passenger information altogether (i.e., insurance companies using telematics) or rely on rough estimates of passenger age and gender obtained from blurred photos (i.e., naturalistic driving studies like State Highway Research Program 2 (SHRP 2)). This research project represents a novel, data-driven approach to this topic. Household travel survey demographic information and global positioning system (GPS) traces were linked to HERE network speed limit to study the impact of vehicle occupancy on speeding. Survey responses from 11 study areas were cleaned, merged, and ultimately used in developing binomial logistic regression models. Of particular interest were the vulnerable user groups of teenagers, adults driving with children, and seniors. The models suggest that drivers speed less when there is a passenger in the vehicle, especially adults with a child passenger.

Authors	Tahmida Hossain Shimu, Dominique Lord, Srinivas Geedipally, Lingtao Wu, Robert Wunderlich
Sponsoring Committee	ANB10
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04761
Paper Title	Investigating Factors that Contributed to the Large Reduction and Subsequent Increase in Roadway Fatalities in the United States between 2005 and 2016
Abstract	The substantial decline in motor-vehicle fatal crashes over the period of 2008 to 2011 and a subsequent increase afterwards in the United States has been subjected to extensive research in the last few years. Following the perceptible reduction in traffic fatalities beginning in 2008, which concurred with a major recession, researchers focused on finding the relative influence of the recession on fatalities using statistical modeling. The Project 17-67 by the National Cooperative Highway Research Program (NCHRP) conducted an in-depth investigation, where the researchers developed two Poisson-gamma regression models, Model Controlling State (MCS) effect and Model Not Controlling State (MNCS) effect to analyze the factors associated with the decline in fatalities. This study sought to serve as an extension of the NCHRP Project 17-67 to provide a thorough investigation of the factors influencing fatalities during and after the 2008 recession using an updated dataset to 2016. The modeling results showed remarkable improvements, where both the MNCS and MCS models could reflect the fluctuations in fatalities over the focus period. The effect analysis revealed that the economic factors contribute as much as 84% to 86% in the reduction and subsequent increase in fatalities during and after the recession. The unemployment rate of 16 to 24 years old, median household income, and the price of gasoline were found to be the most statistically significant parameters in both the models. Changes in vehicle-miles traveled (VMT), government expenditure, and regulatory measures were not significant factors in affecting the number of fatalities over the analysis period.

Authors	Caio Torres, Universidade Federal do Ceara Xavier Vanessa, Universidade Federal do Ceara Flávio José Cunto, Universidade Federal do Ceará
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04917
Paper Title	Relationship Between Road Safety Pillars and the WHO Member States Mortality Rate: A Study Applying Structural Equation Models
Abstract	Road deaths phenomenon suggests the development of studies that consider the complex causal relationship between the factors that influence road traffic mortality at the compatible level with the definition of road safety policies. This paper analyzes the influence of 48 road safety performance indicators on 175 WHO Member States mortality rate. Structural equation models were proposed to evaluate the proposition and use of latent variables that represent five major road safety policy areas and their influence on mortality rates. The proposed model structure indicated that management has a strategic role in public policies, having an indirect influence on reducing the mortality rate through safe vehicles, user safety and safe road and mobility. The results indicated that policies aimed at encouraging safe user behavior were the ones that had the greatest influence in reducing road deaths followed by policies in safer vehicles, road safety management, safer road and mobility and post-crash response.

Authors	Rana Eslamifard, University of Massachusetts, Amherst Eric Gonzales, University of Massachusetts, Amherst
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-04939
Paper Title	School Bus Routing To Allow Later School Start Times
Abstract	School districts providing busing services for students who live too far to walk to school. In many districts a fleet of school buses is used in sequence to transport high school students, then middle school students, and then elementary school students. The result is that high school classes must start much earlier in the morning than the elementary school, and buses may traverse similar routes three times each morning and afternoon. In light of recent research on the benefits of later high school start times and the need to control transportation costs, school districts are seeking efficient school bus routing plans that meet student needs at low cost. This study uses 2018 data for schools in Northampton, Massachusetts, to identify the potential to achieve two objectives: 1) start the high school classes as late as possible in the day, and 2) minimize the cost of busing. The proposed procedure makes use of existing school bus data to optimize bus routes, which can be applicable for smaller cities. A revised routing plan that mixes high school and middle school students on the same buses allows the high school to start 45 minutes later while reducing total school bus operations by 8.5 hours per day. The elementary school and high school start times could also be swapped with minimal effect on the cost of busing.

