TRB Standing Committees

ACS10 – Transportation Safety Management Systems

ACS20 – Safety Performance Analysis

Synthesis Report on Safety-Related Papers

presented at the 102nd TRB Annual Meeting

Prepared by

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TRB Standing Committee ACS10 – Transportation Safety Management Systems

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

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

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Esther Wagner, National Highway Traffic Safety Administration (NHTSA)
Nicole Waldheim, Burgess and Niple, Inc.
Keith Williams, National Highway Traffic Safety Administration (NHTSA)
Robert Wunderlich, Texas A&M Transportation Institute

TRB Standing Committee ACS20 – Safety Performance Analysis

TRB ANB25 (Highway Safety Performance) and TRB ANB20 (Safety, Data, and Evaluation) merged into ACS20 Safety Performance Analysis (draft committee name). This Committee deals with the advancement, integration and institutionalization of quantitative highway safety information to support transportation decision-making at all levels. The function of this committee is to foster the continual development, validation and increased knowledge of science-based methods, procedures and measures that will increase the safety of the nation's highways and roadways.

Website: https://trbacs20.org/

Membership as of November 2022

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George Yannis, National Technical University of Athens (NTUA)

Emeritus Members

Forrest M. Council, UNC Highway Safety Research Center
Ezra Hauer, University of Toronto
Bhagwant Persaud, Ryerson University

Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ACS10-ACS20 related presentations and events at the 102nd Annual Meeting of the Transportation Research Board. With this aim, papers sponsored by the Committees ACS10 – Transportation Safety Management Systems and ACS20 – Safety Performance Analysis have been split into subthemes and the abstracts reproduced. For each subtheme, a brief comment on the methodological and application perspectives of the presented papers is reported. Further, some papers sponsored by other interacting Committees which are within the scopes of ACS10[1]and ACS20[2] have been identified and classified to promote better interaction between ACS10, ACS20 and these other Committees. Indeed, highway safety is a worldwide major social challenge that requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

This year, **thirty-two events sponsored by ACS10 and ACS20 are planned**:

- Three Committee meetings (see Table 1);
- Seven Subcommittee meetings (see Table 2);
- Four workshops (see Table 3);
- Seven lectern sessions (see Table 4); and
- Eleven poster sessions (see Table 5).

The Transportation Safety Management Systems Committee meeting will be held on Wednesday morning, January 11, from 8:00 AM to 12:00 PM.

The Safety Performance Analysis Committee meetings will be held on Wednesday afternoon, January 11, from 1:30 PM to 5:30 PM and on Thursday morning, January 12, from 9:00 AM - 12:00 PM.

The **427 safety-related papers** identified by the sub-committee address the following topics (some papers are classified in more categories):

a) Crash Data and Safety Analysis (146);
b) Network Screening (9);
c) Safety Performance Functions (33);
d) Crash Severity Prediction (82);
e) Crash Modification Factors (12);
f) Surrogate Measures of Safety (49);

[1] The committee will be concerned with the development and coordination of integrated safety management programs to reduce death and injury on transportation systems. Areas of concern include: 1) the advancement of safety management systems, 2) research and technology to improve safety, and 3) models of safety delivery systems.
[2] This Committee deals with the advancement, integration and institutionalization of quantitative highway safety information to support transportation decision-making at all levels. The function of this committee is to foster the continual development, validation and increased knowledge of science-based methods, procedures and measures that will increase the safety of the nation's highways and roadways.

g) Real-Time Safety Prediction (22);
h) Safety Effects of Connected and Automated Vehicles (17); and
i) Transportation Safety Management (57).

Table 1 ACS10 and ACS20 Committee Meetings

Schedule	Title	Details
Wednesday, January 11 8:00 AM – 12:00 PM Marriott Marquis, Capitol (M4)	Transportation Safety Management Systems Committee	https://annualmeeting.mytrb.org/OnlineProgram/Details/18307
Wednesday, January 11 1:30 PM - 5:30 PM Marriott Marquis, Marquis Salon 10 (M2)	Safety Performance and Analysis Committee	https://trbacs20.org/wp-content/uploads/2022/12/ACS20_2023_Wed_AM_FinalDraft_Agenda.pdf
Thursday, January 12 9:00 AM - 12:00 PM Marriott Marquis, Liberty Salon JK (M4)	Safety Performance and Analysis Committee	https://trbacs20.org/wp-content/uploads/2022/12/ACS20_2023_Thurs_AM_FinalDraft_Agenda.pdf

Table 2 ACS10 and ACS20 Subcommittee Meetings

Schedule	Title	Details
Monday, January 9 8:00 AM – 9:45 AM Marriott Marquis, Mount Vernon Square (M3)	School Transportation Subcommittee, ACS10(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/18636
Monday, January 9 10:15 AM – 12:00 PM Marriott Marquis, Independence Salon A (M4)	Emergency Response Subcommittee, AMR00(1), Joint Subcommittee of AMR00, ACP10, ACS10, ACS30	https://annualmeeting.mytrb.org/OnlineProgram/Details/18513
Monday, January 9 3:45 PM – 5:30 PM Marriott Marquis, Marquis Salon 10 (M2)	Rural Road Safety Policy, Programming, and Implementation Subcommittee, ACS10(4), Joint Subcommittee of ACS10, ACS20, AKD30	https://annualmeeting.mytrb.org/OnlineProgram/Details/18637
Monday, January 9 3:45 PM – 5:30 PM Marriott Marquis, Marquis Salon 13 (M2)	Safety Analytical Methods Subcommittee, ACS20(1)	https://annualmeeting.mytrb.org/OnlineProgram/Details/18638
Tuesday, January 10 10:15 AM - 12:00 PM Marriott Marquis, Marquis Salon 13 (M2)	Surrogate Safety Measures Subcommittee, ACS20(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/18640
Tuesday, January 10 1:30 PM - 3:15 PM Marriott Marquis, Marquis Salon 10 (M2)	Pedestrian and Bicycle Safety Analysis, ACS20(4), Joint Subcommittee of ACS20, ACH10, ACH20	https://annualmeeting.mytrb.org/OnlineProgram/Details/18641

Wednesday, January 11 11:15 AM - 1:15 PM Marriott Marquis, Mount Vernon Square (M3)	Safety Performance and Analysis User Liaison Subcommittee, ACS20(2)	https://annualmeeting.mytrb.org/OnlineProgram/Details/18639

Table 3 ACS10 and ACS20 Workshops

Schedule	Title	Details
Sunday, January 8 1:30 PM - 4:30 PM Convention Center, Ballroom C	(1042) Applying the Safe System Approach to Overcome Challenges	https://annualmeeting.mytrb.org/OnlineProgram/Details/18960
Sunday, January 8 1:30 PM - 4:30 PM Convention Center, 150A	(1043) Data Science Meets Statistical Modeling: A Future Research Agenda for Analysis Using Integrated Data and Methods	https://annualmeeting.mytrb.org/OnlineProgram/Details/18871
Sunday, January 8 1:30 PM - 4:30 PM Convention Center, 207B	(1054) No Excuse for Ugly Streets Serving Our Communities	https://annualmeeting.mytrb.org/OnlineProgram/Details/18883
Monday, January 9 1:30 PM - 3:15 PM Convention Center, Hall A	(2160) Incident Response and Roadside Safety	https://annualmeeting.mytrb.org/OnlineProgram/Details/19068

Table 4 ACS10 and ACS20 Lectern Sessions

Schedule	Title	Details
Monday, January 9 1:30 PM - 3:15 PM Convention Center, Salon B	(2117) Doctoral Student Research in Transportation Safety: A Lectern-Poster Session	https://annualmeeting.mytrb.org/OnlineProgram/Details/19445
Monday, January 9 6:00 PM - 7:30 PM Convention Center, Salon B	(2219) Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session	https://annualmeeting.mytrb.org/OnlineProgram/Details/19154
Monday, January 9 6:00 PM - 7:30 PM Convention Center, Salon A	(2220) Infrastructure-Related Connected and Automated Safety Performance	https://annualmeeting.mytrb.org/OnlineProgram/Details/19468
Tuesday, January 10 8:00 AM - 9:45 AM Convention Center, 151A	(3010) Moving Safety Research into Practice	https://annualmeeting.mytrb.org/OnlineProgram/Details/18988
Tuesday, January 10 10:15 AM - 12:00 PM Convention Center, Salon B	(3062) Paper Awards: Transportation Safety Management Systems	https://annualmeeting.mytrb.org/OnlineProgram/Details/19110
Tuesday, January 10 10:15 AM - 12:00 PM Convention Center, 146A	(3081) Last, But Not Least: Post-Crash Care and the Safe System Approach	https://annualmeeting.mytrb.org/OnlineProgram/Details/18998

Tuesday, January 10 3:45 PM - 5:30 PM Convention Center, 101	(3174) The Best of the Best Performance Effects of Geometric Design Paper Submissions	https://annualmeeting.mytrb.org/OnlineProgram/Details/19313

Table 5 ACS10 and ACS20 Poster Sessions

Schedule	Title	Details
Monday, January 9 8:00 AM - 9:45 AM Convention Center, Hall A	(2036) What Can I Learn by Studying Vehicle Conflicts?	https://annualmeeting.mytrb.org/OnlineProgram/Details/19480
Monday, January 9 8:00 AM - 9:45 AM Convention Center, Hall A	(2037) Safety Implications of Risky Driver Behavior	https://annualmeeting.mytrb.org/OnlineProgram/Details/19481
Monday, January 9 8:00 AM - 9:45 AM Convention Center, Hall A	(2038) Infrastructure-Related Safety Effects for Connected and Automated Vehicles	https://annualmeeting.mytrb.org/OnlineProgram/Details/19482
Monday, January 9 8:00 AM - 9:45 AM Convention Center, Hall A	(2045) Advances in Highway Safety Design	https://annualmeeting.mytrb.org/OnlineProgram/Details/19389
Monday, January 9 10:15 AM - 12:00 PM Convention Center, Hall A	(2098) Safety Effects of Roadway Characteristics and Treatments	https://annualmeeting.mytrb.org/OnlineProgram/Details/19479
Monday, January 9 1:30 PM - 3:15 PM Convention Center, Hall A	(2160) Incident Response and Roadside Safety	https://annualmeeting.mytrb.org/OnlineProgram/Details/19068
Tuesday, January 10 10:15 AM - 12:00 PM Convention Center, Hall A	(3097) TRB Minority Student Fellows Poster Session	https://annualmeeting.mytrb.org/OnlineProgram/Details/18997
Tuesday, January 10 1:30 PM - 3:15 PM Convention Center, Hall A	(3149) Transportation Safety Management Systems from Start to Finish	https://annualmeeting.mytrb.org/OnlineProgram/Details/19155
Tuesday, January 10 3:45 PM - 5:30 PM Convention Center, Hall A	(3196) Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others	https://annualmeeting.mytrb.org/OnlineProgram/Details/19472
Tuesday, January 10 6:00 PM - 7:30 PM Convention Center, Hall A	(3215) Safety Models: New, Evolving, and Refreshed	https://annualmeeting.mytrb.org/OnlineProgram/Details/19474
Tuesday, January 10 6:00 PM - 7:30 PM Convention Center, Hall A	(3216) A Fresh Look at Crash Characteristics	https://annualmeeting.mytrb.org/OnlineProgram/Details/19475

2 Crash Data and Safety Analysis

Mohamad Banihashemi
FHWA

Crash Data and Safety Analysis section contains many papers in wide variety of subjects in highway safety. Of over 240 papers submitted to the ACS10 and ACS20 Committees for 2023 Annual Meeting, there are **11 PhD presentations, 3 presentations on Special Session on Post Crash Care, and 146 papers** that fit in this major category, with papers grouped into several sub-categories listed below:

General Data and Data Analysis, Safety of Specific Facility Types, and Some other Specific Situations: This sub-category has 36 papers presented in the Annual Meeting.

Fiorentini and Losa (TRBAM-23-00643) investigated unobserved heterogeneity in factors of severe crashes across Italian two-lane roads. Aguero-Valverde, J. and D. Vargas Aguilar (TRBAM-23-00899) incorporated road network connectivity in neighboring structures for crash prediction models at area level. Son, S. et al. (TRBAM-23-01672) evaluated the safety benefits of a smart tolling system on freeways. Gurbuz, O. et al. (TRBAM-23-01862) studied parking safety. Wang, X. et al. (TRBAM-23-02343) conducted safety analysis of major arterials considering road network characteristics. Wang, X. et al. (TRBAM-23-02345) conducted statistical analysis of traffic crashes on the sections of mountainous freeway tunnels. Li, J. et al. (TRBAM-23-02868) conducted a study on heterogeneous effects of different contributing factors on crash risk prediction for freeway segment. Khanal, B. et al. (TRBAM-23-05023) conducted safety assessment of suburban arterials using Heterogeneity models. Fu, S. et al. (TRBAM-23-02706) used Snowflake schema-based data warehouse for analyzing crash, citation, and warning traffic safety records. Wu, Y. et al. (TRBAM-23-02386) explored the associations between built environment and the traffic accident risk of children in school commuting. Venegas, K. et al. (TRBAM-23-01048) analyzed the safety and speed effects of high traffic volume road diets. Chakraborty, M. and T. Gates (TRBAM-23-01075) studied the association between horizontal curve geometry and single vehicle crash occurrence on rural secondary highways. Zhang, J. et al. (TRBAM-23-00512) developed an index of risk assessment of lane-change on expressway weaving segments. Dong, T. et al. (TRBAM-23-01658) used car-following model to conduct an analytical investigation of traffic safety and stability. Ahern, Z. et al. (TRBAM-23-02483) developed an extensive hypothesis testing for estimation of a crash data count model. Islam, M. et al. (TRBAM-23-03171) used Negative Binomial-Lindley approach to study the regional heterogeneity in crash data with excess zero observations. Blair, M. et al. (TRBAM-23-03482) explored the impact of different parameterizations on developing calibration functions. Istiak Jahan, M. et al. (TRBAM-23-03547) developed an aggregate framework to model crash frequency by crash type. Gil-Marin, J. K. and M. Shirazi (TRBAM-23-03597) developed a comparative analysis of Negative Binomial and Negative

Binomial-Lindley models in crash hotspot identifications. Shangguan, Q. et al. (TRBAM-23-03748) modeled the impact of risky cut-in and cut-out maneuvers on traffic platooning safety. Khodadadi, A. et al. (TRBAM-23-04032) conducted an Empirical Bayes estimate of the Negative Binomial-Lindley model applicable to all Poisson-compound distributions. Olufowobi, O. et al. (TRBAM-23-04140) applied realistic artificial datasets to conduct various crash safety analysis of rural two-lane undivided highways. Grigorev, A. et al. (TRBAM-23-04386) used early traffic disruption detection and segmentation to conduct integrated analysis of accident reports and traffic flow data sets. Okaidjah, D. and C. Day (TRBAM-23-04499) studied the influence of travel time performance metrics on road crashes at the segment level. Liu, J. et al. (TRBAM-23-04530) used Bayesian Hierarchical based Spatiotemporal Approach for to investigate effects of impact factors on crash frequencies in urban area. Avelar, R. et al. (TRBAM-23-04758) assessed the effectiveness of goodness of fit measures from the calibration of safety performance functions. Azmeri Khan, S. et al. (TRBAM-23-02354) applied random parameters Negative Binomial Lindley model to examine the effects of geometric design consistency on run-off road crashes along two-lane rural roadways.

Harwood, D and Z. Hans (TRBAM-23-00217) compared two methods for assessing the need for crash countermeasures based on safe system principles. Ghomi, H. and M. Hussein (TRBAM-23-02224) used Copula-based modeling to evaluate the effectiveness of Toronto's Vision Zero strategies. Burbidge, S. (TRBAM-23-03111) studied the effectiveness of Safe Routes to School projects. Torres, C. and F. José Cunto (TRBAM-23-04009) conducted multivariate analysis of road safety policies in Brazilian cities based on the safe system approach. Mohsena Haque, A. et al. (TRBAM-23-04010) studied the safety in disadvantaged communities by integrating crash and Justice 40 initiative data. Shi, G. et al. (TRBAM-23-04731) studied road safety in New York city after Vision Zero for different land use contexts.

Agarwala, R. and V. Vasudevan (TRBAM-23-00482) studied the influence of economic growth on traffic safety in India. Goyal, V. et al. (TRBAM-23-03087) studied the effect of Transportation Network Companies on road crashes. Wang, W. (TRBAM-23-04741) used ARIMA modeling to evaluate the effectiveness of Vision Zero policies.

Pedestrians, Bicyclists, Other Vulnerable Road Users (VRU), Motorcyclists, First Responders, and Work Zone Safety: This sub-category has 32 papers presented in the Annual Meeting.

Gupta, G. et al. (TRBAM-23-00920) Evaluated the safety effectiveness of textured pavement and speed hump at uncontrolled midblock crosswalks. Penmetsa, P. et al. (TRBAM-23-04406), C. Yang, et al. (TRBAM-23-04261), and J. Liu et al. (TRBAM-23-04281) studied incidents related to first responders.

Anjum, F. et al. (TRBAM-23-02039) studied the risk perception of vehicle-to-vehicle vendors and general pedestrians. Izadi, M. et al. (TRBAM-23-04432) developed an open-source web tool to prioritize safer streets for pedestrians. Shangguan, Q. et al. (TRBAM-23-02767) used

video-based trajectory data to develop countermeasures improve the safety of vulnerable road users at signalized intersections. Rodriguez, O. and N. Ferenchak (TRBAM-23-01238) conducted a longitudinal spatial trends study related to pedestrian fatalities for 1999-2020. Hossain, A. et al. (TRBAM-23-01246) investigated pedestrian crash patterns at high-speed intersection and road segments. Okafor, S. et al. (TRBAM-23-01415) conducted behavioral pathway analysis of pedestrian injury severity in pedestrian-motor vehicle crashes. Shin, S. and S. Choo (TRBAM-23-04294) studied the influence of built environment on micromobility-pedestrian accidents. Nassereddine, H. et al. (TRBAM-23-04347) used Extreme Value Theory (EVT) to estimate vehicle-pedestrian safety surrogates at intersection with right-turn flashing yellow arrow indication. Bonga, N. et al. (TRBAM-23-04513) studied pedestrian crashes near bus stops. Ma, Z. et al. (TRBAM-23-05259) assessed the risk of pedestrian-involved crashes using high-resolution location-based data. Mahmud Hossain, M. et al. (TRBAM-23-00321) studied crashes involving distracted pedestrians. Mahmoud, N. et al. (TRBAM-23-02447) studied the impact of target speed on pedestrian, bike, and speeding crash frequencies.

Ganga, A. et al. (TRBAM-23-00194) conducted a nationwide scoring-based analysis of helmet safety legislation for motorcycles. Lee, S. et al. (TRBAM-23-00709) developed strategies for reducing motorcyclist injuries. Jang, S. et al. (TRBAM-23-04087) studied the relationship between motorcyclist attitudes and behaviors toward safe riding and self-reported crash experiences. Das, S. et al. (TRBAM-23-04325) developed a Bayesian network for motorcycle crash severity analysis. Mansell, R. et al. (TRBAM-23-01748) investigated factors that affect conflicts between bicyclists and right turning vehicles at signalized intersections. Shaaban, K. et al. (TRBAM-23-03503) investigated cyclists' impact in road crashes. Yadav, A. et al. (TRBAM-23-03777) used automated trajectory data to evaluate motorcyclist interaction at unsignalized interaction. Tamakloe, R. et al. (TRBAM-23-02088) estimated risk factors affecting motorcycle-barrier crashes and injury severities.

Schneider, R. et al. (TRBAM-23-04059) linked police and EMS records to strengthen bicyclist injury reporting. Martinez, A. et al. (TRBAM-23-02967) explored neighborhood differences in bicycling accessibility to physical and virtual workplaces. Forrest, M. and S. Heydari (TRBAM-23-00526) estimated the effect of proximity to school on cyclist injury frequencies.

Forcades, A. et al. (TRBAM-23-01323) explored work zone crash risk for different highway functional classifications. Das, S. et al. (TRBAM-23-03524) studied the patterns of contributing factors differ temporarily in work zone related crashes.

Ahsanullah, N. et al. (TRBAM-23-01889) evaluated university students' safety behavior on three-wheel electric rickshaw. Cho, E. et al. (TRBAM-23-00574) developed a monitoring framework for riding safety of delivery scooters using Korean 100 naturalistic riding study (NRS) data. Zhang, C. et al. (TRBAM-23-04328) studied Moped crash data.

Data and Analysis Related to Specific Crash Types (RTL, WWD, Secondary, …) or Specific Treatments: This sub-category has 19 papers presented in the Annual Meeting.

Ling, L. et al. (TRBAM-23-02788) studied the influencing factors for right turn lane crash frequencies. Cunningham, J. and E. Fitzsimmons (TRBAM-23-01004) evaluated the low-cost countermeasures to reduce wrong way driving incidents at partial cloverleaf interchanges. Russo, B. et al. (TRBAM-23-00224) analyzed the safety impacts of left-in left-out median opening treatments. Hossain, A. et al. (TRBAM-23-01078) explored association knowledge in single-vehicle roadway departure crashes on curved segment of rural two-lane highways. Kay, J. et al. (TRBAM-23-01580) studied the safety performance of signalized median U-turn intersections. Biswas, P. et al. (TRBAM-23-02254) conducted the safety evaluation of offset Left-turn lanes and Flashing Yellow Arrow (FYA) signals on multi-lane divided highways. Zhang, X. et al. (TRBAM-23-04250) also studied the safety performance FYA signals. Chatterjee, S. et al. (TRBAM-23-05104) evaluated the effectiveness of flexible poles in safety improvement of horizontal curves. Bayoumi, M. et al. (TRBAM-23-02511) conducted the safety evaluation of high friction surface treatment at signalized intersections. Liu, M. et al. (TRBAM-23-02971) conducted safety analysis of friction improvement surface treatments in Georgia. Song, Y. et al. (TRBAM-23-04059) conducted a National Survey on Wrong-Way Driving Solutions. Song, Y. et al. (TRBAM-23-03753) studied the trends and odds of wrong-way driving fatal crashes on freeways from 2004 to 2020. Reyes, L. et al. (TRBAM-23-01293) investigated factors that influence the spatiotemporal gaps between primary incidents and secondary crashes. Son, S. et al. (TRBAM-23-01668) studied the safety effectiveness of decreasing speed limits of urban areas. Yang, C. et al. (TRBAM-23-04333) investigated the effects of speeds in traffic crashes. Cook, D. et al. (TRBAM-23-03200) studied the effectiveness of Offset Right-Turn Lanes. Ding, X. et al. (TRBAM-23-01516) used a Copula-Based approach to study the relations between freeway primary and secondary crash severities. Zhang, Z. et al. (TRBAM-23-01595) conducted secondary crashes identification and modeling along highways in Utah. Huq, A. (TRBAM-23-03672) examined highway secondary crash risk factors.

Emerging and New analytics: This sub-category has 33 papers presented in the Annual Meeting.

Yang, C. et al. (TRBAM-23-04349) used machine learning to study the relationship between traffic incident responders' safety experience and countermeasure adoption. Qian, X. et al. (TRBAM-23-02299) conducted analysis of intelligent vehicle technologies to improve VRUs safety in urban areas. Zhu, C. and B. Dadashova (TRBAM-23-03617) Investigation on the Driver-Victim Pairs in Pedestrian and Bicyclist Crashes by Latent Class Clustering and Random Forest Algorithm. Du, Y. et al. (TRBAM-23-01435) studied the causes of Two-Wheel riders being run over during road accidents. Das, S. et al. (TRBAM-23-02686) used few-shot learning in classifying pedestrian crash types. Jiang, Z. et al. (TRBAM-23-05126) used text mining and machine learning methods to automate pedestrian crash typing. Rahman, M.A., et al. (TRBAM-23-04962) used Latent Class Clustering and Association Rule Mining to identify attribute associations in fatal speeding crashes. Das, B. and M. Paul (TRBAM-23-04785) used machine learning to conduct a conflict-based rear-end collision prediction model for unsignalized intersections. Moinuddin, M. et al. (TRBAM-23-00162) applied of machine learning models to

predict driver left turn destination lane choice behavior at urban intersections. Zhao, X. et al. (TRBAM-23-02800) conducted an analysis of risk factors for online car-hailing drivers based on LightGBM and SHAP. Sajid Hassan, A. et al. (TRBAM-23-03151) applied machine learning models and SHAP to examine crashes involving young drivers. Zhang, Y. et al. (TRBAM-23-04954) conducted lane-changing risk level prediction using a deep learning method. Chang, Q. et al. (TRBAM-23-04443) used a machine learning approach to quantify effects of traffic control devices and gto pometric design features on wrong-way driving incidents. Charm, T. et al. (TRBAM-23-01882) used machine learning Predict intersection crashes. Ye, F and J. Lu (TRBAM-23-02149) used a Feature-weighted Oversampling approach to conduct crash predication on expressways. Xu, R. et al. (TRBAM-23-03541) developed a machine learning-based road safety classifier that predicts the safety level for road segments. Zhao, B. Et al. (TRBAM-23-00635) used Tree-Based machine learning models to predict pedestrian crashes. Moraldoo, N. Et al. (TRBAM-23-03592) used an Unsupervised machine learning approach to identify corner cases in fatal pedestrian-involved crashes. Huo, Z. And J Lu (TRBAM-23-01162) used a one-dimensional Convolutional Neural Network (CNN) to estimate crash risk on freeways. Li, Y. et al. (TRBAM-23-01456) used CNN-LSTM model with attention mechanism to conduct conflict prediction of merge process on roundabouts. Bai, S. Et al. (TRBAM-23-01557) used KaplanMeier Analysis and Random Survival Forest model to predict the duration of geohazard incidents on road networks. Tongji, J. Et al. (TRBAM-23-02533) used Catboost model and interpretable machine learning framework SHAP to identify freeway safety influencing factors. Lyu, N. And J. Wu (TRBAM-23-02688) used LGBM in the development of a method for short-term prediction of driving risk. Guo, M. et al. (TRBAM-23-02764) studied the relationship between traffic flow, risky driving behavior, and crash probability in spatiotemporal using a dynamic Bayesian network. Owjimehr, O. et al. (TRBAM-23-03068) conducted road collision analysis and accident prediction using Neural Networks. Sun, P. and R. Jayakrishnan (TRBAM-23-05058) used the Vehicle Tube Model for estimating the risk probability for accidents at different points in time. Faden, A. et al. (TRBAM-23-05093) used Multivariate Poisson-Lognormal models for predicting peak-period crash frequency of joint on-ramp and merge segments on freeways.

Ahmad, N. et al. (TRBAM-23-00109) used Copula-based Bivariate Count data regression models for simultaneous estimation of crash counts. Mahmud, A. et al. (TRBAM-23-00165) compared machine learning and statistical models in crash classification. Phan, L. et al. (TRBAM-23-00530) Visualization and Collaboration Platform for Vehicular Crash Hot Spot Prediction in Chattanooga, TN

Wang, S. et al. (TRBAM-23-02552) used a Bivariate Negative Binomial Spatial Conditional Autoregressive model (BNB-CAR) and the Potential for Safety Improvement (PSI) method to identify crash-prone and violation-prone areas. Islam, M. et al. (TRBAM-23-04894) used machine learning algorithm with Unobserved Heterogeneity to conduct an exploratory analysis of two-vehicle crashes for distracted driving. Liu, Y. et al. (TRBAM-23-04876) modeled

the motorized and non-motorized vehicle conflicts using Multiagent Inverse Reinforcement Learning approach.

Data and Analysis Related to Human Factors and Natural Factors such as Animal Crashes and Wildfire: This sub-category has 10 papers presented in the Annual Meeting.

Adavikottu, A. et al. (TRBAM-23-00026) modeled the effect of aggressive driver behavior on longitudinal performance measures during car-following scenario. Fu, C. et al. (TRBAM-23-01387) examined the effect of speeding patterns on speeding-related harsh decelerations for commercial drivers. Fu, C. et al. (TRBAM-23-02270) studied the driving behavior using GPS track data. Kavianpour, S. et al. (TRBAM-23-00590) evaluated the effectiveness of traffic calming zone in crash prone areas in Iran. Zare, A. et al. (TRBAM-23-04189) quantified the deer-vehicle collisions under-reporting on Minnesota roadways. Ahmed, I and M. Ahmed (TRBAM-23-02398) evaluated the safety effectiveness of wildlife-vehicle crash countermeasures using cross-sectional analysis and propensity scores-potential outcomes framework. Wong, S. and W. Troup (P23-20057) studied the effect of wildfires on highway safety. Kim, A. et al. (TRBAM-23-01063) studied the directional analysis of community wildfire evacuation capabilities. Mishra, S. et al. (TRBAM-23-03296) identified the key attributes of high-risk drivers in Canada. Wei, Z. et al. (TRBAM-23-00681) investigated the exposure-lag-response association of hourly weather and speed variation factors on rural freeway crash risk. Zhang, L. et al. (TRBAM-23-04963) investigated the random mutation of driving behaviors using wide-range vehicle trajectory data

Conflict-based Data and Analysis: This sub-category has 10 papers presented in the Annual Meeting.

Chauhan, R. et al. (TRBAM-23-02365) and Y. Miao et al. (TRBAM-23-02504), used rear-end conflicts to conduct safety analysis. Gore, N. et al. (TRBAM-23-03069), Q. Zheng, Q. et al. (TRBAM-23-04773), and Shi, X. et al. (TRBAM-23-03132) studied Trajectory-Based Safety Assessment. Patel, V. et al. (TRBAM-23-04799) developed a framework for estimating dynamic critical threshold for crossing conflicts at unsignalized intersections. Bidkar, O. et al. (TRBAM-23-04838) investigated the Impact of construction work-zone on rear-end conflicts by vehicle type under mixed traffic conditions. Paul, A. et al. (TRBAM-23-02612) modeled the influence of pet-types on crossing conflicts at urban unsignalized intersections in India. Paul, A. et al. (TRBAM-23-02622) conducted Before-After safety evaluation of geometric improvements at un-signalized intersections using traffic conflicts. Bhattarai, N. Et al. (TRBAM-23-04001) conducted safety analysis using roadside Lidar-based vehicle trajectory data.

Data and Analysis Specific to Covid-19 Period: This sub-category has 6 papers presented in the Annual Meeting.

Das, S. and A. Khodadadi (TRBAM-23-03152) conducted short-duration crash modeling to understand impact of operating speed on freeway crashes during COVID-19. Wang, M. and B. Tefft (TRBAM-23-01013) compared fatal crashes during the COVID-19 pandemic to forecasts

based on pre-existing trends. Papadimitriou, E. And A. Afghari (TRBAM-23-01036) used Global Macroscopic analysis to explore common attributes between the traffic safety 'pandemic' and the Covid-19 pandemic. Gong, Y. et al. (TRBAM-23-02610) investigated the impact of COVID-19 on traffic safety. Marshall, E. et al. (TRBAM-23-03136) used probe data to model speeding on limited access highway segments during the COVID-19 pandemic. Shahlaeegilan, A. et al. (TRBAM-23-04224) modeled the impact of the COVID-19 pandemic on speeding at rural roadway facilities using short-term speed and traffic count data.

Besides the above papers there were also the following doctoral student research conducted by the following students (Lectern Session 2117). There were no ABSTRACT available for these dissertations.

Student / School	**Presentation Number**	**Dissertation Topic**
Smrithi Ajit, Iowa State University	P23-21160	Evaluation of the Real-World Impacts of Crash Safety Ratings on Crash Severity
Asim Alogaili, University of South Florida	P23-21161	Statistical Models of Traffic Injury Severities: The Effects of Driver Nationality and the Time-of-day on Pedestrian Injuries
Carolina Baumanis, University of Texas, Austin	P23-21162	Enhancing Active Transportation Safely
Chris Byaruhanga, University of Birmingham, Edgbaston	P23-21163	Analysis of Crash/casualty Unit Costs Used in Road Safety Investment Appraisal Models
Morgan Dean, Virginia Polytechnic Institute and State University (Virginia Tech)	P23-21164	Applications of Event Data Recorder Derived Crash Severity Metrics to Injury Prevention
Md Rakibul Islam, University of Central Florida	P23-21165	Real-Time Safety Assessment Framework Incorporating Crash Likelihood, Severity, and Types Prediction, and Traffic Restoration Time Estimation
Asif Mahmud, Pennsylvania State University	P23-21166	Estimation of Crash Type Frequency Accounting for Misclassification in Crash Data
Nitesh Shah, University of Tennessee	P23-21167	Scrutinizing e-scooter Crashes and Crash Risk
Scott Shea, AECOM	P23-21168	Approach-level Statistical Road Safety Modeling for Estimating Road, Vehicle, and Occupant Characteristics on Crash Type and Injury Severity Outcomes at Intersections
Oliver Stover, Vanderbilt University	P23-21169	A Risk-based Data-driven Decision Framework to Improve Pedestrian Safety
Archana Venkatachalapathy, Iowa State University	P23-21170	Investigating the Relation Between User's Physiology and Traffic Environment to Identify Its Impact on Their Road Behavior

Special Session on Post Crash Care

Lectern Session 3081
Last, But Not Least: Post-Crash Care and the Safe System Approach
Convention Center, 146A

Lectern | PDH

Scott Parr, Embry Riddle Aeronautical University
Sponsored by: Section - Transportation Systems Resilience (AMR00)
Standing Committee on Regional Transportation Systems Management and Operations (ACP10)
Standing Committee on Transportation Safety Management Systems (ACS10)
Standing Committee on Traffic Law Enforcement (ACS30)
Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)

Authors	Seth LaJeunesse, University of North Carolina
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Session Number	Lectern Session 3081
Session Title	**Last, But Not Least: Post-Crash Care and the Safe System Approach**
Paper Number	P23-20928
Paper Title	**Safe Routes to School**
Abstract	No ABSTRACT available.

Authors	Dia Gainor, National Association of State EMS Officials
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Session Number	Lectern Session 3081
Session Title	**Last, But Not Least: Post-Crash Care and the Safe System Approach**
Paper Number	P23-20929
Paper Title	**State Emergency Medical Services**
Abstract	No ABSTRACT available.

Authors	Sean Parr
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Session Number	Lectern Session 3081
Session Title	**Last, But Not Least: Post-Crash Care and the Safe System Approach**
Paper Number	P23-20930
Paper Title	**Fire Sciences**
Abstract	No ABSTRACT available.

Poster Session 2036

What Can I Learn by Studying Vehicle Conflicts?
Monday, January 09 8:00 AM- 9:45 AM ET
Convention Center, Hall A
Poster

Karen Dixon, Texas A&M Transportation Institute

Sponsored by:
Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Ritvik Chauhan, Sardar Vallabhbhai National Institute of Technology Ashish Dhamaniya, Sardar Vallabhbhai National Institute of Technology, Surat Shriniwas Arkatkar, Sardar Vallabhbhai National Institute of Technology, Surat Said Easa, Ryerson University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-02365
Paper Title	**Safety Assessment for Rear-End Conflicts in Weak Lane Disciplined Traffic due to Dilemma Zone at Signalized Intersections**
Abstract	At the end of the green phase and during the amber phase of the signalized intersection, the traffic stream attains the highest speed. Traffic collisions of high severity occur when the speed of the vehicles is high. During the amber phase, the vehicles often face the dilemma in deciding to stop or go at the intersection. This creates rear-end conflict between the leader-follower vehicles near the stop-line during the amber phase. The probability of rear-end conflicts due to the dilemma is increased even more in weak lane disciplined heterogeneous traffic conditions observed in India. The present study aims to assess rear-end collisions during the dilemma period by analyzing the arriving vehicular trajectories during the amber phase at the intersections. A methodology for assessing the variation of safety aspects regarding rear-end conflicts due to the dilemma in decision-making during the amber phase is presented. The spatial variation and critical locations of the rear-end conflicts due to the dilemma are studied. The distance between the stop line and 40m (upstream of the stop line) is the most critical for weak lane disciplined traffic conditions. A binary logistic regression model is developed to estimate the probability of a rear-end conflict for an individual vehicle using multiple traffic parameters. Using the developed model, a speed restriction (limit) strategy is developed to mitigate the likelihood of rear-end conflicts. Another measure of providing a driver's decision-assistance system for enhancing proactive safety during the amber phase is also explored with positive results.

Authors	Yunting Miao, Tongji University, Jiading Ziliang He, Tongji University Dr. Ling Wang, Tongji University Qian Gao, Qingdao Academy of Transportation Sciences Wanjing Ma, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-02504
Paper Title	**Expressway Rear-end Conflict Pattern Classification and Modeling**
Abstract	The study of expressway rear-end conflicts is of great significance to analyze driving behaviors and improve traffic safety. However, research on the classification and modeling of conflict patterns is still lacking. This study aimed to explore conflict patterns and their relationship with influencing factors. The conflict data used in this study was extracted from a trajectory dataset collected from 7:40 to 10:40 a.m. on a section of the Shanghai Inner Ring. An improved K-Means algorithm, which can automatically obtain the optimal number of clusters, was used to classify the conflict events into six conflict patterns. The conflict patterns were interpreted from five aspects, including risk level, speed of risk-changing, risk-avoidance response, risk-avoidance attitude, and risk-avoidance action. Furthermore, a multivariate Poisson-lognormal (MVPLN) model considering spatial-temporal correlation was applied. The relationship between the independent variables and the number of each conflict pattern within the spatial-temporal unit was obtained. The Root Mean Square Error (RMSE) of MVPLN model was 0.81. Compared to univariate Poisson model, univariate negative binomial model, and univariate Poisson-lognormal model, MVPLN model improved 73.8%, 81.3%, and 29.6% in accuracy respectively. The results of this study can classify expressway rear-end conflict patterns and obtain the number of each conflict pattern with roadside traffic data. It helps to provide personalized driver assistance and targeted traffic control strategies.

Authors	Ninad Gore, Ryerson University: Toronto Metropolitan University Ritvik Chauhan, Sardar Vallabhbhai National Institute of Technology Said Easa, Ryerson University Shriniwas Arkatkar, Sardar Vallabhbhai National Institute of Technology, Surat
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-03069
Paper Title	**Comprehensive Traffic Conflict Assessment Framework Using Macroscopic Traffic Flow Variables: A Novel Method for Trajectory-Based Proactive Safety Assessment**
Abstract	Traffic dynamics at different traffic facilities and vehicle operations such as lane change, lateral shift, overtaking, and merging involve interaction with multiple vehicles in two dimensions (2-D) and, therefore, could result in a spectrum of traffic conflicts like rear-end and sideswipe conflicts. Consequently, it is imperative to account for the 2-D vehicle-to-vehicle interactions for analyzing traffic conflicts. The present study develops a comprehensive traffic conflict assessment framework using macroscopic traffic state variables. To this end, vehicular trajectories extracted for a midblock section of a ten-lane divided Western Urban Expressway in India are used. A macroscopic indicator termed "time spent in conflict (TSC)" is adopted to evaluate traffic conflicts. A two-dimensional framework based on the influence zone of the subject vehicle is proposed and employed to evaluate TSCs . The TSCs are modeled as a function of macroscopic traffic flow variables, namely, traffic density, speed, the standard deviation in speed, and traffic composition, using data-driven machine learning models. Three machine learning models, namely, random forest (RF), support vector machine (SVM), and eXtreme gradient boosting (XGB), were used to model TSCs. Results revealed that intermediately congested traffic flow conditions are critical for traffic safety. Among different machine learning models, the random forest (RF) model was observed as the best-fitted model to predict TSC based on macroscopic traffic variables. The developed machine learning model facilitates the monitoring of traffic safety in real-time.

Authors	Xueqian Shi, Purdue University Raul Pineda-Mendez, Purdue University Jose Thomaz, Purdue University Mario Romero, Purdue University Andrew P. Tarko, Purdue University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-03132
Paper Title	**Intersection Crash Expansion Factors Based on Probability Models Applicable to Traffic Conflicts**
Abstract	Traffic conflicts are the most promising surrogate measures of safety. Traffic conflicts collected in relatively short periods can be converted to the corresponding number of crashes in expected these periods. This paper attempts to develop a method of expanding a short-term crash frequency into the corresponding annual value – a safety estimate widely used in existing safety management systems. This conversion step is not sufficiently addressed in the past research. Thus, an important task of estimating the annual expected crash frequency based on a short-term estimate remains unanswered. Addressing this need is the research objectives and contribution of this study. Advanced statistical methods are successfully used to develop models to estimate the expected crash frequencies in annual and even short periods. The ratio of such two estimates can be seen as a crash frequency expansion factor. This study presents the modeling effort aimed at providing crash expansion factors applicable to different types of crashes at signalized and unsignalized intersections. Traditional and emerging data, such as traffic volumes, speeds, road characteristics, weather, and other features were collected and assembled at randomly selected 194 intersections. Then, the assembled data were used to estimate logistic models of hourly crash probability. The models were utilized to calculate the expansion factors for a selected existing intersection to illustrate the method and its results.