Authors	Beau Burdett, University of Wisconsin, Madison Zhixia Li, University of Louisville Andrea Bill, University of Wisconsin, Madison David Noyce, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05134
Paper Title	Assessing the Accuracy of “Serious Injury” Reporting with the Implementation of the New MMUCC KABCO Definition
Abstract	Across the United States large discrepancies have been found between law enforcement officer’s (LEOs) injury severity assessments and medically assessed health outcomes of crash victims. To better monitor traffic safety serious injury reporting is now federally mandated, making accurate injury severities more important. New federal KABCO injury severity definitions introduced to standardize and add clarity may

	help reduce inaccuracies in LEO assessments. Wisconsin implemented the new definitions January 1, 2017. Linked crash and medical data from 2009 through 2016 was compared with data from 2017 using the new definitions to determine impacts on injury severity accuracy. Large differences were evident between injuries assessed 'A' and 'B' or 'C' suggesting LEOs are able to differentiate between more serious injuries and less severe injuries. However, despite this difference, approximately two-thirds of crash victim's injury severities were overestimated (assessed more severely than actual health outcomes) from 2009 through 2017. Underestimation of injury severity decreased from 3.5% to 2.5% after the KABCO definition changes. Furthermore, injuries assessed as minor by medical professionals were less often considered "serious injuries" by LEOs. LEO's assessment of body regions with more superficial injuries, such as the face, improved. Assessments of body regions with more internal, occult injuries, such as the thorax and abdomen also improved. More accurate assessments may be due to the added clarity of the new definitions. Despite continuing issues, the definition change does suggest that injury severity assessments have improved, which in turn may lead to more accurate traffic safety data.

Authors	Ryan Archibald, University of Colorado, Denver Wesley Marshall, University of Colorado, Denver
	A Deep Reinforcement Learning-Based Intelligent Intervention Planning Framework for Real-Time
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05231
Paper Title	Road Safety Focusing Events
Abstract	Focusing events are a concept developed and studied in the policy science field. They are described as rare events that reveal a problem to both the public and the government. For example, the events of 9/11 were a rare event that revealed security problems and resulted in policy changes. Focusing events in the road safety field are not as widely studied, nor does a method exist to determine them. In this paper, we develop a definition of a road safety focusing event derived from existing literature from the policy science field. Once defined, we propose a method to determine if a road safety incident is a focusing event or not. The method is based upon an investigation of whether or not the public and the policymakers/government were not only aware of, for instance a child pedestrian fatality, but that they were aware of an infrastructure or policy problem (e.g. no sidewalks in a neighborhood). We test the method on a subset of 2014 child pedestrian fatality data and identify six focusing events and four potentially non-focusing events. This research is important since studies on road safety focusing events are lacking. In addition, solutions that work for the United States to improve road safety are needed. Research into road safety focusing events might reveal what has and has not worked for communities. To get there, we must first develop a framework for studying road safety focusing events, which begins with defining and identifying them.

Authors	Brian Taylor, University of California, Los Angeles Yu Hong Hwang, University of California, Los Angeles
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05268
Paper Title	The Eighty-Five Percent Solution: A Historical Look at Crowdsourcing Speed Limits and the Question of Safety
Abstract	

Authors	Ananya Roy, Tokyo Institute of Technology Yasunori Muromachi, Tokyo Institute of Technology Moinul Hossain, Islamic University of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05301
Paper Title	Proactive Road Safety Management
Abstract	This goal of this study is improving safety of urban expressways. A dynamic Bayesian network based real-time crash prediction model (RTCPM) and deep Q-network-based intervention is proposed to achieve the goal. Both models are highly dependent on high quality and high density traffic and crash data. These data are collected from the detectors or sensors installed on road networks. For this thesis, route 3 Shibuya (11.9 km) and route 4 Shinjuku (13.5 km) - two radial routes of Tokyo metropolitan expressway were chosen because of the availability of one minute resolution traffic data from 250 meters (approximately) spaced detectors. To make data collection flexible, uniformly spaced (150 meters) detectors (cells) were generated using a macroscopic model called cell transmission model (CTM). The CTM was then modified to incorporate the variable speed limit control in it. The CTM generated traffic data and DBN-based RTCP were fed into the DQN-based intervention model. The DQN-based intervention model then selects several VSL controls in situations when crash risk was detected to be more than or equal to 10. After several iterations the intervention model was able to learn the optimum VSL values take for related hazardous situations to reduce crash risk at the target location by about 19%.