Authors	Qikang Zheng, Southeast University Yuxuan Wang, Southeast University Chengcheng Xu, Southeast University Pan Liu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-04773
Paper Title	**A Highway Conflict Prediction Framework based on Empirical Trajectory Data**
Abstract	This paper proposed a framework of highway conflict prediction method using empirical trajectory data and compared the contribution of traffic characteristic features extracted by different methods. Two data aggregating approaches were applied for traffic flow features extraction from the highD dataset in a 30 s time interval. Traffic flow features were categorized into virtual loop detector variables and target section variables. Logistic Regression models and XGBoost models were developed with the two types of variables and also with the entire variables. Four resampling methods (RENN, SMOTE, SMOTEENN, and SMOTETomek) were utilized for dataset rebalancing. SHAP technique was used to visualize the relationships between traffic flow features and conflicts. The results show that: (1) Models with only loop detector variables perform better than models with only target section variables; (2) With the help of SHAP, the relationship between traffic conflicts and traffic flow variables can be interpreted more visually. The proposed approach could be used to identify the hotspots with high conflict risks on highway.

Authors	Barun Das, Indian Institute of Technology, Kharagpur Madhumita Paul, Indian Institute of Technology, Kharagpur
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-04785
Paper Title	**A Conflict-based Rear-End Collision Prediction Model for Unsignalized Intersections under Mixed Traffic Using Machine Learning**
Abstract	Rear-end collisions at high-speed unsignalized intersections are one of the primary causes of crash fatalities. In recent years, Time to Collision (TTC) has been widely used for traffic conflict-based proactive safety evaluation of rear-end collisions. However, in developing countries like India, identifying rear-end conflicts utilizing a single time-based indicator could be pretty misleading because different vehicle classes have distinct dynamic characteristics and travel at varying speed. Consequently, this study used three proximal indicators: TTC, deceleration rate (DR), and relative speed of leader-follower vehicles to identify rear-end conflicts along intersections' approaches from two crash-prone unsignalized junctions located in the National Capital Region, India. Trajectory profiles of each leader-follower vehicle pair extracted using a semi-automated tool were used for estimating these indicators. Rear-end conflicts were further classified into "severe" and "non-severe" groups based on K-mean clustering and indicators' threshold values applicable to mixed traffic conditions. Results showed that the highest percentage of severe conflict was observed at a 4-legged intersection compared to a 3-legged one. Considering, different vehicle types, Light Motor vehicles (LMV) were majorly involved in severe conflicts. This study further developed crash-prediction models to predict rear-end collisions at high-speed unsignalized intersections using seven machine learning (ML) techniques. Among all, the Random Forest (RF) algorithm performed the best for both sites. Study outcomes suggested that despite the lack of reliable crash data in developing nation like India, the combination of proximal safety indicators and machine learning algorithms could create reliable rear-end collision prediction models without depending solely on historical crash data.

Authors	Vishal Patel, MS University: The Maharaja Sayajirao University of Baroda Pankaj Prajapati, MS University: The Maharaja Sayajirao University of Baroda Aninda Paul, SVNIT Surat: Sardar Vallabhbhai National Institute of Technology Shriniwas Arkatkar, Sardar Vallabhbhai National Institute of Technology, Surat Gaurang Joshi, Sardar Vallabhbhai National Institute of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-04799
Paper Title	**A Framework for Estimating Dynamic Critical Threshold for Crossing Conflicts at Unsignalized Intersections**
Abstract	Surrogate safety measures use thresholds to distinguish between critical and non-critical conflicts. The critical conflict thresholds explain the near-crash scenarios by its conflict estimation mechanism, and the thresholds also indicate the various possible severity levels by conflict-crash correlation. When the crash data is non-reliable, the established crash-conflict relationship will not represent the ground truth. In such cases, the present proposes an alternative framework for establishing the critical thresholds of conflicts for crossing conflicts at unsignalized intersections by using the survival function at two urban and one rural unsignalized intersection. PET is modeled using Random Intercept Weibull AFT models as a function of the accepted gap, vehicle speeds, and compositions. The random intercepts account for unobserved heterogeneity and provide a better model fit than the fixed parameter model. The survival model developed estimated the critical thresholds at the 50th percentile, with equal chances of survival and failure. The influence of the vehicular compositions was also considered, and the thresholds were estimated by weighted average. The present study established a threshold of 1 second for the rural and urban intersections. The developed framework is easy to understand and adopt and considers the conflict mechanism of PET to derive the critical thresholds.

Authors	Omkar Bidkar, Sardar Vallabhbhai National Institute of Technology Shriniwas Arkatkar, Sardar Vallabhbhai National Institute of Technology, Surat Gaurang Joshi, Sardar Vallabhbhai National Institute of Technology Said Easa, Ryerson University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-04838
Paper Title	**Investigating the Impact of Construction Work-Zone on Rear-End Conflicts by Vehicle Type under Mixed Traffic Conditions**
Abstract	Road transportation is a critical mode of transportation because of its mobility characteristics. Road construction work zones (WZ) are widespread on the roads because of the increased travel demand. Thus, studying traffic safety for the WZ and regular sections is necessary. In this study, traffic safety is analysed regarding the conflict probability at selected roads with WZ and without work-zone (WWZ) sections along the same road. Vehicular trajectory data for three traffic flow levels (free-flow, near capacity, and congestion) were extracted using the newly developed machine learning-based semi-automated trajectory extractor tool. Using MATLAB, the derived trajectory data from both sections were used to identify the leader-follower vehicle pairs. To avoid a collision, two surrogate safety measures were estimated to compute the rear-end conflicts: time-to-collision and deceleration rate to avoid a collision. Hence, the variation of the rear-end conflicts was further examined using the generalized extreme value theory. It is found that the conflict probability is more in the WWZ section than the WZ section, which may be attributed to the variation in speed and acceleration. It is also found that the conflict probability for WWZ and WZ sections is reduced as the angle between the two vehicles increases. The results of this study should help highway authorities to implement suitable safety measures to reduce conflicts and crashes in the work zones.

Authors	Yan Liu, Northeast Forestry University Rushdi Alsaleh, University of British Columbia Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	TRBAM-23-04876
Paper Title	**Modeling motorized and non-motorized vehicle conflicts using Multiagent Inverse Reinforcement Learning approach**
Abstract	Microsimulation models provide an efficient way for analyzing road users interaction behaviour and can be used to evaluate traffic safety and facilities' performance in mixed traffic conditions. However, limited studies have developed simulation models for studying the conflicts between motorized and non-motorized vehicles. This is due to the complexity and heterogeneity in the mixed traffic conditions and the difficulty in capturing the road users' avoidance maneuver mechanism. Therefore, this study aims to develop a novel multiagent simulation model to replicate road users (i.e., motorized and non-motorized vehicles) microscopic behaivour and their collision avoidance mechanisms in conflict situations. Traffic data from two study sites in China are extracted by means of automated computer vision techniques. The conflicts are modeled using the Markov Game framework. Road users reward functions are recovered by the multiagent adversarial inverse reinforcement learning approach. The multiagent Actor-Critic deep learning algorithm is applied to estimate road users optimal policies and predict trajectories. The results show that the multiagent simulation model led to high accuracy in predicting road users trajectories and avoidance mechanisms. Furthermore, results show that the modeled conflict indicator (time to collision, TTC) in the simulated trajectories highly correlates with that in the actual trajectories.

Poster Session 2037

Safety Implications of Risky Driver Behavior
Monday, January 09 8:00 AM- 9:45 AM ET
Convention Center, Hall A
Poster

Karen Dixon, Texas A&M Transportation Institute

Sponsored by:
Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Anusha Adavikottu, Indian Institute of Technology, Bombay Nagendra Velaga, Indian Institute of Technology, Bombay Sabya Mishra, University of Memphis
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-00026
Paper Title	**Modelling the Effect of Aggressive Driver Behavior on Longitudinal Performance Measures During Car-Following Scenario**
Abstract	Driving aggression is a major concern during car-following situations as it is closely associated with collision risk and crash severity. Despite the tendency for reckless driving actions and increased crash risk with the vehicle ahead, aggressive driver behavior remains unexplored. The present study aimed to investigate the effects of aggressive driver behavior (three driver categories: aggressive, moderately aggressive, and non-aggressive drivers) and drivers' tendency to aggressive stimuli (due to lead vehicle (LV) reckless driving) on car-following behavior. A sample of fifty-eight Indian drivers participated in a driving simulator study. The simulator design includes a lead vehicle dynamic maneuver with rapid accelerations and decelerations (at 1 m/s 2 , 1.5 m/s 2 , and 2 m/s 2). To investigate the drivers' risk-taking behavior, four longitudinal performance measures, including speed variability (SPV) from LV, speed recovery time (SRCT), and time spent tailgating, were analyzed during the LV acceleration stage using three separate generalized linear models (GLM). Further, to assess collision avoidance behavior deceleration adjusting time (DAT) was analyzed during the LV sudden deceleration stage using Weibull Accelerated Failure Time (AFT) analysis. The findings indicate that aggressive drivers decreased their SPV, SRCT by 25% and 18%, respectively, and increased tailgating time by 107% and 53% for aggressive and moderately aggressive drivers, respectively. The survival probabilities of non-aggressive, moderately aggressive, and aggressive drivers were 98.4%, 82.82%, and 69.63%, respectively, at 3 sec DAT. This study findings can be used in car-following models to enhance the model performance, and design interventions to improve safety.

Authors	Mohammed Moinuddin, UT Tyler: The University of Texas at Tyler Eric Proffer, UT Tyler: The University of Texas at Tyler Matthew Vechione, University of Texas, Tyler Aaditya Khanal, UT Tyler: The University of Texas at Tyler
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-00162
Paper Title	**Application of Machine Learning Models to Predict Driver Left Turn Destination Lane Choice Behavior at Urban Intersections**
Abstract	When there are multiple lanes to choose from downstream of a turning movement, drivers should choose the innermost lane so that drivers at other approaches of the intersection may make concurrent turning movements in the outermost lane(s). However, human drivers do not always choose the innermost lane, which could lead to crashes with other vehicles. Therefore, predicting human driver behaviors is vital in reducing crashes, as the need to share the roadways with automated vehicles (AVs) continues to grow. In this research, various machine learning models have been used to predict the left turn destination lane choice of human-driven vehicles (HDVs) at urban intersections based on several quantifiable parameters. A total of 174 subject vehicles were extracted and analyzed in Los Angeles, California, and Atlanta, Georgia, using HDV trajectory data from the Next Generation SIMulation (NGSIM) database. Five machine learning techniques, namely binary logistic regression, k nearest neighbors, support vector machines, random forest, and adaptive neuro-fuzzy inference system, were applied to the extracted data to predict the lane choice behavior of drivers. The random forest model showed the most promising results for the evaluated data with an F1 score of 0.71 for the unseen test data. This model may be programmed into: (i) AVs, in conjunction with sensors, to predict if an HDV is about to turn into the incorrect destination lane; and (ii) microscopic traffic simulation tools so that modelers can identify potential conflicts when HDVs do not select the appropriate destination lane.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-01387
Paper Title	**Examining the Effect of Speeding Patterns on Speeding-related Harsh Decelerations for Commercial drivers with Survival Analysis**
Abstract	Commercial drivers are usually observed with more speeding behaviors than other driving cohorts. Some of their speeding behaviors occurring under specific conditions may cause more hazards to the driving safety. Therefore, there is a need to verify the hazard caused by different categories of speeding. This study considers the speeding-related harsh decelerations (SHDs) as a surrogate measure of safety. The speeding distance ratios in different categories of speeding (i.e., speeding patterns) and several operational attributes are modeled as the risk factors. An accelerated failure time (AFT) model with the lognormal density is developed to relate the potential risk factors to the safe operation hours which refer to the average durations between the adjacent SHD events. The results indicate that speeding greater than 50% during daytime and speeding greater than 20% on peak hours/at night significantly decrease the safe operation hours on roads with a high-speed limit (≥60 km/h). In addition, it is challenging to maintain long safe operation hours when commercial drivers commit speeding at night on roads with a lower speed limit (≤50 km/h). Conversely, speeding less than 20% is not linked to the deterioration of driving safety in all the scenarios. As such, the countermeasures should be more effective at restricting the hazard-related speeding rather than speeding of all kinds.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-02270
Paper Title	**Relative Abnormal Driving Behavior Extraction of Drivers Based on GPS Track Data**
Abstract	With the development of vehicle networking technology, transportation manufacturers have generated a vast amount of GPS-based operating vehicle track data, which provides new possibilities and ideas for studying driver behavior that has the greatest impact on traffic safety. This paper proposes a method to extract data on the relative abnormal driving behaviors of drivers in different segments of the road, includingrapid acceleration, rapid deceleration, sharp turns, sharp lane changes and overspeeding, etc., through the analysis and mining of GPS track data, and then discover potential threats to urban traffic. For the behaviors of rapid acceleration, rapid deceleration, sharp turns, and sharp lane changes, factor analysis based on the characteristic parameters reduce the 16 characteristic parameters to a few principal component variables that contain explicit driving behavior information. Using this as an indicator to extract judgment thresholds from each relative abnormal driving behavior category through K-means clustering, respectively 2.45m/s2, -2.73m/s2, 15.23°/s, 23.12°/s ; The 90th percentile of the speed of each road segment is chosen as the judgment threshold for overspeeding behavior. Finally, the number of relative abnormal driving behaviors in each statistical road segment is then calculated. The results of the study are a reference for traffic management departments to pinpoint dangerous road sections in the urban road network.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-02800
Paper Title	**Analysis of risk factors for online car-hailing drivers based on LightGBM and SHAP**
Abstract	Within the past decade, online car-hailing services have gradually become popular in China, bringing great convenience to people's travel. However, with a large number of non-professional drivers becoming online car-hailing drivers, the number of traffic accidents involving online car-hailing has gradually increased. To address the serious safety situation of online car-hailing, this paper explores the influencing factors of driving safety from the perspective of drivers' individual characteristics. Based on the risky behavior data, the driver safety level is classified using the data envelopment analysis method. Then, based on the driver characteristics data (including personal attributes, personality traits and driving traits), a risk causation model is constructed using the Light Gradient Boosting Machine (LightGBM) model, and the model is analyzed with the help of the SHAP to find out the characteristic factors that affect driving safety.The results showed that the LightGBM model was able to accurately establish the link between drivers' individual characteristics and driving safety levels, with an accuracy rate of 80.53%, precision rate of 80.46%, recall rate of 81.11%, F1 value of 80.71%, and Auc of 0.913. Driving experience, working age, and age are the three characteristics that have the most significant effect on driving safety, and they play a positive effect, while the characteristics of high education and cooperative-oriented value orientation have negative effects on driving safety. The results of this study provide important information for online car-hailing companies to develop reasonable driver qualification regulations and improve the safety of drivers through targeted educational interventions.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-03151
Paper Title	**Application of Machine Learning Models and SHAP to Examine Crashes Involving Young Drivers in New Jersey**
Abstract	Motor vehicle crash is the leading cause of the death of teenagers in the United States. Young drivers have shown their propensity to get involved in crashes due to using a cellphone while driving, breaking the speed limit, and reckless driving. This study analyzed the motor vehicle crashes involving young drivers using New Jersey crash data. Specifically, four years of crash data (2016-2019) was gathered and analyzed. This study applied different machine learning methods such as Random Forest, Catboost, Light GBM, and XGBoost to estimate the types of injury severity. Some statistical evaluation parameters such as accuracy, precision, and recall scores were calculated to evaluate model performances. In addition, interpretable machine learning techniques like sensitivity analysis and Shapley values were conducted to assess the most influential factors' impact on young driver-related crashes. The results revealed that XGBoost performed better than Random Forest, CatBoost, and LightGBM models in crash severity prediction. Results from the sensitivity analysis showed that multivehicle crashes, angular crashes, crash at intersections, and dark-not-lit conditions had increased crash severity. A partial dependence plot of SHAP values revealed that speeding while in clear weather had a higher likelihood of injury crashes and multivehicle crashes at the intersection had more injury crashes. We expect that the results obtained from this study will help policymakers and practitioners to take appropriate countermeasures to improve the safety of young drivers in New Jersey. Keywords: Random Forest, Boosting Method, Young Driver Involved Crash, Sensitivity Analysis, Shapley Values, New Jersey

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	TRBAM-23-04954
Paper Title	**Lane-changing risk level prediction considering dynamic decision process: a deep learning method based on spatial-temporal series characteristics**
Abstract	Dangerous lane-changing (LC) behaviors have a high probability of accident occurrence. Identifying LC risk in advance can assist driver's LC decision-making and ensure driving safety. This paper aims to comprehensively analyze the risk evolution of the LC process and predict the LC risk. A lane change risk index (LCRI) is used to evaluate the risk of lane change decision (LCD) and lane change execution (LCE) process, and to analyze the risk evolution and causal relationship between the two stages by Random-forest-based SHAP methods. A Spatial-Temporal Transformer Model (STTM) is proposed to extract the temporal and spatial characteristics of the LC vehicle group in the LCD to predict the risk in the LCE. The results of the study show that: (1) LCD is a dynamic trade-off process, and drivers will always choose the time with the least risk to change lanes. (2) The influencing factors of LC risk are different between LCD and LCE. The risk in LCD is mainly caused by the interaction between following and leading vehicles in the target lane, while the risk in LCE is mainly caused by the interaction between leading and following vehicles in the original lane. (3) The STTM outperforms other algorithms in LC risk prediction, with a prediction accuracy of up to 91% for low- and medium-risk samples and 86% for high-risk samples. The results reveal the risk evolution during the dynamics of lane change, and are helpful for the traffic safety management and the design of Advanced Driving Assistance System (ADAS).

Poster Session 2045

Advances in Highway Safety Design

Monday, January 09 8:00 AM- 9:45 AM ET
Convention Center, Hall A
Poster

Jeffrey Shaw, Federal Highway Administration (FHWA),
Hermanus Steyn, Kittelson & Associates, Inc. (KAI),
Sarah Binkowski, HNTB Corporation

Sponsored by:
Standing Committee on Performance Effects of Geometric Design (AKD10)
Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Lu Ling, Purdue University Satish Ukkusuri, Purdue University Wenbo Zhang, Southeast University Jie Bao, Nanjing University of Aeronautics and Astronautics
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2045
Session Title	**Advances in Highway Safety Design**
Paper Number	TRBAM-23-02788
Paper Title	**Influencing factors for right turn lane crash frequency based on geographically and temporally weighted regression models**
Abstract	Right-turn lane (RTL) crashes are among the key contributors to intersection crashes in the US. Unfortunately, the joint effects of RTL geometric factors, intersection characteristics, and environmental factors on crash frequency are poorly understood. Taking Indiana state as a case study, this study investigates the traffic safety performance of the RTL based on multi-sources, including official crash reports, official databases, and the field study. Besides, we introduce the geographically and temporally weighted negative binomial model (GTWNBR) to capture the space and time instability in crashes. The new methodology addresses the spatiotemporal effects of the influencing factors on crash frequency by incorporating the space and time-varying crashes. The results confirm the superiority of the GTWNBR model for modeling overdispersed crash data. Moreover, we obtain several insights by associating the estimated parameters with road classes, localities, and counties. First, the exclusive RTLs are more likely to decrease crashes for larger urban counties than the smaller urban counties as defined by the Economic Research Service. Second, despite the exclusive RTLs decreasing 14% of crashes more than the shared RTLs on average, the exclusive RTLs on the county road are more likely to increase crash frequency than shard RTLs. Third, the interchange is more likely to decrease crashes in urban areas than in rural areas. Besides, the installment of traffic roundabouts increases crashes by 65% than intersections in the rural area of counties on average. The insights provide vital guidance to improve the safety performance of geometric configuration for RTLs and intersections.

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Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2045
Session Title	**Advances in Highway Safety Design**
Paper Number	TRBAM-23-04443
Paper Title	**A Machine Learning Approach to Quantify Effects of Traffic Control Devices and Geometric Design Features on Wrong-Way Driving Incidents at Partial Cloverleaf Interchange Terminals**
Abstract	The partial cloverleaf (parclo) interchange is the second most popular interchange type in the United States. Past studies suggest that the parclo interchange terminal is one of the most common initial entry points for wrong-way driving (WWD) crashes on the freeways. However, only a few studies have focused on quantifying the effects of wrong-way-related traffic control devices (TCDs) and geometric design features on WWD entries at this type of interchange. This study aims to apply two modern machining learning techniques to quantify the effects of various TCDs and geometric design features on recurring WWD incidents at parclo interchange terminals. Seventyfive parclo interchange terminals from 13 states were monitored to collect WWD incident data. Among the 75 monitored locations, 28 ramp terminals were found to have recurring WWD incidents, which experienced a total of 410 WWD incidents during the data collection period. The eXtreme gradient boosting (XGboost) and the Least Absolute Shrinkage and Selection Operator with logistic regression (Lassologistic regression), were applied to quantify the effects of various TCDs and design features on the occurrence of WWD incidents. The average accuracy of the fitted XGboost model was 80%, and the average accuracy of the fitted Lasso-logistic regression model was 78%. The fitted model was used to develop a network screening tool to identify the locations with potential WWD incidents. The results from this study can help state and local transportation agencies to improve the design features and TCDs to deter WWD incidents.

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Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2045
Session Title	**Advances in Highway Safety Design**
Paper Number	TRBAM-23-00590
Paper Title	**Effectiveness of Traffic Calming Zone in Crash Prone Areas: a Case Study in Iran**
Abstract	Speeding constitutes a major contributing factor of road crashes, especially in crash-prone areas. Although traffic calming has proven an active approach to promoting traffic safety in recent years, limited studies have focused on its use in crash blackspots and its effectiveness at different distances. In the present study, the effect of perceptual calming on the speed behavior of drivers of light and heavy vehicles near the crash blackspots of a crash-prone road in Iran was studied before and after the installation of road signs. To that end, an experimental system through IoT technology that records and collects vehicles' speeds was developed. The results of the study showed that the deceleration of vehicles is not the same for light and heavy vehicles. T-tests showed that changes in average speed start at distances of 50 meters before the sign location and continue to affect the behavior of light and heavy vehicle drivers up to distances of about 400 meters, although at a diminishing rate. The maximum deceleration was found to occur at initial distances of about 50 meters after the signs. The results of before-after evaluation indicate a longer effect on drivers of heavy vehicles than those of light vehicles. It can be concluded that the cautious behavior of drivers could continue up to a certain distance due to traffic calming, and thereafter, speed gradually increases. This finding re-iterates the high importance of traffic calming in crash-prone areas and also suggests that calming should be performed intermittently along consecutive crash-prone areas.

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Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2045
Session Title	**Advances in Highway Safety Design**
Paper Number	TRBAM-23-01004
Paper Title	**Evaluation of Low-Cost Countermeasures to Reduce Wrong Way Driving Incidents at Partial Cloverleaf Interchanges on Kansas Interstates**
Abstract	Wrong-way crashes on limited-access interstates continue to be a serious problem for state highway agencies and communities. These crashes are more likely than other traffic incidents to result in fatalities or serious injuries due to vehicles traveling at high speeds, and often on roadways with limited horizontal space and time to avoid a crash. Although a significant amount of research has been conducted to investigate wrong-way crashes, at-grade intersections, and proposed revised wording in the Manual on Uniform Traffic Control Devices (MUTCD), limited research has specifically investigated interchange geometry and whether it promotes wrong-way driving incidents. This study was designed to specifically investigate how partial cloverleaf interchange design affects wrong-way driving incidents and evaluate the effectiveness of low-cost countermeasures. Wrong-way driving incident data were collected using pneumatic road tubes at six study sites, including two control sites in Topeka, Kansas. Countermeasures to be evaluated include flashing LED wrong-way sign, lowered and oversized signs, relocation of signs, and reflective poles. Afterdata was collected once and will be collected again three months after installation using the same method described in the manuscript. The research study found low-cost countermeasures to be effective at some study sites by reducing the number and type of wrong-way driving incidents, but inconclusive or ineffective at other sites.

Poster Session 2098

Safety Effects of Roadway Characteristics and Treatments
Monday, January 09 10:15 AM- 12:00 PM ET
Convention Center, Hall A
Poster

Karen Dixon, Texas A&M Transportation Institute
Sponsored by:

Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Brendan Russo, Northern Arizona University David Smith, City of Henderson, Nevada Samuel Taylor, City of Scottsdale, Arizona
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-00224
Paper Title	**Analyzing the Safety Impacts of Left-In Left-Out Median Opening Treatments at Intersections/Driveways**
Abstract	Over the past few decades the City of Scottsdale, Arizona has installed left-in/left-out (LILO) median opening treatments at approximately sixty intersections/driveways; typically at three-leg intersections or driveways on arterials with medians where the minor leg is stop-controlled. The treatment is relatively unique and consists of a channelizing island with an acceleration length provided for vehicles turning left out of the minor road (these left-turning vehicles then merge with major road traffic). Although anecdotal evidence suggests the treatment has performed well, a data-driven safety evaluation had not been conducted. As such, this study presents the first comprehensive safety evaluation of the LILO median opening treatment, including development of crash modification factors (CMFs). Crash, traffic, and roadway data from 25 LILO treatment sites and 25 control sites were utilized to assess the overall safety impacts of the LILO treatment using a cross-sectional study design, and an Empirical-Bayes before-after analysis was conducted on a subset of treatment sites based on year of installation. Overall, the LILO median opening treatment was shown to be effective in reducing the frequency of angle and left-turn crash types, as well as the frequency of injury crashes. Additionally, the potential safety impacts of LILOspecific design features (e.g. signage, acceleration length, etc.) were explored.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-00643
Paper Title	**Investigating Unobserved Heterogeneity in Factors of Severe Crashes across Italian Two-lane Roads: Fixed and Random Parameters Approach**
Abstract	Developing Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) represent one of the leading approaches for determining how infrastructure-related features impact crash likelihood. In Italy, few works investigated the causes of crash occurrences on secondary road networks, i.e., minor rural, suburban, and urban two-lane roads, connecting the primary road network (freeways and highways) with local roads. Furthermore, few or no studies addressed the issue of unobserved heterogeneity of factors contributing to crash occurrence in Italy. To fill this gap and intending to provide an in-depth analysis of causes of Fatal and Injury (FI) crashes that occur on such networks, this paper proposes the development of SPFs and related CMFs across the whole 905-km secondary road network managed by the Tuscany Region Road Administration (TRRA). Incorporating geometrical, functional, and road context information, a Negative Binomial Regression with Fixed Parameters (FP-NBR) and Random Parameters (RP-NBR) to account for unobserved heterogeneity have been adopted for fitting 5,802 FI crashes that occurred within 2008-2016. Capturing unobserved heterogeneity affecting factors, outcomes show that the RP-NBR markedly outperforms the FP-NBR in terms of predictive performance. Conversely, the latter shows a higher level of interpretation; elasticities and CMFs indicate that traffic flow, carriageway width, driveway density (especially in urban areas), the density of intersections, and road area type are the most influential ones, whereas longitudinal gradient and road alignment have a weaker effect on FI occurrences. These SPFs and related CMFs can improve planning activity, as well as monitoring and maintenance duties of road authorities.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-00899
Paper Title	**Incorporating Road Network Connectivity in Neighboring Structures for Crash Prediction Models at Area Level**
Abstract	Spatial correlation models have been traditionally used in road safety to account for spatial effects resulting from unmeasured or unknown risk factors that induce spatial correlation between neighboring areas. In transportation, the interaction between neighboring areas is highly influenced by the number of roads that connect those areas and the importance of those roads. This paper proposes an approach in which the spatial interaction (and therefore the spatial correlation) between areas depends on the number of road connections between those areas and the importance of those connections. The results using districts in Costa Rica show that the inclusion of road network connectivity in the models of spatial correlation significantly improve model fit, even after accounting for model complexity using the DIC and WAIC. The inclusion of higher weights to national roads compared to municipal o local roads further improved model fit. The best three models in terms of posterior deviance, DIC and WAIC are those that give at least three times more weight to national roads compared to local roads. In terms of site ranking, those three models present similar results, which also highlights the consistence among those models.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-00920
Paper Title	**Evaluating the Safety Effectiveness of Textured Pavement and Speed Hump at Uncontrolled Midblock Crosswalk in Mixed and Heterogeneous Traffic Conditions**
Abstract	Pedestrian safety in an uncontrolled mid-block section is always a point of concern for road safety experts. Over-speeding of vehicles and the low yielding rate of drivers increase the risk for pedestrians in such settings. Traffic calming measures are suggested to reduce vehicles' speed and increase their yielding. This paper evaluated the effectiveness of two traffic calming devices, speed hump and textured pavement, to reduce vehicle speed and increase the safety of pedestrians. A calibrated and validated micro-simulation model was developed using Simulation of Urban MObility (SUMO) to simulate the field conditions. Pedestrian safety is compared in different scenarios with the help of time-to-collision (TTC), modified time-to-collision (MTTC), deceleration rate to avoid the collision (DRAC), and crash index (CI) as surrogate safety measures. Compared to the baseline, textured pavement reduced the speed of vehicles by 51% and increased their time loss by 70%, while for the speed hump, the speed reduction was 44%, and the increase in time loss of vehicles was 47%. In the case of textured pavement, the percent share of events when the value of TTC and DRAC exceeds the threshold value reduces to half, while for speed hump, the percent share reduces by one-third only. The results show that the textured pavement is more effective in reducing pedestrians' speed and increasing pedestrians' safety than the speed hump. These insights could be used as guidance when designing locations with restricted vehicle speeds.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-01078
Paper Title	**Exploring Association Knowledge in Single-Vehicle Roadway Departure Crashes on Curved Segment of Rural Two-lane Highways**
Abstract	Curved segments are associated with a disproportionate number of fatal and severe crashes, particularly on rural two-lane (R2L) highways. In 2019, R2L roadways accounted for around a quarter of roadway departure (RwD) crashes in Louisiana, with more than half of the R2L fatal crashes occurring on curved segments. Therefore, exploring the factors associated with RwD crashes, particularly those occurring in curved segments, is critical. The objective of this study is to identify the hidden patterns of single-vehicle roadway departure (SV-RwD) crashes on R2L curved segments in Louisiana using fatal and injury crash data (2008-2017) collected from the Louisiana Department of Transportation and Development. To achieve this objective, this study utilized Cluster Correspondence Analysis (CCA), a robust joint dimension reduction and clustering method for handling high-dimensionality and multicollinearity. Based on the cluster validation measures, the study identified five clusters with specific traits, including alcoholimpaired male drivers with no seatbelt usage, young (15-24 years old) female drivers' crash involvement in cloudy weather conditions, animal-involved crashes in rainy weather conditions, crashes occurring on hillcrest locations under cloudy weather conditions, and crashes in the darkwith-streetlight condition with higher traffic volume. Furthermore, young (15-24 years old) female drivers are identified in most clusters, implying that this specific age group of female drivers requires special attention when dealing with SV-RwD collisions on R2L curved segments. Policymakers can utilize the findings of this study to develop data-driven policies and improve safety on R2L curved segments.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-01580
Paper Title	**Safety Performance of Signalized Median U-Turn Intersections**
Abstract	Alternative intersection designs can offer safety and operational benefits with potentially lower costs than conventional intersections when implemented in the proper setting. The Federal Highway Administration has previously identified a subset of alternative designs called reduced left-turn conflict intersections as a proven safety countermeasure. Median U-turn intersections (also known as “Michigan lefts”) are one such design that accommodates all left-turn movements via directional Uturn crossovers within the median. Prior work has consistently shown that median U-turn intersections can provide superior safety performance when used in the appropriate conditions. This study evaluated historical traffic crashes and volume data at 167 signalized intersections throughout Michigan. This included the collection of data for 82 median U-turn sites and 85 reference group sites to estimate safety performance functions and crash modification factors for conversion of conventional intersections to signalized MUTs. Several design features of signalized MUT intersections were identified as having a significant impact on safety performance, including the distance to crossovers from the main intersection, the length of weaving areas, the number of signalized crossovers, and the number of storage lanes. Crash modification factors (CMFs) of 0.656 for fatal and injury crashes and 0.684 for property damage only crashes were developed for the conversion of conventional signalized intersections with undivided approaches to a MUT design. While CMFs specific to converting a conventional signalized intersection with a divided major approach suggest increases in both fatal and injury crashes (1.423) and property damage only crashes (1.668), considerable reductions were observed in potentially severe crash types.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-01672
Paper Title	**Evaluating the Safety Benefits of a Smart Tolling System on Freeways Applying Improved Calibration Method**
Abstract	This study proposed the crash modification factor (CMF) estimation technique using the calibration method to analyze the safety improvement effect of installing the open road tolling (ORT). Although the OPT system in South Korea has recently been introduced in many highway tollgate sections, it is impossible to collect statistically significant crash data samples due to a short operating period as an initial stage of introduction. Therefore, in this study, CMF was estimated by applying the calibration method to the research results conducted in Highway Safety Manual (HSM) and Florida. The calibration method proposed by HSM was used as the basic method, and a new calibration method was developed and applied based on the fact that the relationship between the observed and predicted crashes was not a simple linear relationship. The CMF of ORT installation was estimated by applying the calibration method, and the safety improvement effect was 43% to 51%. In addition, among the proposed calibration functions, the function using the quadratic model was found to be the best in terms of prediction accuracy. This study is meaningful in that CMF was estimated using the calibration method in situations where the sample size was insufficient. In addition, it has a research contribution in that it utilizes new functions to predict nonlinear relationships that are difficult to calibrate with simple linear relationships in existing calibration methods.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-01862
Paper Title	**The Future of Parking Safety**
Abstract	Every trip is associated with parking at its origin and at its destination and thus parking facilities are considered one of the main components of transportation infrastructure. However, parking safety research is limited, and little is known about the incidence of crashes, injuries, and fatalities that occur when vehicles park. Parking facilities are intense driving environments that require both drivers and pedestrians to pay close attention. Slower speeds in parking facilities give people a false sense of safety. This situation is clearly reflected in non-motor traffic crash statistics, as most of them occur in parking facilities. With the advent of emerging vehicle technologies, the parking experience is expected to improve significantly. Car manufacturers have been working on the development of self-driving and self-parking features. The goal of this research is to explore parking facility design and operational change recommendations to improve parking safety in the advent of vehicle self-parking features. This study identified potential design changes and vehicle self-parking market penetration scenarios to improve the safety. Expected changes of the parking and street design were assessed in terms of the reduced number of conflicts for vehicles and pedestrian exposure for pedestrians using microsimulation techniques. Comparing the existing conditions, self-parking cars can reduce the number of conflict points by 7% to 45% with the market penetration rates of 25% and 75% respectively. The changes were consistent through different parking types. The reduction in pedestrian-vehicle exposure ranges from 14% to 72% with the recommended layout improvements considering the different penetration rates.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-01882
Paper Title	**Predicting Crash Occurrence at Intersections in Texas: an Opportunity for Machine Learning**
Abstract	This paper studies the frequency of traffic crashes at intersections across Texas by employing zero-inflated negative binomial (ZINB) models using the MLE method, and various tree-based ML methods, namely random forests (RF), XGBoost, LightGBM, and Bayesian additive regression trees (XBART) to predict the frequency of crashes at intersections. Official records of traffic crashes from 2010 to 2019 were used in addition to the roadway inventory database and other sources to map more than 700k intersections. The performances of the MLE and ML models were computed and compared, using R-square and Root Mean Square Error as the metrics. Results indicated that RF had the best model performance in predicting crash frequency. Resampling the data led to better prediction performances for all the models and was useful in dealing with highly imbalanced crash data. Road design variables had the highest feature importance on the ML models to predict crash occurrence. Sensitivity analysis showed that the effects of several predictors have different directions across different ML models making interpreting their contribution in predicting crash occurrences difficult. The findings suggest that machine learning models are better at predicting crash occurrences, whereas statistical models are better at investigating the contributing factors of a crash event.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02149
Paper Title	**Crash Predication on Expressway Incorporating a Feature-weighted Oversampling Approach Based on Abnormal Driving Behavior**
Abstract	Real-time crash prediction helps identify and prevent traffic crashes from occurring. For years, various real-time crash prediction models have been investigated to provide effective information for active traffic management. But most previous studies have been based on traffic flow data of expressways to predict the real-time crash, and the impact of abnormal driving behavior on crash prediction has been less considered. Before crash prediction modeling, we need to take into account the class imbalance of the data. Existing processing methods such as SMOTE, assume that the weights of feature parameters are the same when defining the neighborhood of minority samples, which is not valid for most machine learning methods. This study assumed that the model performance in the presence of noisy or redundant features can be improved by changing the feature weights in the data processing method. A feature-weighted minority sample oversampling technique (FWMOTE) was proposed, and incorporating machine learning methods to conduct real-time crash prediction research based on the abnormal driving behavior data on expressways. The results show that the data processing method proposed in this paper achieves better prediction results than classical oversampling methods. It is also confirmed that some abnormal driving behaviors can have a significant impact on traffic crashes. Through this study, new insights have been gained in the field of class-imbalanced data processing, a development in the use of abnormal driving behavior data for traffic crash prediction on expressways and support has been provided for active traffic safety management.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02254
Paper Title	**Safety Evaluation of Offset Left-Turn Lanes and FYA Signals at Signalized Intersections on Multi-lane Divided Highways in Alabama**
Abstract	The present study conducted an Empirical Bayes (EB) before-after analysis to investigate the combined effects of offset left-turn lanes and Flashing Yellow Arrow (FYA) signals implemented at signalized intersections on multi-lane, divided highways in Alabama. A total of thirty-five signalized intersections were selected for the EB safety analysis. Among them, thirty intersections were classified as a reference group and five were classified as a treatment group. The reference group includes intersections which have not undergone any left-turn treatments from the period of 2010 to 2020, while the treatment group includes those improved with offset left-turn lanes and FYA signals implementation concurrently during years in that period. Safety Performance Functions were developed with data collected at reference group intersections to predict crashes at such intersections under a no treatment scenario. A study focus was then given to understanding the change in crash frequency before and after the combined treatments for the treatment group intersections, using the EB method. Results show that the combined left-turn treatments could reduce total and left-turn crashes by 30% (CMF = 0.70) and 43% (CMF = 0.57), respectively. It is important to note that such huge crash reduction effects are due to the combined effect of both offset left-turn lanes and the FYA signals implementation, not because of a single treatment.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02343
Paper Title	**Safety Analysis of Major Arterials: An Investigation into the Safety Impacts of Road Network Characteristics**
Abstract	With the construction of high-density roadway networks, neither macro- nor micro- level safety analysis can provide a comprehensive interpretation of the safety impacts of network characteristics. This study employed a meso-level analysis unit which combined the intersections with adjacent segments to investigate the safety impacts of intersection spacing and network connection characteristics. Three main intersection spacing characteristics, including the density of intersection spacing (DOIP), the standard deviation of intersection spacing (SDIP), and the variation of intersection spacing (VOIP) were extracted to represent the interaction between arterials in the network. Additionally, this study introduced the concept of hierarchical differences to quantitatively analyze the safety effects of road connection with different functions. To illustrate the hierarchical structure of the model, a two-level hierarchical negative binomial conditional autoregressive (HNB-CAR) model was adopted to examine the safety effects of network characteristics at the meso level. The results showed the existence of unobserved heterogeneities among the selected arterials. DOIP was negatively associated with crashes, while SDIP and VOIP were found to have positive effects on crash occurrences. Combining all the three intersection spacing characteristics, long and uniform signal spacing could achieve more efficient safety improvement. As for network connection, the units with moderate connection were found to have more crashes than those with appropriate connection, while the meso units with the highest hierarchical difference instead had fewer crashes. The results are expected to provide suggestions on potential safety hazard screening and crash prevention.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02345
Paper Title	**Statistical Analysis of Traffic Crashes on the Sections of Mountainous Freeway Tunnels**
Abstract	Tunnels on mountainous freeways are affected by the abrupt changes in brightness, complex geometrical alignments, heavy traffic flow, bad weather, and other factors, some of which contribute toward tunnels having more traffic crashes than other sections of the freeway. Previous research has given limited attention to tunnel length and heterogeneity in the sections of the tunnels, such as at the tunnels' entrances and exits. This paper utilizes 36 tunnels of Guidu Freeway in China's Guizhou Province as spatial entity, collects data on crashes and their influencing factors over two years (2020-2021), constructs a negative binomial panel random effect model, and analyzes single-vehicle crashes, multi-vehicle crashes and total crashes. The results show that: 1) multi-vehicle crashes occur in most of the tunnel sections, 2) crashes are more likely to occur in long tunnel sections, 3) the crash risk from the tunnel entrance zone to the mid zone is higher than other areas of the tunnel, 4) the crash risk is higher for circular curve/easy curve sections than for straight sections in the flat curve type, 5) the crash risk is higher for downhill and concave curve sections than for flat sections in the vertical curve type, 6) the crash risk increases with heavy traffic flows and adverse weather conditions, and finally 7) the crash risk increases as road surface skidding resistance and ride quality decrease. These findings can provide theoretical support for engineering improvement and specification revision formulation of freeway tunnel sections, especially in mountainous areas.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02612
Paper Title	**Investigating and Modeling the Influence of PET-Types on Crossing Conflicts at Urban Unsignalized Intersections in India**
Abstract	Un-signalized intersections in India witnessed the maximum number of crashes and fatalities in 2019. The nature of the crash investigation in India is reactive. Further, the crash records are unscientific, and critical details are missing. Therefore, a proactive approach using surrogate safety measures is more promising and prudent in analyzing traffic safety. The present study investigates and models crossing conflicts at unsignalized intersections under mixed traffic conditions. Traffic video data for fourteen un-signalized intersections (eight un-signalized three-legged intersections and six un-signalized four-legged intersections) were collected. The crossing conflicts were identified and characterized based on the values of post encroachment time (PET). The observation revealed the existence of both positive and negative PET values. The physical interpretation of positive and negative PET values of risk and crash risk is investigated and discussed. The results revealed that crossing conflicts with negative PET values are riskier and more unsafe than crossing conflicts with positive PET values. Therefore, the crossing conflicts with positive and negative PETs were modeled separately. The positive and negative PET-based critical crossing conflicts are modeled as a function of traffic flow and intersection geometry-related characteristics using truncated negative binomial regression under a full Bayesian modeling framework as an essential practical outcome. The modeling results revealed that the volume and traffic composition of the offending and conflicting stream and intersection geometry significantly influence the number of positive and negative PET-based critical crossing conflicts.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02622
Paper Title	**Before-After Safety Evaluation of Geometric Improvements at Un-Signalized Intersections using Traffic Conflicts**
Abstract	The use of traffic conflicts for before-after evaluation is widely recognized and appreciated because of the problems associated with the historical crash records. The present study presents a traffic conflict-based before-after safety evaluation of intersection geometry improvement schemes at un-Signalized intersections. Traffic video data for two un-signalized intersections were collected under fair weather conditions during the before and after periods. The crossing conflicts are identified using PostEncroachment Time (PET). The safety benefit of the intersection geometry improvement scheme is evaluated by adopting the Extreme Value Theory (EVT) based safety assessment framework. The safety benefits were quantified by computing the changes in (a) crash risk and the number of theoretical crashes and (b) the Probability of Critical Crossing Conflicts (PCCC). Compared to the before condition, a reduction of 33.43% to 57% in crash risk for the after the condition was noted. Therefore, the geometric improvements had improved the safety at un-signalized intersections. The study proposed a framework for evaluating the safety benefits of geometric improvement schemes using a before-after perspective. Traffic conflicts can be used to evaluate the safety benefits of geometric improvements in the absence of a historical crash database.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02868
Paper Title	**A comparative study on heterogeneous effects of different contributing factors on crash risk prediction for freeway segment**
Abstract	Crash risk analysis have been conducted to investigate the crash mechanisms and analyze the contributing factors from the aspects of traffic operation and geometric design perspectives. Previous studies have investigated the heterogeneous effects of geometric or traffic operational characteristics on crash risk estimation. However, few studies considered the heterogeneity of geometric design and traffic operational characteristics at the same time, and which heterogeneity will lead to higher crash risk prediction accuracy was rarely discussed. Using Yongtaiwen freeway rear-end crashes, traffic flow, and road alignment data, this study focused on investigating the heterogeneous impact of different contributing factors on crash risk. Aiming at investigating the heterogeneous effects of geometric characteristics on crash risk, a Latent Class Analysis (LCA) method is proposed to classify the samples. Aiming at studying the heterogeneous effects of traffic operational states on crash risk, a Latent Profile Analysis (LPA) method is proposed to classify the samples. Based on the classified homogeneous subgroups of crashes, logit models were used to study the relationship between microscopic traffic flow variables and crash risk. In addition, a latent class logit (LCL) model was also developed to simultaneously analyze the heterogeneous effects of geometric design features and traffic operational states on crash risk. The modeling results showed that the LCA + logit model has better classification results and prediction performance than the LPA +logit model or the LCL model, demonstrating that the heterogeneous effect of geometric design characteristics of the road segment had better interpretability and prediction accuracy in crash risk analysis.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-04189
Paper Title	**Quantifying deer-vehicle collisions under-reporting on Minnesota roadways: Preliminary data collection**
Abstract	Deer-vehicle collisions (DVCs) have been recognized as a significant risk for safety on Minnesota roadways. Thereby, operational strategies based on real-world data are necessary to mitigate the probability of having a DVC. Most DVCs are unreported, probably because many DVCs have minimal property damage, and drivers decide not to report the collision. Therefore, the total number of DVCs is never known. In this work, we collected roadkill deer data in a six-month survey from November 2021 to the end of April 2022 to estimate the number of unreported DVCs in and around the Duluth area and some selected roadways in Minnesota. An analysis of the DVC reporting rate is presented based on a comparison between historic DVCs and observed DVCs during the survey. The results indicate that drivers are more likely to report a DVC in regions with developed land, on roadways with higher traffic volume, and broader road segments and divided highways such as federal highways where there is less expectation of a deer collision occurring. The methodological approach in this study can be applied more broadly across Minnesota or other parts of the US. Furthermore, the results of DVC preliminary analysis and mapping of DVCs can predict hot spots for DVCs and areas that would benefit from immediate action to reduce DVCs.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-04250
Paper Title	**Safety Performance Evaluation of Flashing Yellow Arrow: Time-of-Day vs 24-hour Operations**
Abstract	The flashing yellow arrow (FYA), as the permissive left-turn indication, has been widely implemented to mitigate driving confusion caused by the permissive steady green indication. The selection of an appropriate FYA operation type, however, remains an open-ended question as few studies have evaluated the safety effectiveness of FYA under different FYA operation types, i.e., 24-hour, time-of-day (TOD), and switching from 24-hour to TOD. Moreover, since FYA has been typically used at intersections with a single left-turn lane, its safety effectiveness at intersections with dual left-turn lanes has not been well investigated. To bridge these gaps, this paper focuses on evaluating the safety effectiveness of FYA at intersections with varying numbers of left-turn lanes under different operation types and examining whether the FYA operation type switch affects safety performance. Empirical Bayes (EB) before-after studies are conducted for 24-hour, TOD, and switching from 24-hour to TOD FYA operation types using multivariate adaptive regression splines (MARS) models in comparison with traditional negative binomial (NB) models. Safety performance functions (SPFs) are developed for different combinations of crash types and a different number of left-turn lanes. Results show that for intersections with either a single left-turn lane or dual left-turn lanes, 24-hour and TOD FYA operation types reduce crashes by 8.76% to 50%. However, intersections with dual left-turn lanes experience a 31.2% increase in total crashes when switching from 24-hour to TOD FYA operation type, while intersections with a single left-turn lane see a 60% decrease in rear-end crashes.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-05023
Paper Title	**Safety Assessment of Suburban Type Arterial Roadways: New Findings Using Heterogeneity Models**
Abstract	The design elements of a roadway significantly impact its safety performance by influencing how road users access the facilities. Traditionally, these designs focus on the needs of the most prevalent road user group, such as drivers, while minimally accommodating other users, such as pedestrians and bicyclists. In recent years, specific roadway type has become particularly confounding for safety professionals, even as gains are made across much of the road network: the suburban-type arterial. These medium-speed roadways with wider right-of-way prioritize high mobility for high vehicular traffic volume and low mobility for low pedestrian and bicyclist traffic volume. Although such a design would meet minimal safety requirements, the increased vehicle speeds and high amount of traffic could make the situation for all road users far more dangerous. This study is conducted to understand better the safety performance of suburban-type roads (STR) exhibiting these roadway characteristics. The correlated random parameters ordered probit model is used to analyze the severity of police-reported crashes at STR. The results of this study can be used to understand the contextual scenarios of crashes at STRs and to identify factors influencing the injury severity of such crashes. The findings would help decision-makers create workable plans to reduce the severity of crash injuries and improve safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-05104
Paper Title	**Effectiveness of Flexible Poles in Safety Improvement of Horizontal Curves**
Abstract	Quantifying the effectiveness of a safety treatment is a critical aspect of systematic road safety planning. However, a review of the existing research has proven that effective intervention in the developed world may not be equally successful in the LMICs, especially when the social, cultural, and economic conditions are different. As a result, realistic and relevant changes are required for LMICs to use countermeasures that worked in the developed world. Therefore, documentation of systematic reviews of the evidence for LMICs is vital for identifying and quantifying the effects of interventions. In the present study, an attempt was made to document the effectiveness of flexible poles on horizontal curves with restricted sight distance. In this regard, a quasi-experimental design with control groups was adopted with 12 high crash locations on the two-lane undivided highway in eastern India. The systematic safety planning highlighted instances of a high share of head-on crashes and overtaking at high speed on the curves. The insights from the safety study suggested the installation of flexible poles along the centreline of the curve. The observations suggested that although flexible poles can be used to segregate traffic from opposing directions and restrict overtaking at sites without adequate sight distance but for traffic with a high share of two-wheelers, they may not be as effective. As a result, the installation of flexible poles should also be accompanied by shoulder rumble strips or edge line rumble strips to discourage two-wheelers from overtaking from the left.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02398
Paper Title	**Evaluating Safety Effectiveness of Wildlife-Vehicle Crash Countermeasures using Cross-Sectional Analysis and Propensity Scores-Potential Outcomes Framework**
Abstract	Wildlife-vehicle crashes (WVC) pose a significant threat to not only wildlife populations but also highway safety. The most expensive WVC countermeasures include crossing structures with fencing, while the least expensive countermeasure is the wildlife warning signs. This study is aimed at estimating the crash modification factors (CMFs) for these two countermeasures using cross-sectional analysis and propensity scores-potential outcomes approach. Propensity-scores matching approach is a viable method for identification and selection of a suitable reference group. Two types of WVC data are used in this study: carcass removal data and traditional crash data. A random-intercept Bayesian approach was utilized to incorporate the contributing factors representing traffic volume, roadway geometry, weather conditions, and unobserved heterogeneity due to between-site variance. The No-U-Turn Hamiltonian Monte Carlo sampling technique was employed due to its high efficiency in handling complex models.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02511
Paper Title	**Safety Evaluation of High Friction Surface Treatment at Signalized Intersections in British Columbia: Automated Video-based Traffic Conflict Analysis**
Abstract	High Friction Surface Treatment (HFST) is a pavement treatment intended to reduce crashes at locations with friction-demand issues. The increased pavement friction reduces tire skidding during speed/direction changes and helps motorists maintain better control in dry and wet driving conditions. Typical crash types targeted by HFST are road-departure at horizontal curves or rear end at off-ramps and intersection approaches. This study aims to quantify the safety effectiveness of HFST at signalized intersection approaches using automated video-based traffic conflict analysis. The frequency and severity of rear-end conflicts were extracted from 147 hours of video data collected at two signalized intersections in British Columbia, Canada, where the HFST has been implemented by the Ministry of Transportation and Infrastructure. The video data were collected before and after the HFST implementation and classified into a treatment group and a comparison group. While accounting for traffic volumes, the safety effectiveness evaluation included two methods: before-after evaluation and cross-sectional evaluation. The results indicated that the HFST led to a significant decrease in rear-end vehicle-vehicle conflicts. Specifically, the before-after evaluation and the cross-sectional evaluation showed a reduction of 38.7% and 36.5% in rear-end conflicts, respectively.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02706
Paper Title	**SNOWFLAKE SCHEMA BASED DATA WAREHOUSE FOR ANALYZING CRASH, CITATION, AND WARNING TRAFFIC SAFETY RECORDS**
Abstract	Decision-makers in traffic agencies and police departments require a wide variety of high-quality data to support traffic safety problem identification, program implementation, and result evaluation. But analyzing such a vast amount of data in the traditional transactional database sometimes faces challenges. Because of the complex table structure, a great number of table joins, and constrained to a single application, performing the analytic queries in the database is difficult and the result only contains static and one-time lists. However, the data warehouse technique offers the benefits of large data storage and multidimensional analysis for any number of applications, which would be appropriate to utilize for traffic safety related execution and assessment. This study describes the design and implementation of a Wisconsin traffic safety data warehouse for analyzing traffic safety related crash, citation, and warning records to support the context of the State of Wisconsin's Traffic Records Coordinating Committee (TRCC) led traffic safety records improvement program. The design of the data warehouse is determined by the selection of data source, description of the data flow architecture, and design of the data warehouse schema. The snowflake schema design has been adopted to integrate multidimensional data sources because it has the ability to address different traffic safety problems with rare changes. The suitability and validity of this data warehouse design would benefit traffic safety analysis research and interest to other state agencies.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	TRBAM-23-02971
Paper Title	**Crash Reduction Analysis of Friction Improvement Surface Treatments in Georgia**
Abstract	Crashes on curves represent 25 % of all roadway fatalities the vast majority of these fatalities are roadway departures. An effective treatment to mitigate roadway departures are friction improvement surface treatments (FISTs). The Georgia Department of Transportation (GDOT) has implemented friction improvements on more than 400 curves. Before this study, there were no crash modification factors (CMFs) for these friction improvements in Georgia. Thus, the objective of this study was to analyze the crash reduction effectiveness of three FISTs in Georgia. These materials include phonolite, lightweight aggregate (LWA), and high friction surface treatment (HFST, or calcined bauxite). This objective was achieved by using naïve Bayes and empirical Bayes methods to develop CMFs. The calculated CMFs show that HFST significantly reduces curve crashes with an overall CMF of 0.672. HFST is the only material implemented where the calculated CMFs provided significant evidence for crash reduction. Crash types that were significantly reduced include single vehicle, those labeled as negotiating a curve, and wet road. The CMF was then modeled as a function of the roadway environment. It was found that significant curve site characteristics that led to a lower (i.e., more effective) CMF were 1) prior crash frequency, 2) absence of an intersection, and 3) lower traffic volumes. These findings are used to display CMFs for different site characteristics and can be used to strategize implementation of HFST on curves in the future. It is recommended to perform life cycle cost-integrated crash reduction benefit cost analyses.