Authors	Qifan Nie, University of Alabama Xing Fu, University of Alabama Xiaobing Li, University of Alabama Jun Liu, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05447
Paper Title	Are Uninsured Drivers Less Likely to Request Emergency Medical Services After A Crash?
Abstract	Emergency Medical Services (EMS) are found to be effective in dealing with injuries caused by traffic crashes, especially for severe crashes. However, some people may tend to not call the EMS after crash due to various reasons. According to the Alabama crash reports in 2017, over 10% of injured drivers declined to contact EMS. Auto insurance status may be factor than influences the decision-making of EMS requests. The objective of this study is to uncover correlates of EMS requests with a focus on the role of auto insurance. This study performed a comparative analysis for crashes that caused different damages. Considering the unobserved heterogeneity, this study employed a random-parameter modeling approach to disentangle the relationships between factors. Unexpectedly, the model results indicated that after minor vehicle damage crashes, drivers with valid auto insurance seem to be less likely to request EMS; while for crashes that caused major vehicle damages, there is no significant correlation between EMS requests and auto insurance status. Other important factors such as vehicle registration status, driver license status, driving under impairment, seat belt use were also found to be related to EMS requests. The results offer researchers and traffic incident responders an understanding of relationship between EMS requests and crash related factors, and consequently help develop effective strategies to reduce fatality rate of crashes. In addition, medical facilities may cooperate with auto insurance companies to develop an insurance-based response system in responding to uninsured crashes with diversified plans.

Authors	Yue Zhang, Tongji University Yajie Zou, Tongji University Lingtao Wu, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05512
Paper Title	A Linear Poisson Autoregressive Model for Analyzing Dynamic Fatal Traffic Accident Data
Abstract	Annual fatal traffic accident data often demonstrates characteristics of time series . The existing traffic safety analysis approaches (e.g., Negative Binomial (NB) model) often cannot accommodate the dynamic feature in fatal traffic accident data and may result in biased parameter estimation results. In order to consider the time series characteristics of the count traffic accident data, a linear Poisson autoregressive (PAR) model is proposed in this study. The objective of this study is to apply the PAR model to analyze the dynamic impact of traffic laws on the frequency of fatal traffic accident occurred from 1975 to 2016 in Illinois. In addition to the PAR model, the NB model and the autoregressive integer moving average (ARIMA) model are also developed and their performance and impact multipliers are compared. The important conclusions from the modeling results can be summarized as follows: (1) The PAR model outperforms the NB and ARIMA models in terms of analyzing the dynamic influences and fitting performance. The PAR model is more suitable for analyzing the dynamic impact of traffic laws on annual fatal traffic accidents, especially the instantaneous impacts. (2) The law allowing red running leads to an increase in the frequency of annual fatal traffic accidents in both the short and long term. Thus, the modeling results suggest that the PAR model is more suitable for annual fatal traffic accident data and has an advantage in estimating the dynamic impact of traffic laws.

Authors	Margaret Herrera, Maricopa Association of Governments
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1284
Session Title	Transportation Safety Management from Start to Finish
Paper Number	20-05787
Paper Title	Systemic Strategy to Mitigate Intersection Left-Turn Crashes A Regional Analysis Methodology
Abstract	This paper presents a crash analysis methodology utilized by the Maricopa Association of Governments (MAG) to identify intersections with the best potential of benefitting from safety improvements related to creating positive offset. The Phoenix metropolitan planning area consists of 27 cities and towns and three (3) Native Nation communities with a population over five million. MAG has conducted over 70 Road Safety Assessments (RSAs) at intersections across the region. A detailed review of observations and recommendations of RSAs conducted where the left-turn crashes were overrepresented showed 26 percent of the observations related to the lack of sufficient sight distance noted as a potential causal factor. It is widely accepted that “a positive offset of left turn lanes” improves sight distance and would help mitigate this crash risk. Although a larger percentage of recommendations for mitigating left-turn crashes related to modifications to left-turn signal phasing, it was determined that the analysis should focus on the countermeasure related to sight visibility for a more meaningful screening and analysis to address a greater need in the MAG region. MAG identified a project to study a Systemic Strategy to Mitigate Intersection Left-Turn Crashes. The methodology outlined in this paper was used to screen all signalized intersections in the region. The study resulted in 1) a sample of intersections in the MAG region that would provide meaningful analysis of the left-turn crash problem as it relates to lack of sight visibility, and 2) a project assessment which included development of HSIP funding applications.