Poster Session 2160

Incident Response and Roadside Safety
Monday, January 09 1:30 PM- 3:15 PM ET
Convention Center, Hall A
Poster

Scott Parr, Embry Riddle Aeronautical University

Sponsored by:
Section - Transportation Systems Resilience (AMR00)
Standing Committee on Regional Transportation Systems Management and Operations (ACP10)
Standing Committee on Transportation Safety Management Systems (ACS10)
Standing Committee on Traffic Law Enforcement (ACS30)
Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)

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Session Number	Poster Session 2160
Session Title	**Incident Response and Roadside Safety**
Paper Number	TRBAM-23-04349
Paper Title	**The Relationship between Traffic Incident Responders' Safety Experience and Countermeasure Adoption: A Machine Learning Study Based on the National Survey**
Abstract	Working with the Emergency Responder Safety Institute (ERSI), this study conducted a national responder safety survey to gather first responders' working experience, training background, and behaviors as well as opinions on adopting safety countermeasures and protocols. The survey received 1,757 responses. With the survey data, this study employed machine learning to identify the correlates of first responders' safety experience being involved in incidents such as near-miss and struck-by incidents. The objective of this study is to establish the relationship between firster responders' safety experience and their countermeasure adoption behaviors. Four machine learning models were developed and the average marginal effects of independent variables (e.g., adopted countermeasures) were calculated to quantify the relationship between factors and experiences of struck-by and near-miss events. Results showed that young responders or those from the tow and recovery department and department of transportation are associated with a higher probability of experiencing struck-by incidents. The use of recommended countermeasures can reduce the probability of being struck. These countermeasures include high visibility clothing or safety uniforms and emergency vehicle lighting. The findings provide suggestions to strengthen the adoption of some countermeasures and safety protocols that are effective in protecting first responders on roadways.

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Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Session Number	Poster Session 2160
Session Title	**Incident Response and Roadside Safety**
Paper Number	TRBAM-23-04406
Paper Title	**Incident Response Personnel's Compliance and Non-compliance to Recommended Safety Countermeasures and Protocols**
Abstract	In this study, the research team conducted a national survey among incident response personnel to assess compliance and non-compliance with recommended safety countermeasures and protocols. Incident response personnel include police, fire, emergency medical service providers, roadside assistance providers, tow truck operators, mobile mechanics, department of transportation and public works, and safety service patrol operators. The survey was administered through Qualtrics. Emergency Responder Safety Institute (ERSI) and AAA Foundation for traffic safety circulated the survey among its members who are incident response personnel. A total of 1,757 responses from incident response personnel were received. Most survey participants received Transportation Incident Management (TIM) responder training. Responders from towing and recovery industry have higher odds of not receiving training, and not being aware of training programs seems to be the prominent reason for not obtaining training. These agencies may not have adequate resources such as time, money, effort, and staffing to provide sufficient training. High visibility and emergency vehicle lighting were the two most frequently used countermeasures by the responders. Complacency is the common reason responders do not use high-visibility clothing. Advance warning signs and traffic cones were not frequently used.

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Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Session Number	Poster Session 2160
Session Title	**Incident Response and Roadside Safety**
Paper Number	TRBAM-23-04261
Paper Title	**Analysis of First Responder-Involved Traffic Incidents by Mining News Reports**
Abstract	Roadside service and incident response personnel face the risk of being killed or severely injured by passing vehicles when performing their duties on or along a road. This study investigated 5,113 responder-involved event news reports to understand the characteristics of first responder-involved incidents. Through text mining, this study examined and compared the characteristics of three types of responder-involved incidents: near-miss incidents, struck-by incidents, and line-of-duty-deaths (LODD). A higher proportion of struck-by and LODD incidents are associated with law enforcement agencies. In terms of the time of day, morning and night incidents are frequently reported in the news. DUI or DWI is a major cause of LODD incidents. Compared to struck-by incidents, LODD incidents have a larger portion related to out-of-control vehicles. Further, this study built a model to relate the incident characteristics to the odds of an incident being a LODD incident. The modeling result shows that tow truck drivers are associated with a greater likelihood of being involved in a news-reported LODD incident than other responders. LODD incidents are more likely to occur when a responder is assisting or patrolling than entering/leaving/staying at the scene.

The results offer insights on understanding the characteristics and possible reasons for first responder-involved incidents so that potential countermeasures could be developed to improve responder safety.

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Standing Committee on Regional Transportation Systems Management and Operations (ACP10)
Standing Committee on Transportation Safety Management Systems (ACS10)
Standing Committee on Traffic Law Enforcement (ACS30)
Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Session Number Poster Session 2160
Session Title **Incident Response and Roadside Safety**
Paper Number TRBAM-23-04281

Paper Title **Are First Responders Prepared for Electric Vehicle Fires? A National Survey**

Abstract Transitioning to electric vehicles (EVs) will create not only opportunities but challenges. Although some programs and resources related to EVs have been made available to first responders, it remains unknown whether our first responders are well prepared for traffic incidents that involve EVs and whether there are any organizational and geographic disparities in the preparedness. To answer these questions, a national survey was conducted to collect feedback on responders' incident management knowledge, and training experiences related to EVs, as well as their attitudes and concerns towards EVs. Over 1,000 first responders across the country participated in the survey, and the survey had representation from all 50 states and Washington DC. Over 40% of first responders reported never receiving EV-related safety training. Paramedics or EMS are associated with the highest odds of not receiving EV-related training, followed by law enforcement. Geographically, FEMA Region 8 (e.g., Montana and North Dakota) is associated with the highest percentage of not receiving EV training. Speaking of EV fire tactics, more than half (57%) of law enforcement officers said they do not know any; responders from towing & recovery also have little knowledge compared to firefighters. Statistical modeling was conducted to explore correlates of responders' EV safety training and knowledge of EV fire tactics. The survey also provided insights about the challenges and risks of managing EV-involved incidents. In summary, responders are greatly concerned about the risks that EVs can pose to their community, and actions must be taken now.

Lectern Session 2191

Wildfires and Transportation: Contending with Escalating Risks
Monday, January 09 3:45 PM- 5:30 PM ET
Convention Center, 146B
Lectern | *PDH*

Stephen Wong, University of Alberta,
Diana Herriman, FEMA

Sponsored by:
Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20)
Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))

Authors	Stephen Wong, University of Alberta William Troup, U.S. Fire Administration
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Lectern Session 2191
Session Title	**Wildfires and Transportation: Contending with Escalating Risks**
Paper Number	P23-20057
Paper Title	**Wildfires and Transportation: Contending with Escalating Risks**
Abstract	Fueled by a changing climate and growing land development in high-risk areas, wildfires are a growing problem, and we need to prepare now. Smoke and fire will begin to affect many more people than have been impacted in the past and could take place in areas where they have not traditionally occurred before. Transportation is a critical lifeline that can facilitate evacuations, move first responders, and ensure relief supplies are distributed. This session will cover a number of emerging topics, research needs, and lessons learned from wildfires as it relates to developing more resilient transportation systems.

Authors	Amy Kim (amykim@civil.ubc.ca), University of British Columbia Abdullah Al Zahid, University of Alberta Jennifer Beverly, University of Alberta Department of Renewable Resources
Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Joint Subcommittee on Emergency Response (with AMR20, ACS10, and ACP10) (AMR00(1))
Session Number	Lectern Session 2191
Session Title	**Wildfires and Transportation: Contending with Escalating Risks**
Paper Number	TRBAM-23-01063
Paper Title	**Directional Analysis of Community Wildfire Evacuation Capabilities**
Abstract	Wildfires are a natural part of forest ecosystems, but sometimes pose a threat to communities. In Canada, when public safety is threatened due to wildfire encroaching into the wildland-urban interface (WUI), most fire management agencies will call evacuations. While evacuating a community, roadway egress capacity plays an important role in evacuation efficacy. If a fire spreads quickly towards a community and egress capacity is insufficient, the safety of citizens may be in question. This paper presents an interdisciplinary approach for assessing community directional vulnerabilities for wildfire evacuation, combining techniques from wildfire fire science and transportation engineering. We identify communities in Alberta (a province in western Canada) that are vulnerable to wildfire due to the configuration of the transportation network in relation to surrounding wildfire potential. 21 potentially vulnerable communities were selected for analysis based on expert input. We plotted directional fire hazard and transportation facility characteristics around each community, and coupled and compared estimated fire travel times and evacuation travel times, to understand the potential for complete community egress against fire encroachment. Our results show that some communities (mainly within the boreal forest and Rocky Mountain foothills) have egress routes highly exposed to potential fire. Our findings also indicate that evacuation timing for some larger communities may be critical, given relationships between estimated fire travel times and evacuation times. The results are presented in an interactive online map, and can be used to inform the province as well as communities towards preparation in wildfire mitigation and community evacuation planning.

Lectern Session 2219

Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Monday, January 09 6:00 PM- 7:30 PM ET
Convention Center, Salon B *Lectern* | *PDH* Frank Gross, VHB
Sponsored by: Standing Committee on Transportation Safety Management Systems (ACS10)

Authors	Subasish Das, Texas State University Ali Khodadadi, Texas A&M University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2219
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	TRBAM-23-03152
Paper Title	**Short-duration Crash Modeling to Understand Impact of Operating Speed on Freeway Crashes during COVID-19**
Abstract	Gaining an understanding of speed-crash relationships is a critical issue in highway safety research. Due to the ongoing pandemic (COVID-19) there has been a reduction in traffic volume, and some early studies explain that speeding in an environment with less traffic is associated with a high number of crashes, especially fatal and serious injury crashes. This study aims to shed light on this issue. The study conflated several databases (speed data, roadway inventory data, and crash data) that contain data from Dallas, Texas, spanning from 2018 to 2020, in order to examine the speed-crash association. Using the Negative Binomial Lindley regression model, this study showed that the trends of crash prediction models vary over the years (2018, 2019, and 2020) by different injury severity levels (i.e., fatal crashes, fatal and incapacitating injury crashes). The 2020 models show that operating speed measures (i.e., average operating speed) have a significant impact on crash frequencies. The magnitudes of the speed measures show variations across the models at different injury severity levels.

Authors	Farhan Anjum Badhon, Islamic University of Technology Shoumic Shahid Chowdhury, Tongji University Tashdid Haque, Islamic University of Technology Saifur Rahman, Islamic University of Technology Md Asif Raihan, Bangladesh University of Engineering and Technology Moinul Hossain, Islamic University of Technology Abdullah Al Mamun, Universita degli Studi di Roma La Sapienza
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2219
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	TRBAM-23-02039
Paper Title	**Risk Perception of Vehicle-to-vehicle Vendors and General Pedestrians: A Comparative Study**
Abstract	Pedestrians account for 65 percent of all traffic fatalities worldwide. A sub-category of pedestrians is vehicle-to-vehicle vendors, who pose a concern to countries with growing infrastructure. For example, 70 percent of traffic fatalities in Nigeria involve general pedestrians and vendors. Previous studies have highlighted vendors' heterogeneous road crossing and car-following demeanors. Furthermore, they create a nuisance for general pedestrians. This study contrasts the risk perception of vehicle-to-vehicle vendors and general pedestrians and analyzes vendors' grouped and ungrouped illegal crossings. A questionnaire survey was developed based on literature review and expert knowledge for extracting variables associated with risk perception. Interviews based on a questionnaire were conducted in various locations in Dhaka city to collect 1,019 responses. This procedure collected information on their demographic attributes, risk perception, aggressive behavior, near-crash experiences, and accepted yielding distances. Next, ordinal logit/probit and complementary log-log models were used to analyze the data. The findings revealed vehicle-to-vehicle vendors had a lower risk perception compared to general pedestrians. It also indicated that vendors would take a higher risk than general pedestrians. Furthermore, vendors jaywalking alone had a significantly lower perception of risk. Finally, "Gender", "Age", "Education", "Accepted Yielding Distance" and "Aggressive Behavior" were the most prominent factors affecting vendors' risk perception. Gradually separating vendors from the traffic system by shifting them to proper street markets could be a critical solution.

Lectern Session 3010

Moving Safety Research into Practice
Tuesday, January 10 8:00 AM- 9:45 AM ET
Convention Center, 151A
Lectern | *PDH*

Stacy Williams, University of Arkansas, Fayetteville

Sponsored by:
Standing Committee on Research Innovation Implementation Management (AJE35)
City Transportation Issues Coordinating Council (A0030C)
Standing Committee on Transportation Safety Management Systems (ACS10)

Authors	Maryam Izadi, University of New Orleans Jessica Schoner, Safe Streets Research & Consulting Tara Tolford, University of New Orleans Theja Putta, Toole design group Rachel Finfer, Toole design group Daniel Jatres, City of New Orleans Daniel Patterson, Toole design group Jennifer Ruley, City of New Orleans Jacob Nigro, Toole design group Robert Stickney, New Orleans RTA
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35) City Transportation Issues Coordinating Council (A0030C) Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 3010
Session Title	**Moving Safety Research into Practice**
Paper Number	TRBAM-23-04432
Paper Title	**Developing an Open-Source Web Tool to Prioritize Safer Streets**
Abstract	Vulnerable road user traffic deaths in the United States have increased in number and proportion over the previous decade. This growing disparity points to a larger need to prioritize safety for vulnerable road users on our streets. Evaluating and predicting vulnerable road user crash risk is a data-intensive and complex process. This study aims to make safety analysis for vulnerable road users easier and more accessible by (1) developing a modeling framework with minimal data input needs, (2) converting model outputs into cost equivalents to better link the results to planning and project scoping processes, and (3) building this functionality into an online tool and dashboard. In this paper, we develop an approach to modeling vulnerable road user crash risk that uses Bayesian probability updating and Markov chain Monte Carlo simulations to blend an existing published statistical model with simple roadway and crash data inputs, which we built into an online tool and dashboard called the Safer Streets Priority Finder. We apply the tool to crash data from the City of New Orleans and describe the application of model outputs for both roadway safety planning and transit planning use cases. The paper includes validation results for New Orleans and two other jurisdictions. Overall, we found that this modeling approach performs as well or better than Sliding Window Analysis and traditional High Injury Networks, and the tool has the potential to make safety analysis easier and more accessible to planners and engineers.

Authors	Yukun Song, Auburn University Huaguo Zhou, Auburn University Priscilla Tobias, Arora and Associates, P.C. Qing Chang, Auburn University
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35) City Transportation Issues Coordinating Council (A0030C) Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 3010
Session Title	**Moving Safety Research into Practice**
Paper Number	TRBAM-23-04059
Paper Title	**The National Survey on Wrong-Way Driving Solutions, Policy and Guidance in the United States**
Abstract	This paper presents an investigation into the current and emerging solutions, policies, and guidance employed as well as the opinions on the effectiveness of wrong-way (WW) related countermeasures by different agencies to mitigate wrong-way driving (WWD) activities. A two-pronged approach was used to collect information from state transportation agencies, tollway authorities, and law enforcement. The initial step was an online survey that aimed to obtain general ideas about the current and emerging solutions, policies, and guidance employed by different agencies to mitigate WWD activities. The survey questionnaire, which contains 12 questions regarding mitigation policies, practices, and programs; crash/incident data collection and analysis; and countermeasures evaluation and application guidelines, was emailed to traffic and safety engineers for the 50 state transportation agencies and 59 tollway authorities across the nation. As a second step, follow-up phone interviews were conducted with the respondents identified from the online survey in the first step. The interview questions focused on crash/incident data collection method, crash-prone location identification, countermeasure selection and implementation, experience on ITS application, and future initiatives. The survey and interview results revealed an increasing awareness and the current practices to combat WWD. The best practices aimed at deterring WWD were introduced by different states. The valuable lessons learned from the survey and interview results from the various agencies will be used to develop systemic and systematic approaches and guidelines in the national handbook on WWD solutions. Keywords : Wrong-Way Driving; Survey; Policies and guidance; Advanced countermeasure; ITS technologies

Lectern Session 3062

Paper Awards: Transportation Safety Management Systems
Tuesday, January 10 10:15 AM- 12:00 PM ET
Convention Center, Salon B
Lectern | *PDH*

Jaeyoung Lee, Central South University

Sponsored by:
Standing Committee on Transportation Safety Management Systems (ACS10)

Authors	Yukun Song, Auburn University Huaguo Zhou, Auburn University Qing Chang, Auburn University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 3062
Session Title	**Paper Awards: Transportation Safety Management Systems**
Paper Number	TRBAM-23-03753
Paper Title	**Trends and Odds of Wrong-Way Driving Fatal Crashes on Freeways from 2004 to 2020 in the United States**
Abstract	The purpose of this study is to conduct a comprehensive analysis of the trends, distribution, and odds of wrong-way driving (WWD) fatal crashes on divided highways in the United States. The study extracted 17 years (2004–2020) of WWD fatal crash data from the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) database. The descriptive statistical analysis was conducted to reveal general crash characteristics and update the national trends in WWD fatal crashes. The results showed that an average of 302 WWD fatal crashes occurred annually on divided highways in the United States, which resulted in a total of 6,953 fatalities during the 17 years. The number of WWD fatal crashes on divided highways remained steady with a slight increase over the years. The second part of the study was to compute the odds between WWD fatal crashes and other fatal crashes to identify factors contributing to those WWD fatal crashes. Odds ratios were computed based on a binomial logistic regression model. The significant contributing factors identified by the odds ratios include temporal variables, crash characteristics, and driver characteristics. Keywords: wrong-way driving, fatal crashes; crash trends; contributing factors; FARS data, odds ratio

Authors	Robert Schneider, University of Wisconsin, Milwaukee Josie Willman, Civiltech Engineering, Inc. Stephen Hargarten, Medical College of Wisconsin
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 3062
Session Title	**Paper Awards: Transportation Safety Management Systems**
Paper Number	TRBAM-23-04059
Paper Title	**Linking Police and EMS Records: An Approach to Strengthen Bicyclist Injury Reporting**
Abstract	Bicyclist injuries are underreported in police crash databases. We explored the value of linking police-reported crash data with emergency medical services (EMS) data within the City of Milwaukee, Wisconsin. Using data from 2014 to 2016, we linked records by inspection (identical date, similar time of day, and similar roadway location) and found 154 matching records between the two databases (representing 41% of the 375 police crash records and 44% of the 348 EMS injury records). Matched records were more likely to involve fatal and severe injuries according to police-assessed injury ratings. The two datasets also provided different insights into bicyclist injury crashes. Injuries captured only by police reports were significantly more likely than injuries captured only by EMS to be along high-traffic streets and commercial districts and significantly less likely to be near parks. Nearly all police records described driver and bicyclist movements (e.g., turning) and operating behaviors (e.g., failure to yield) that contributed to the crash. In addition to capturing more bicyclist injury events, EMS records revealed additional information about their causes. 23% of EMS narratives described falls. These falls involved intoxication, striking a curb, swerving to avoid automobiles or other bicyclists, doing tricks, and getting a tire caught in rail tracks. Another 11% described bicyclists striking objects, including a bus stop shelter, stop sign, fire hydrant, and fence. While there are strengths and limitations to both datasets, linking police-reported crashes with EMS records produced a broader understanding of bicyclist injuries.

Authors	Qiangqiang Shangguan, Tongji University Jessica Keung, University of Waterloo Liping Fu, University of Waterloo Lana Samara, Transoft Solutions, Inc. Junhua Wang, Tongji University Ting Fu, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 3062
Session Title	**Paper Awards: Transportation Safety Management Systems**
Paper Number	TRBAM-23-02767
Paper Title	**Do Traffic Countermeasures Improve the Safety of Vulnerable Road Users at Signalized Intersections? A Combination of Case-control and Cross-sectional Studies Using Video-based Trajectory Data and Surrogate Measures of Safety**
Abstract	Driven by the vision to eliminate road fatalities, Vision Zero initiatives have been widely adopted by many cities around the world, with significant investments of resources in various safety programs and countermeasures. However, there is still a lack of reliable quantitative evidence on the effectiveness of those countermeasures and their relation to various external factors. This research attempts to address this challenge with a combination of case-control and cross-sectional studies, aiming at quantifying the safety effects of three commonly applied Vision Zero countermeasures, namely, Leading Pedestrian Interval (LPI), No Right Turn On Red (NRTOR), and installation of a dedicated Bicycle Lane (BL). A case study was conducted using video trajectory data from ten signalized intersections in the City of Toronto. The traffic interactions between vehicles and vulnerable road users (VRUs) were extracted using a video data processing platform and two surrogate measures of safety, including post-encroachment time (PET) and conflict speed, were obtained and then used to classify the conflict severity into different levels. A comparative analysis using mixed-effects negative binomial regression was conducted to quantify the impacts of different treatments on the frequency of traffic conflicts under specific road weather and traffic conditions. The results show that these three types of traffic countermeasures can effectively reduce the frequency of high-risk and moderate-risk traffic conflicts, moderated by various, traffic exposure, weather and environmental conditions, and accessible pedestrian signals (APS). These findings could help road safety engineers and decision makers make better informed decisions on their road safety initiatives and projects.

Poster Session 3097

TRB Minority Student Fellows Poster Session
Tuesday, January 10 10:15 AM- 12:00 PM ET
Convention Center, Hall A
Poster

Karen Febey, Transportation Research Board

Sponsored by:
Section - Executive Management Issues (AJE00)
Standing Committee on Pedestrians (ACH10)
Standing Committee on Transportation Demand Management (AEP60)
Standing Committee on Information Systems and Technology (AED30)
Standing Committee on Aviation Administration and Policy (AV010)
Standing Committee on Community Resources and Impacts (AME80)
Standing Committee on Public Transportation Planning and Development (AP025)
Section - Pavements (AKP00)
Standing Committee on Accessible Transportation and Mobility (AME50)
Standing Committee on Safety Performance and Analysis (ACS20)
Standing Committee on Resource Conservation and Recovery (AMS20)
Standing Committee on Roundabouts and other Intersection Design and Control Strategies (AKD80)
Standing Committee on Traffic Control Devices (ACP55)
Standing Committee on Bicycle Transportation (ACH20)
Standing Committee on Aggregates (AKM80)
Standing Committee on Bridge and Structures Management (AKT50)
Standing Committee on Freeway Operations (ACP20)
Standing Committee on Transportation Demand Forecasting (AEP50)
Standing Committee on Transit Management and Performance (AP010)
Standing Committee on Freeway Operations (ACP20)

Authors	Ossiris Rodriguez, University of New Mexico Nicholas Ferenchak, University of New Mexico
Sponsoring Committee	Section - Executive Management Issues (AJE00) Standing Committee on Pedestrians (ACH10) Standing Committee on Transportation Demand Management (AEP60) Standing Committee on Information Systems and Technology (AED30) Standing Committee on Aviation Administration and Policy (AV010) Standing Committee on Community Resources and Impacts (AME80) Standing Committee on Public Transportation Planning and Development (AP025) Section - Pavements (AKP00) Standing Committee on Accessible Transportation and Mobility (AME50) Standing Committee on Safety Performance and Analysis (ACS20) Standing Committee on Resource Conservation and Recovery (AMS20) Standing Committee on Roundabouts and other Intersection Design and Control Strategies (AKD80) Standing Committee on Traffic Control Devices (ACP55) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Aggregates (AKM80) Standing Committee on Bridge and Structures Management (AKT50) Standing Committee on Freeway Operations (ACP20) Standing Committee on Transportation Demand Forecasting (AEP50) Standing Committee on Transit Management and Performance (AP010) Standing Committee on Freeway Operations (ACP20)
Session Number	Poster Session 3097
Session Title	**TRB Minority Student Fellows Poster Session**
Paper Number	TRBAM-23-01238
Paper Title	**Invited Student Paper: Longitudinal Spatial Trends in U.S. Pedestrian Fatalities, 1999-2020**

Abstract The number of pedestrian deaths from motor vehicle crashes in the United States has risen 59% since 2009. Several studies have researched crash characteristics such as the people, vehicles, and roadways involved when examining this sharp increase. But where are these fatalities occurring and what spatial characteristics of these locations could be influencing this trend? We looked at pedestrian fatality data from the Fatality Analysis Reporting System (FARS) and socioeconomic, demographic, and built environment data from the U.S. Census and the U.S. Environmental Protection Agency (EPA) Smart Location Database (SLD) for the study period of 1999 through 2020. After inputting the data into QGIS, we made graphs with 95% confidence intervals to analyze longitudinal trends in crash location characteristics and created heat maps of pedestrian fatality locations in nine large U.S. cities to compare clustering in the beginning of the study period (1999-2002) to clustering at the end (2017-2020). The results of this study indicate that pedestrian fatalities are moving away from downtown areas (with a 63.0% decrease in study cities' downtowns) and are now happening more in suburbs (a 32.1% increase outside downtowns). Many of these suburbs are postwar suburbs that were built in the 1950's, 1960's, and 1970's and have low population and road densities and low levels of pedestrian commuting. Additionally, these fatalities are happening in neighborhoods with high proportions of minority residents, low educational attainment, and high poverty rates that are more than 60% above the national average.

Authors Anthony Forcades, Florida International University
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Sponsoring Committee Section - Executive Management Issues (AJE00)
Standing Committee on Pedestrians (ACH10)
Standing Committee on Transportation Demand Management (AEP60)
Standing Committee on Information Systems and Technology (AED30)
Standing Committee on Aviation Administration and Policy (AV010)
Standing Committee on Community Resources and Impacts (AME80)
Standing Committee on Public Transportation Planning and Development (AP025)
Section - Pavements (AKP00)
Standing Committee on Accessible Transportation and Mobility (AME50)
Standing Committee on Safety Performance and Analysis (ACS20)
Standing Committee on Resource Conservation and Recovery (AMS20)
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Standing Committee on Freeway Operations (ACP20)
Standing Committee on Transportation Demand Forecasting (AEP50)
Standing Committee on Transit Management and Performance (AP010)
Standing Committee on Freeway Operations (ACP20)
Session Number Poster Session 3097
Session Title **TRB Minority Student Fellows Poster Session**
Paper Number TRBAM-23-01323
Paper Title **Invited Student Paper: Exploring Work Zone Crash Risk for Different Highway Functional Classifications**

Abstract Traffic safety and the safety of workers in work zones have drawn the attention of several transportation agencies due to a recent increase in the number of work zone-related crashes. Although a number of strategies have been implemented to improve work zone safety, the frequency and severity of work zone-related crashes are still substantially high. The effect of work zones on traffic safety can be aggravated by different factors, including spatial-temporal characteristics and the functional classification of the roadway. Thus, understanding the factors associated with work zone-related crashes on different roadway functional classifications is essential in improving traffic safety and the safety of workers. This study explored the factors influencing the work zone-related crashes based on roadway functional classification using ten years (2012-2021) of crash data from Florida's roadways using a Bayesian multinomial logit model. The findings indicated that work zone area types, rear-end, sideswipes, and run-off-road crashes were associated with a higher likelihood of work zone-related crashes on freeways than on arterials. Also, compared to collector roads, results revealed that work zone-related crashes are more severe on arterials than on freeways. Other contributing factors, such as dark lighting conditions, adverse weather conditions,

wet road surface conditions, weekend, and rural areas, were associated with an increase in the likelihood of work zone-related crashes, both on freeways and arterials. The study's findings may help transportation agencies develop guidelines for improving the safety of work zones specific to a given roadway.