9 Interacting Committees

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

ABE25, Congestion Pricing
The Committee fosters research aimed to gain a better understanding of the technological, operational, business, administrative, political and institutional aspects of innovative congestion pricing of systems and services for all modes of transportation. Strategies include integrated transit, variable aviation pricing, parking pricing, parking "cash-out", and other mechanisms that seek to affect transportation demand and use. The Committee seeks to develop a comprehensive understanding of the effects of congestion pricing on the transportation system, in addressing passenger and freight mobility, transit and highway interdependence, and interoperability of systems.

ABG30, Technology Transfer
This committee is concerned with information exchange and research on the processes and methods for technology transfer, and assisting the Transportation Research Board and other TRB committees in their role as an agent for technology transfer.

ABJ80, Statistical Methods
This committee is concerned with the appropriate application of statistical methods in the field of transportation. The committee will serve as a resource on statistical matters for all other TRB committees or activities; will foster understanding and use of statistics through dissemination and education activities; and will identify and foster research needed in statistics for use in transportation.

ABR30, Emergency Evacuations
This Committee is concerned with preparedness for, and operational issues of, emergency evacuations associated with any natural or human made hazards. Evacuations with notice, little, or no notice, as well as building, urban and regional evacuation are included. It seeks to identify research needs, encourage and facilitate individual and joint research efforts, and disseminate research findings aimed at enhancing the effectiveness and efficiency of operations and increasing safety and survivability of those involved in emergency evacuation. The Committee acts as a resource to governmental and nongovernmental organizations concerned with evacuation planning and operations.

AHB10, 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.

AHB20, Freeway Operations
This committee is concerned with the operational aspects of freeway corridors which affect traffic carrying capacity, operating costs, energy conservation, air quality and motorists' convenience and safety.

AHB35, Managed Lanes
This committee is concerned with the evolving role of high-occupancy vehicle, high-occupancy toll, and managed lanes in response to the challenges of congestion, energy consumption, and climate change. The committee examines methods for enhancing person throughput, energy conservation, air quality, and user choices and safety through the optimization of preferential lanes, priority treatments, and other supporting systems for bus transit, carpooling, and vanpooling. The committee's activities focus on the planning, design, operation, pricing, and evaluation of preferential lane facilities and on the development, validation, and dissemination of theoretical, experimental, and applied research related to preferential lanes.

AHB50, Traffic Control Devices
This committee is concerned with the development, design, application, and evaluation of traffic control devices, and their effect on traffic operation and safety.

AHD55, Signing and Marking Materials
This committee is concerned with all factors affecting the choice, use and performance of paints, durable markings, plastics, and optical elements used in retroreflective signing and marking materials.

AHB60, Highway/Rail Grade Crossings
This committee is concerned with the safety and other affected characteristics (including economic considerations, traffic flow and delay, and countermeasures) of both highway and rail traffic at points where they intersect at grade, including the proximate surrounding environment and also including rail transit facilities.

AHB65, Operational Effects of Geometrics
This committee is concerned with geometric design as related to traffic operations and safety.

ANB40, Traffic Law Enforcement

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

ANB45, 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.

ANB50, Alcohol, Other Drugs, and Transportation

This committee is concerned with alcohol and other drugs as they relate to all significant modes of transportation with particular emphasis on those relationships that are common to more than one mode.

ANB70, Truck and Bus Safety

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

AND20, User Information Systems

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

AND30, Simulation and Measurement of Vehicle and Operator Performance

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

AND40, Visibility

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

ANF20, Bicycle Transportation

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

ANF30, Motorcycles and Mopeds

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