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Sponsoring Committee	Section - Executive Management Issues (AJE00) Standing Committee on Pedestrians (ACH10) Standing Committee on Transportation Demand Management (AEP60) Standing Committee on Information Systems and Technology (AED30) Standing Committee on Aviation Administration and Policy (AV010) Standing Committee on Community Resources and Impacts (AME80) Standing Committee on Public Transportation Planning and Development (AP025) Section - Pavements (AKP00) Standing Committee on Accessible Transportation and Mobility (AME50) Standing Committee on Safety Performance and Analysis (ACS20) Standing Committee on Resource Conservation and Recovery (AMS20) Standing Committee on Roundabouts and other Intersection Design and Control Strategies (AKD80) Standing Committee on Traffic Control Devices (ACP55) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Aggregates (AKM80) Standing Committee on Bridge and Structures Management (AKT50) Standing Committee on Freeway Operations (ACP20) Standing Committee on Transportation Demand Forecasting (AEP50) Standing Committee on Transit Management and Performance (AP010) Standing Committee on Freeway Operations (ACP20)
Session Number	Poster Session 3097
Session Title	**TRB Minority Student Fellows Poster Session**
Paper Number	TRBAM-23-02967
Paper Title	**Invited Student Paper: Exploring Neighborhood Differences in Bicycling Accessibility to Physical and Virtual Workplaces**
Abstract	Health concerns of disease transmission brought by the Covid-19 pandemic coupled with technological advancements over the past two decades have resulted in dramatic changes to the traditional workplace setting. Professionals in the tertiary and quaternary economic sectors, who had grown more accustomed to virtual working environments in recent years, are now increasingly likely to fulfill their work tasks from their homes. However, other job sectors including those which employ essential workers, have proven to be less flexible in this regard and maintain a demand for employees to commute to a physical workplace. During the pandemic, residents of under-resourced communities, who tend to have more limited mobility options that may require them to adopt lower-cost shared-use travel modes and would benefit from good access to higher-quality bicycling infrastructure, embody a greater share of the non-healthcare workforce who was required to commute to a physical work setting. This study explores the differences in bicycling accessibility to so-called physical and virtual jobs and its associations with variations in the social context of neighborhoods where commute trips originate and level of traffic stress that may be encountered by a current or prospective bicyclist. Findings from this study of bicycling accessibility in Flagstaff, Arizona offer unique insights into how the changing nature of work should be accounted for as active transportation planners and policymakers seek to provide safe and robust bicycle networks to their diverse communities.

Authors	Leonor Reyes, Florida International University Jimoku Salum, Florida International University Priyanka Alluri, Florida International University
Sponsoring Committee	Section - Executive Management Issues (AJE00) Standing Committee on Pedestrians (ACH10) Standing Committee on Transportation Demand Management (AEP60) Standing Committee on Information Systems and Technology (AED30)

	Standing Committee on Aviation Administration and Policy (AV010) Standing Committee on Community Resources and Impacts (AME80) Standing Committee on Public Transportation Planning and Development (AP025) Section - Pavements (AKP00) Standing Committee on Accessible Transportation and Mobility (AME50) Standing Committee on Safety Performance and Analysis (ACS20) Standing Committee on Resource Conservation and Recovery (AMS20) Standing Committee on Roundabouts and other Intersection Design and Control Strategies (AKD80) Standing Committee on Traffic Control Devices (ACP55) Standing Committee on Bicycle Transportation (ACH20) Standing Committee on Aggregates (AKM80) Standing Committee on Bridge and Structures Management (AKT50) Standing Committee on Freeway Operations (ACP20) Standing Committee on Transportation Demand Forecasting (AEP50) Standing Committee on Transit Management and Performance (AP010) Standing Committee on Freeway Operations (ACP20)
Session Number	Poster Session 3097
Session Title	**TRB Minority Student Fellows Poster Session**
Paper Number	TRBAM-23-01293
Paper Title	**Invited Student Paper: Investigating Factors that Influence The Spatiotemporal Gaps Between Primary Incidents and Secondary Crashes**
Abstract	Mitigating secondary crashes is one of the priorities in traffic incident management. However, limited information on secondary crashes may impede the selection of appropriate mitigation efforts. The objective of this study was to investigate the spatiotemporal gaps (i.e., distance and time gaps) between secondary crashes and primary incidents. The study used a dynamic method to accurately identify secondary crashes by integrating real-time traffic speed data with incident data. The analysis was based on data collected from 261,153 incidents on a 382-miles section of I-95 from 2017-2019 in Florida. The results indicated that 3,906 crashes were secondary to 3,547 primary incidents, accounting for 1.5% of total incidents analyzed. The average distance and time gaps between primary and secondary crashes were 1.0 mile and 43.2 minutes, respectively. Overall, 46.5% of secondary crashes occurred within 45 minutes and 1.0 mile upstream of primary incidents. Key findings from the hazard-based models indicated that peak hours, left or right shoulder closure, and traffic volume significantly increased the distance gap. In contrast, partial or all lane closure and the number of lanes significantly decreased the distance gap. Incident type, left or right shoulder closure, and traffic volume significantly increased the time gap, and morning peak hours, 4-lane sections, and vehicle speed significantly decreased the time gap. Traffic volume and left or right shoulder closure significantly increased both distance and time gaps. These findings could be beneficial to incident managers and responders in making informed decisions on mitigating secondary crashes.

Poster Session 3149

Transportation Safety Management Systems from Start to Finish
Tuesday, January 10 1:30 PM- 3:15 PM ET
Convention Center, Hall A
Poster

Frank Gross, VHB,
Jaeyoung Lee, Central South University,
Stephanie Malinoff, University of Minnesota, Twin Cities

Sponsored by:
Standing Committee on Transportation Safety Management Systems (ACS10)

Authors	Arjun Ganga, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Eric Kim, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Oliver Tang, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Joshua Feler, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Rahul Sastry, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Matthew Anderson, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Sharonda Keith, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Jared Fridley, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Ziya Gokaslan, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Deus Cielo, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Steven Toms, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School Patricia Sullivan, Warren Alpert Medical School of Brown University: Brown University Warren Alpert Medical School
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-00194
Paper Title	**The Cost of Unhelmeted Motorcycle Injury: a Nationwide Scoring-based Analysis of Helmet Safety Legislation**
Abstract	Motorcycle collisions comprise a large portion of motor vehicle injuries and fatalities. Unhelmeted riders have worse outcomes and generate billions of dollars in costs. Despite helmets having been shown to lower the risk of injury and death, legislation concerning helmet use varies widely across the US. In this study, we reviewed statutes to evaluate the stringency of helmet policies across the country using a legislative scoring system termed the Helmet Safety Score (HSS) ranging from 0-7 points, with higher scores denoting more stringent statutes. Regression modeling was used to predict unhelmeted mortality in all jurisdictions using our safety scores. The mean score across all jurisdictions was 4.73. We found that states with higher helmet safety scores generally had lower percentages of unhelmeted fatalities in terms of total fatalities as well as lower unhelmeted fatalities per 100,000 people and registered motorcycles. In contrast, some lower-scoring states had over 100 times more unhelmeted fatalities than higher-scoring states. Our helmet safety scores significantly predicted unhelmeted motorcycle fatalities per 100,000 people (β = -0.228 per 1-point HSS increase, $p < .0001$) and per 100,000 registered motorcycles (β = -6.17 per 1-point HSS increase, $p < .0001$). Aspects of our score concerning helmet exemptions for riders and motorcycle-type vehicles independently predicted fatalities ($p < .0001$). Universal helmet laws are an effective mechanism for maximally decreasing unhelmeted mortality. We advocate for a federal, universal helmet law to decrease motorcycle-related injury and fatality burden. In states with existing helmet laws, we advocate for elimination of exemptions.

Authors	Douglas Harwood, Harwood Road Safety LLC Zachary Hans, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-00217
Paper Title	**Comparison of Safe System Assessment Methods**
Abstract	This paper compares two methods for assessing the need for crash countermeasures based on safe system principles. These methods are the Road Assessment Program (RAP) methodology and the Australian safe system assessment framework (SSAF). Both methods were applied to the same set of rural roadways in North Carolina. Comparison of the results from applying the two methods show that both methods can be effective in identifying sites with potential need for crash reduction improvements. However, the SSAF scores do not appear to be useful in distinguishing between sites where the countermeasures identified with the RAP methodology have higher benefit cost-ratios and those with lower benefit-cost ratios. The results indicate that the SSAF method involves subjective judgements, and the ratings from the SSAF methodology may not be repeatable. The SSAF results are dependent on the expertise and interpretations of the individual safety professionals assigned to do the ratings. By contrast, the RAP methodology, while incorporating a few judgement-based ratings, is less subjective and more likely to repeatable. The SSAF results are useful to safety professionals as a guide for identifying countermeasures, while the RAP methodology provides additional output that identifies specific crash countermeasures and estimates their benefits, costs, and benefit-cost ratios. While its lack of repeatability is a limitation in its usefulness, the SSAF methodology appears to be a valuable tool in educating users about the nature of the safe system concept and showing how to understand and utilize safe system principles.

Authors	Ruchika Agarwala, Indian Institute of Technology, Bombay Vinod Vasudevan, University of Alaska, Anchorage
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-00482
Paper Title	**Influence of Economic Growth on Traffic Safety in Developing Countries: Insights from Indian Household Level Survey Data**
Abstract	With the growth of the economy of a region, the vehicle ownership increases thereby improving mobility. While economic growth has historically been associated with increased mobility, its impact on traffic safety has not been studied in detail, especially in developing countries. In this study, the relationship between economic growth and traffic fatality is studied for a total of 27 states and union territories of India. Two separate models are developed, one in which all the regions are combined together and one in which the regions are grouped based on NSDP per capita. A new economic indicator, Monthly Per capita Consumption Expenditure is considered. Results obtained confirmed a positive relationship between economy and traffic fatality. However, contrasting results are obtained for the group-wise models. This study points to the importance of incorporating adequate infrastructure and other facilities to accommodate the increased number of vehicles due to economic growth in developing nations.

Authors	Michael Forrest, University of Southampton Shahram Heydari, University of Southampton
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-00526
Paper Title	**Estimating the Effect of Proximity to School on Cyclist Injury Frequencies**
Abstract	The safety of cyclists is a universal concern and identifying factors which affect the frequency of cycling injuries is crucial in understanding how to target interventions to improve cycling safety. Safety around schools is a particular point of concern and as such these locations are often the subject of safety interventions. However, it is difficult to estimate the impact of proximity to school on traffic safety due to an inherent endogeneity of the presence of a school which might be associated with safety (e.g., cyclist injury frequencies) and other site characteristics at the same time. This paper uses a simultaneous econometric approach to estimate the effect of proximity to a school on cyclist injuries at signalised intersections while accounting for endogeneity. It was found that a number of exposure and built environment factors had a significant association with cyclist injury frequency and the presence of schools at intersections. We found that the presence of a school was associated with an increase in cyclist injuries and this association was stronger when endogeneity was accounted for in the model, confirming the importance of considering endogeneity in studies of school safety interventions. This research offers policy implications based on the findings of the analysis including the need for safety interventions at intersections with high turning vehicle counts and those in proximity to public transport stops. A safety-in-numbers effect is also found for cyclists in the study area and period, suggesting that as volume increases the rate of injuries per cyclist decreases.

Authors	Steve Lee, The University of Tennessee Knoxville Numan Ahmad, The Pennsylvania State University Jerry Everett, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-00709
Paper Title	**Strategies for Reducing Motorcyclist Injuries in Tennessee: Relevance of Evidence-Based Countermeasures that Work**
Abstract	One of the recent issues in transportation safety is the rise in fatalities and severe injuries among motorcyclists. Since motorcyclists are far more vulnerable than enclosed vehicle users on the road, they are substantially more likely to be injured given a crash. While countermeasures against motorcycle crashes are available, this study aims to shorten the implementation cycle by thoroughly investigating motorcyclist injury severity, exploring flashpoint locations, and relating the findings from this study to countermeasures that are based on recent evidence from quality studies. According to recent motorcycle crash data (N=14,677) in Tennessee, 73.4% of motorcycle crashes resulted in rider injuries, with 5.1% causing fatalities. Statistical analysis with an ordered probit model reveals that improper use of a DOT-compliant helmet is associated with severer injuries, compared with properly wearing a DOT-compliant helmet. Not wearing a helmet and wearing a non-compliant helmet are also associated with higher injury risk, given a crash. Other injury risk factors include impaired riding and riding on undivided two-way roads. The provision of lighting in the dark could help mitigate the severity of motorcyclist injuries. High-frequency motorcycle crash flashpoints are located in large cities, but also on the Great Smoky Mountains National Park with tight curves and elevation changes. The findings from this study are a valuable reference to help prepare and apply evidence-based countermeasures that can deal with rider-related and environmental risk factors to prevent motorcyclist injuries in the future.

Authors	Meng Wang, University of Massachusetts, Amherst Brian Tefft, AAA Foundation for Traffic Safety
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-01013
Paper Title	**Comparing Fatal Crashes in the United States During the COVID-19 Pandemic to Forecasts Based on Pre-Existing Trends**
Abstract	After initial reductions early in the COVID-19 pandemic, traffic fatalities in the U.S. surged in 2020 to their highest levels in over a decade. The purpose of the current study was to quantify the involvement of specific crash, vehicle, and driver-related factors in fatal crashes during May-December 2020 relative to what would have been expected in the absence of the pandemic based on models of pre-existing trends. Data from all fatal crashes in the U.S. from January 1, 2011 through December 31, 2020 were used to develop Seasonal Autoregressive Integrated Moving Average models of monthly counts of fatal crashes through December 2019, which were used to forecast how many fatal crashes would have occurred in May-December 2020 had the pandemic not occurred. The main outcome measures were the difference and ratio of the actual versus forecasted counts. Separate models were developed for total fatal crashes and for categories of crash, vehicle, and driver factors. Total fatalities in May-December 2020 exceeded the forecast by 3,083 (12.1%). The increase was not uniform across factors examined. Actual counts exceeded forecasts by large amounts in both difference and ratio for late night/early morning crashes, single-vehicle crashes, speeding drivers, drivers aged 25-34, drivers with suspended/revoked/no license, drivers of vehicles registered to others, and vehicles 15+ years old. Crashes during hours 6-10AM and involvements of drivers aged 55+ were fewer than forecast. Results can inform deployment of countermeasures intended to slow or reverse the increase in traffic fatalities that occurred during the COVID-19 pandemic.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-01036
Paper Title	**Exploring Common Attributes between the Traffic Safety 'Pandemic' and the Covid-19 Pandemic: a Global Macroscopic Analysis**
Abstract	This paper aims to explore common attributes between two ongoing pandemics: the Covid-19 pandemic which onset on year 2020, and the traffic safety 'pandemic' which – although not formally declared as such – has a comparable burden of 1.35 million fatalities annually. For that purpose, we apply the SUNflower 'pyramid' for both causes of mortality, to link structural and socioeconomic indicators, exposure, policy and measures, as well as Key Performance Indicators (KPIs) of the operational level of risk, with the mortality rates due to both causes. Data for >100 countries are collected from international databases and other official sources, including indicators that correspond to each layer of the pyramid. Log-linear regression models are developed for the mortality rates and individual or composite variables of different layers. The results suggest that structural socioeconomic indicators such as GDP per capita, share of paved roads and ageing of the population play a key role in the outcomes of both pandemics. Moreover, exposure, either traffic (e.g. urbanisation, vehicle fleet) or epidemiological (e.g. number of infections), taking explicit account of vulnerable populations, has a strong positive effect on both final outcomes. On the other hand, an opposite impact of measures and KPIs was found in the two pandemics: while traffic enforcement decreases traffic mortality, a higher government stringency index on Covid-19 measures increased covid19 mortality rate. This may be attributed to higher perceived urgency, lack of experience and more variability of the measures in the Covid-19 pandemic, possibly resulting in reactive rather than proactive management.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-01668
Paper Title	**Safety Effectiveness Evaluation for Decreasing Speed Limits of Urban Areas**
Abstract	This study develops a set of crash modification factors (CMFs) to evaluate the effects of lowering urban-road speed limits on vehicle and pedestrian safety. Cross-sectional methods and observation before-after methods are used to develop CMFs. In general, a CMF estimates the expected change in the frequency of crashes after specific countermeasures are applied on the road. In this study, the safety improvement effect in the section adjacent to the applied section, as well as the section for which the policy to lower the speed limit was applied, were evaluated. The results indicate that lowering the speed limit is effective in reducing the number of crashes. In particular, the CMFs for crashes involving serious injury and death are 0.6656 to 0.7804 in the application sections and 0.7979 to 0.8273 in the adjacent sections. This means that lowering the speed limit can reduce not only the number of crashes but also the occurrence of serious crashes. This study can be used to promote safety by analyzing the effect of the policy to lower the speed limits in the future and can be applied to the evaluation of the effectiveness of various safety policies in cities.

Authors	Haniyeh Ghomi, McMaster University Mohamed Hussein, McMaster University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-02224
Paper Title	**A Joint Effectiveness Evaluation of Toronto's Vision Zero Strategies: A Time-Series Analysis and Copula-based Model**
Abstract	The current study proposed an integrated time-series modeling technique and a copula-based model to evaluate the safety benefits of multiple safety treatments implemented in the City of Toronto as part of the city's Vision Zero commitments. In this regard, the Vision Zero Mapping Tool was utilized to obtain the pedestrian-vehicle collision records that occurred in the City of Toronto between 2017 and 2020, along with the implemented safety treatments. The City of Toronto was divided into 158 neighbourhoods. Fatal and serious injury pedestrian collisions and the density of the different safety treatments were aggregated to the neighbourhood level. First, the proposed time-series technique, Bayesian Vector Autoregressive (BVAR), was employed in each neighbourhood to investigate the safety impacts of the selected safety measures over the analyzed period. The model results showed that leading pedestrian intervals and speed limit reduction were among the most effective treatments implemented in the city. However, the results also showed that the effects of the treatments can vary between neighbourhoods. As such, a copula-based negative binomial model was developed for each countermeasure in order to investigate the association between the neighbourhood characteristics and the treatment performance. The results of the copula models demonstrated an association between the performance of the implemented safety treatments and a wide range of neighbourhood characteristics, including built-environment factors, land use, and road network characteristics.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-02299
Paper Title	**Analysis of Intelligent Vehicle Technologies to Improve Vulnerable Road User Safety from Cars and Trucks in Urban Areas**
Abstract	As advanced vehicle technologies become available, we have more reliable solutions to improve the safety of all traffic agents, especially vulnerable road users (VRUs). We need to know how these Intelligent Vehicle Technologies (IVTs) can improve VRU safety in different environments and conditions (e.g., sight distance and traffic flows) at signalized intersections. However, there are limited studies on technical and operational differences between these various IVTs, and on technology adoption rates for safety improvement. To address these knowledge gaps, this study first develops a simulation model to mirror realworld driver/VRU perception limitations and then implements four IVTs in micro-level traffic simulations. According to the simulation results, Intersection Safety (INS) is the most efficient technology amongst the four studied IVTs to reduce average collision counts for passenger cars and trucks under seven predefined collision types involving VRUs and vehicles. Blind Spot Detection (BSD) has the most minimal effects on those types. The safety improvement of VRU Beacon Systems (VBS) and Bicycle/Pedestrian to Vehicle Communication (BPTV) are between INS and BSD. More importantly, results indicate that IVTs can significantly reduce the collision probability when sight distance is under a threshold and also improve safety under good sight conditions if collisions happen right in front of vehicles. Additionally, this research conducts a sensitive analysis of traffic volume. For some collision types, INS and BPTV can even reduce approximately 50% of collisions when traffic volume is extremely high.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-02386
Paper Title	**Exploring the Associations between Built Environment and the Traffic Accident Risk of Children in School Commuting**
Abstract	Understanding how built environment attributes are associated with traffic accident risk in school commuting is essential for planners to improving school travel safety through land use and transportation policies. The measurement model of accident scale was conducted to quantify accident risk in school commuting. This study established three models, spatial dubin model (SDM), geographically weighted regression (GWR) and multi-scale geographically weighted regression (MGWR), to analyze the influence direction, degree and path of the built environment on traffic accident risk in school commuting at different school/scale/time windows. The results show that the accident scale can represent the traffic accident risk in school commuting accurately. The built environment within the 200-meter buffer has a more significant impact on the traffic accident risk in school commuting. With the increase of grades, the key built environment variables affecting the risk of school traffic accidents increased: secondary (9) > primary (7) > preschool (6). Only the road network density and educational facilities density have a significant impact on the traffic accident risk in any school, the former is positively correlated. The built environment factors that affect the traffic accident risk of secondary school mainly include 6 factors of traffic system and school factors, especially the traffic system factors account for the largest proportion (66.67%). There are 4 key built environment factors that affect the traffic accident risk of secondary school in leaving school, 50% of which belong to school factors. These findings offer nuanced guidance for transit-oriented school site selection street planning and neighborhood planning.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-02447
Paper Title	**The Impact of Target Speed on Pedestrian, Bike, and Speeding Crash Frequency**
Abstract	This research aims to investigate the influence of adopting the target speed concept on different types of crashes including pedestrian, bike, and speeding related crashes. The Target speed is the highest speed that vehicles should operate on a roadway segment in a specific context. Based on the reviewed literature, this is the first study to investigate the relationship between target speed and crash frequency. Hence, big data including probe-vehicle data, traffic characteristics, geometric features, and land use attributes were utilized to develop crash prediction models. The main contributions of this research are to quantify the impacts of target speed on traffic safety considering context categories and to conclude the potential recommendations to lower different types of crash. The 85 th percentile speed was calculated and utilized in the developed models. Three crash prediction models were developed for pedestrian, bike, and speeding related crashes. They were used in the analysis to quantify the impact of adopting target speed on different crash types. The results showed a significant reduction in the three crash types when using the target speed. Most of the improvements took place in three context categories: C3C-Suburban Commercial, C3R-Suburban Residential, and C4-Urban General. Hence, this research recommends adopting target speed specifically in urban and suburban areas. Further, it suggests considering some measures to lower vulnerable road users' and speeding related crashes. Following the recommendations of this research would help to reduce different types of crash frequency, hence, improve the mobility and safety for all users in different context classifications.

Authors	Yaobang Gong, University of Utah Pan Lu, North Dakota State University Xianfeng Yang, University of Maryland, College Park
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-02610
Paper Title	**Investigating the Impact of COVID-19 on Traffic Safety: From "Lockdown" to the "New Normal"**
Abstract	COVID-19 pandemic has placed pronounced and prolonged impacts on traffic safety. Many studies found the crash frequency reduced but the severity level increased during the earlier "Lockdown" period. However, there is a lack of studies investigating the pandemic's impact on traffic safety during the later stage of the pandemic. Therefore, this study employs statistical methods to investigate whether the impact of COVID-19 on traffic safety differs during the different stages. Pairwise t-tests were conducted to compare the crash frequency and crash severity levels before, during the earlier stage, and the later stage of the pandemic. Negative binomial models and binary logit models were utilized to study the effects of the pandemic on the crash frequency and severity respectively while accounting for the exposure, environmental and human factors. The results show that the crash frequency is significantly less than that of the pre-pandemic during the whole course of the pandemic. However, it significantly increases during the later stage due to the relaxed restrictions and possibly drivers' behavioral changes. Crash severity levels increased during the earlier pandemic due to the prevalence of risky driving behavior and increased presence of commercial vehicles, but it reduced to a level comparable to the pre-pandemic later. Statistical models show that the impacts of the pandemic on drivers' behavior are decaying, leading to the insignificance of all pandemic quantifiers during the later stage of the pandemic when accounting for the exposure, weather, and economic factors.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-03087
Paper Title	**Do transportation network companies increase or decrease road crashes? Evidence from San Francisco**
Abstract	In just one decade, ridehailing or Transportation Network Companies (TNCs) have revolutionized how people commute. While their impact on urban mobility, including car ownership, transit usage, and congestion, is well established, their effect on road crashes, even after many scholarly articles, is yet to be firmly ascertained. Our study aims to fill this literature gap by analyzing the impact of TNC operations on various road crash types, including total crashes, fatal and injuries, pedestrian & bicyclist, and alcoholinvolved road crashes. Set in San Francisco County, our study compares the YR 2016 traffic flows containing TNC trip estimates to the traffic flows for the YR 2010, where they did not exists. We use panel data regression models with fixed effects to examine whether TNC service operations are associated with road crash outcomes. Our results suggest that the association between TNC parameters and most road crash types is statistically insignificant. Except for fatal and injury crashes where each 1% additional TNC Vehicle Miles Travel decreases the road crashes occurrence by 9%. However, for the same crash type, TNC-related pick-up and drop-off instances (PUDO) result in a 7% increase in road crashes within San Francisco County. Our findings provide means to understand the direct impact of TNCs on road safety and allows city planners to rationally set policy measures to achieve the goals of safer streets and safer mobility in their respective regions.

Authors	Shaunna Burbidge, Avenue Consultants
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-03111
Paper Title	**Gauging the Effectiveness of Safe Routes to School Projects**
Abstract	Walking to school, which was once a commonplace rite of passage, now makes up only a small minority of school trips. Multiple studies have shown that concerns are strongly linked to the physical environment that exists between home and school. Over the past decade, hundreds of projects have been funded through the Utah Safe Routes to School and Safe Sidewalk programs, however, there is currently no mechanism in place to determine how effective these projects have been at promoting safety because in most cases, once a project is funded and constructed no follow-up evaluation is conducted. This research evaluated past projects to determine which project types are the most effective at promoting safety by reviewing infrastructure projects funded under the programs and evaluating non-motorized crashes within a one-mile buffer of the project site before and after the infrastructure was put in place. The analysis found no statistical change in the number of non-motorized crashes before and after construction. The probability of minor injury non-motorized crashes increased after construction, likely due to increased volumes and exposure. Crashes occurring in wet or snowy weather were less severe, and a majority of severe injury crashes occurred during the day. Bicycle crashes resulted in less severe injuries than pedestrian crashes and were less common after construction. Future research should include volumes for both non-motorist and vehicle traffic.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-03136
Paper Title	**Leveraging Probe Data to Model Speeding on Limited Access Highway Segments During the COVID-19 Pandemic**
Abstract	Stay-at-home orders - imposed during the COVID-19 pandemic - drastically reduced traffic volumes. Despite this, the rate of fatal and serious injury crashes increased significantly across the United States due to increased speeding on roads with less traffic congestion and speed enforcement. This paper uses a mixed effect binomial regression model to investigate the impact of the lockdown on the odds of speeding for urban limited access highways in Maine and Connecticut. This paper also establishes a link between traffic density (vehicles/mile) and the odds of speeding. Hourly speed and volume probe data were collected on relevant highway segments in Maine and Connecticut to estimate traffic density. Density was combined with roadway geometric characteristics, speed limit, and dummy variables denoting the time of the week, time of the day, and COVID-19 phases (before, during and after stay-at-home order), and the interactions between them. Modeled as Level of Service, density, was found to be associated with the odds of speeding, with better levels of service, resulting in higher odds of speeding. Furthermore, we found that during the stay-at-home order, the odds of speeding by more than 10, 15, and 20 mph increased respectively by 54%, 71% and 85% in Connecticut, and by 15%, 36%, and 65% in Maine during evening peak hours. Additionally, one year after the pandemic started, during evening peak hours, the odds of speeding greater than 10, 15, and 20 mph were still 34%, 29%, and 19% greater in Connecticut and 35% 35% and 20% greater in Maine.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-03296
Paper Title	**Identifying the key attributes of high-risk drivers in Canada and investigating their attitude toward traffic safety laws**
Abstract	An investigation of risky driving groups on Canadian roads is conducted using self-reported number of accidents and demerit points data (Case 1), and self-reported driver behaviour (Case 2) data collected using an online survey. Identification and prediction of high-risk drivers will significantly assist in the development of proactive driver education programs and safety countermeasures. The objectives of this study are twofold: (1) to predict high-risk drivers based on driver attributes, and (2) to identify the factors responsible for determining whether individuals accept additional traffic safety laws. The following multivariate analyses are performed in stages: k-means clustering for categorizing "high-risk" and "low-risk" drivers, factor analysis using EFA and CFA to aggregate safety laws into three factors"speeding", "distracted and intoxicated driving", and "red-light violation", and logistic regression to determine if driver characteristics are associated with risky driving groups and the level of support or opposition to these laws. Conclusions are as follows: (1) Driver's region of residence in Canada contributes significantly to high-risk driver classification in Case 1 due to high levels of variation in individual driving laws and traffic rules set differently by each province, (2) In Case 2, driving frequency influences exposure to varied traffic conditions and contributes significantly to high-risk driver classification, (3) High-risk drivers in Case 1 are less likely to support traffic laws aimed at combating distracted and intoxicated driving, while high-risk drivers in Case 2 are more likely to support speeding laws, and older drivers are more likely to support red-light violations.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-03541
Paper Title	**TOWARDS BETTER DRIVER SAFETY: EMPOWERING PERSONAL NAVIGATION TECHNOLOGIES WITH ROAD SAFETY AWARENESS 3 4**
Abstract	Recent research has found that navigation systems usually assume that all roads are equally safe, directing drivers to dangerous routes, which led to catastrophic consequences. To address this problem, this paper aims to begin the process of adding road safety awareness to navigation systems. To do so, we first created a definition for road safety that navigation systems can easily understand by adapting well-established safety standards from transportation studies. Based on this road safety definition, we then developed a machine learning-based road safety classifier that predicts the safety level for road segments using a diverse feature set constructed only from publicly available geographic data. Evaluations in four different countries show that our road safety classifier achieves satisfactory performance. Finally, we discuss the factors to consider when extending our road safety classifier to other regions and potential new safety designs enabled by our road safety predictions.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-03617
Paper Title	**Investigation on the Driver-Victim Pairs in Pedestrian and Bicyclist Crashes by Latent Class Clustering and Random Forest Algorithm**
Abstract	Both driver and pedestrian/bicyclist play an important part in the occurrence of a roadway crash, while the existing literature tend to investigate the crashes from one party. Drivers and victims from similar socioeconomic backgrounds might be more likely to involved in a crash due to the similarity in their traveling behavior and proximity of residence. To find the crash patterns within the pairs of driver and victim, we employed a probability-based latent class cluster analysis on the income and ethnicity of both driver and victim and random forest algorithm to model the contributing factors to the crash patterns from crash specific information, driver's and victim's socioeconomic profile, road infrastructure, and traffic exposure. Results of the pedestrian and bicyclist crashes in Harris County, Texas, show that lower income and non-White drivers tend to be involved with lower income and non-White victims, while high income and white drivers tend to be involved with higher income and white victims in both pedestrian and bicyclist crashes. The most influential factors in determining this crash patterns include pedestrian/bicyclist exposure, driver's age, victim's age, car used year, AADT, speed limit, road width, and lane width. Crashes of lower income and non-White driver-victim pairs are more likely to happen on the road with higher traffic exposure, speed limit and road width.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04009
Paper Title	**Multivariate Analysis of Road Safety Policies in Brazilian Cities based on The Safe System Approach**
Abstract	The globally accepted best-practice approach to addressing the road safety crisis is the Safe System approach. This strategy consists of a system of key actions working together to eliminate death and serious injury. Evidence-based information is required on each of these key actions in order to understand current deficiencies and opportunities in regions to promote efficient road safety policies. This paper analyzes the influence of 28 performance indicators associated with the five actions pillars to promote road safety policies. Structural Equation Models were proposed to evaluate the relation of these action pillars on the road traffic fatality rate of 110 Brazilian cities. The results indicated that policies aimed to ensure safer roads and users had the greatest and direct effect in reducing road traffic deaths. Road safety management and post-crash response policies had an indirect effect. The findings can assist in decision-making at the Brazilian cities level.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04010
Paper Title	**Investigating Safety in Disadvantaged Communities by Integrating Crash and Justice40 Initiative Data**
Abstract	The United States Department of Transportation's (USDOT) effort to identify disadvantaged communities (DACs) on a census tract level has evoked possibilities of transportation justice and vision zero goal achievement in DAC communities. USDOT has developed six comprehensive indicators to identify DACs based on economy, environment, equity, health, resilience, and transportation. This study will utilize these indicators to explore the association between fatal crashes and disadvantages faced by communities. Five years of fatal crash data are combined with demographic information for 72,769 census tracts of the US. Zero-inflated Negative Binomial (ZINB) model is used for the analysis. The results demonstrate that higher fatal crash rates are associated with census tracts that are disadvantaged health-wise (35.01%), resilience-wise (40.38%), and transportation-wise (48.72%). Furthermore, transportation disadvantaged tracts are associated with substantially higher impaired fatal crashes (60.00% higher). The impaired fatal crashes per 100,000 population in all disadvantaged tracts are 15.15 and 12.22 in non-disadvantaged or privileged tracts. The highest number of pedestrian and bicyclist fatalities are among Hawaiian or other Pacific Islanders. This study can provide information to support policymakers in deciding which disadvantaged community can benefit from resources for transportation improvements.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04087
Paper Title	**Relationship Between Motorcyclist Attitudes and Behaviors Toward Safe Riding and Self-reported Crash Experiences**
Abstract	In July 2019, Florida had 1.33 million licensed drivers with a motorcycle endorsement and 622,347 registered motorcycles. As part of a long-standing effort to collect data on Florida motorcyclist behaviors, attitudes, and opinions, a web-based survey was issued to registered motorcycle owners in Florida during 2019. This study analyzed the results of the survey to identify relationships between motorcyclist attitudes and behaviors towards safe riding and self-reported crash experiences. A total of 1,668 surveys were used for data analysis, and 471 respondents indicated that they visited a hospital or doctor's office because they were involved in a motorcycle crash. Conventional binary logistic regression model results indicate that younger ages (under 30), riding standard motorcycles, and increased exposure to traffic in daily/weekly motorcycle trips are associated with increased crash risk. Respondents who said they were very unlikely to ride 20 mph or more above the posted speed limit and who usually wear three-quarter helmets were less likely to be involved in a crash. Interestingly, respondents who had not attended any formal motorcycle safety training courses other than a basic rider course in the past 12 months were less likely to be involved in a crash, confirming bidirectional findings regarding the effectiveness of motorcycle training programs at reducing crash outcomes. A larger scale survey, including a good representation of young motorcyclists, will help better understand motorcyclists' attitudinal and behavioral characteristics, and the findings will contribute to designing, implementing, and evaluating tailored motorcycle safety programs.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04224
Paper Title	**Modeling the Impact of the COVID-19 Pandemic on Speeding at Rural Roadway Facilities in Maine using Short-Term Speed and Traffic Count Data**
Abstract	The COVID-19 pandemic caused a significant change in traffic operations and safety. For instance, various U.S. states reported an increase in the rate of fatal and severe injury crashes over this duration. In April and May 2020, the comprehensive stay-at-home orders were issued across the country, including in Maine. These orders resulted in drastic reductions in traffic volume. Additionally, there is anecdotal evidence that speed enforcement had been reduced during pandemic. Drivers responded to these changes by increasing their speed. More importantly, data show that speeding continues to occur, even one year after the onset of the pandemic. This study develops statistical models to quantify the impact of the pandemic on speeding in Maine. We developed models for three rural facility types (i.e., major collectors, minor arterials, and principal arterials) using a mixed effect Binomial regression model and short duration speed and traffic count data collected at continuous count stations in Maine. Our results show that the odds of speeding by more than 15 mph increased by 34% for rural major collectors, 32% for rural minor arterials, and 51% for rural principal arterials (non-Interstates) during the stay-at-home order in April and May of 2020 compared to the same months in 2019. In addition, the odds of speeding by more than 15 mph, in April and May of 2021, one year after the order, were still 27% higher on rural major collectors and 17% higher on rural principal arterials compared to the same months in 2019.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04325
Paper Title	**A Bayesian Network for Motorcycle Crash Severity Analysis**
Abstract	Due to the lack of protective structural barriers and advanced restraints, motorcyclists are vulnerable road users, comparable to pedestrians and bicyclists. In 2020, motorcycle-involved fatalities occurred 28 times more frequently per vehicle mile traveled than passenger car occupant fatalities. In addition, there were 5,579 motorcycle-related fatalities in the United States in 2020 – the highest number of motorcyclists killed since in 1975. The discovery of patterns and relationships between important contributing elements can aid in the development of strategies for reducing motorcycle-related crashes. In addition to present efforts, additional research must be performed in innovative avenues with increased funding. Bayesian Networks can better discover the relationships between potential speed compliance variables. This study used six years (2014-2019) of motorcycle crash data in Louisiana to determine the conditional probabilities of the influential factors. The findings of this study can be used for decision making and strategy development for motorcycle safety.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04333
Paper Title	**Revisiting the Roles of Speeds in Traffic Crashes: A Geospatial Modeling Study**
Abstract	Speeding or improper speed behaviors are unsafe on road, increasing the risk of crashes as well as the chance of severe injuries in crashes. Extensive research has been conducted to establish the role of speed in traffic safety. However, there are two types of improper speed behaviors: exceeding the posted speed limit (EPSL) and driving too fast for conditions (DTFFC) and most studies do not distinguish them. Crashes that involve these two types of behaviors may exhibit different characteristics of contributing factors and crash injury outcomes. Using a statewide crash database that records the specific improper speed behaviors, this study develops separate models to revisit and compare the correlates of injury severity in crashes involving EPSL and DTFFC, respectively. To capture the geography-related unobserved heterogeneity inherently embedded in traffic crashes, this study adopts a geospatial modeling approach, namely Geographically Weighted Logistic Regression (GWLR), to identify the correlates of injury severity by allowing the model estimates to vary across the space. This paper provides premilitary results with a limited number of variables and more variables will be incorporated in the future. Modeling results show the significant correlates of injury severities are different in two types of crashes (involving EPSL or DTFFC), and the correlates from both models vary substantially across the space. The findings of this study are expected to help agencies identify the high-risk regions for specific speeding behaviorrelated crashes so that transportation planners can provide corresponding countermeasures for different locations.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04731
Paper Title	**Road Safety in New York City After Vision Zero for Different Land Use Contexts**
Abstract	Over the past decade, more than 45 cities have committed to Vision Zero in the United States. New York City is one of them that has made good progress in reducing car occupant fatalities but struggled to achieve similar declines in pedestrian and bicyclist fatalities. This study assesses road safety performance based on land use context at the census tract level. We use the combined density of population and jobs to categorize NYC census tracts and compare fatalities and fatality risk for different classes of road users in each group. Using aggregate crash data for 2004-2008 and 2014-2018, we track the changes before and after launch of Vison Zero in 2014. We identify a large and growing discrepancy in fatality rates between pedestrians, bicyclists, and car occupants at places with different land use features. Surprisingly, the low density group has the largest number of pedestrian fatalities compared to other density groups in 2014-2018. This is unexpected since low density areas are places where one would not expect to see large numbers of pedestrians. Fatalities per 1,000 road users and fatality risk for pedestrians and bicyclists decreased with the density of the land use. There were very little or no declines in pedestrian and bicyclist fatalities from before to after Vision Zero, expect in the highest density areas. It suggests the need for cities to better understand the relationship between land use context and traffic safety and to implement context appropriate strategies to effectively address traffic fatality issue.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04741
Paper Title	**Vision Zero is Not a Failure but a Matter of Action: Policy Intervention Analysis using ARIMA Modelling**
Abstract	In the last year, the US witnessed about 43,000 traffic deaths on roads, making 2021 the deadliest year in traffic safety in the past 16 years. With surging traffic fatalities nationwide, Vision Zero has gained its rapid growth in the US with a goal of zero traffic fatalities and serious injuries. Since Chicago's commitment in 2012, to date, more than 50 localities have adopted Vision Zero. Despite increasing popularities of and dedications to the policy, some Vision Zero communities have seen rising traffic fatalities, including Los Angeles, raising a critical question: Is Vision Zero a failure or hope? To answer this question, the current study uses the Autoregressive Integrated Moving Average (ARIMA) modeling to estimate the policy impact and effectiveness of Vision Zero on traffic fatalities and serious injuries, by differing types of road users. Overall, the results suggest that Vision Zero is not a failure, in which one explanation is the outcomes of policy intervention analysis turn to be sensitive to the chosen time point at which the effects of policy intervention present. Evidence also suggests that the policy impact of Vision Zero on traffic safety differs by road users, in which compared to others, pedestrians have a potential to benefit from the policy implementation to a larger degree. The study concludes that working towards eliminating traffic fatalities and serious injuries, further efforts on concrete methods and strategies in advancing policy implementations and understanding equity impacts of Vison Zero are needed.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04894
Paper Title	**An Exploratory Analysis of Two-vehicle Crashes for Distracted Driving with A Mixed Approach: Machine Learning Algorithm with Unobserved Heterogeneity**
Abstract	Two-vehicle crashes, particularly due to distraction and impacting other vehicles, lead to a disproportionately higher number of fatalities and serious injuries over time. The intent of this study is to identify the contributing factors to driver injury severity with the assessment of the machine learning model and quantify those factors affecting injury severity outcomes for two-vehicle crashes in the US. The crash data were extracted from the Crash Report Sampling System (CRSS) from 2016 to 2018. This study applied an XGBoost to identify the top variables based on SHAP value by driver injury levels and mixed logit with heterogeneity in means and variances approach to model driver injury severity. The model results indicate that there is a complex interaction of driver characteristics, such as demographics (male drivers), driver actions (careless driving, driving over the speed limit more than 15 mph, hitting stopped vehicle), a driver without violation destroy, turning violation, drinking, roadway and traffic characteristics (non-interstate highways, undivided and divided roadways with positive barrier, curved roadways, dry surface condition), environmental conditions (rainy weather condition), vehicle characteristics (motorcycle, displacement volume up to 2500 cc, newer vehicle within 5 years from crash), temporal characteristics (afternoon peak: 4 to 6 PM, 3rd quarter of the analysis period (July to September), and analysis year of 2017). The results clearly indicate the importance of driving behavior and roadway design concerning distracted driving behavior that needs to be prioritized for driver training as well as the law enforcement, roadway design, and maintenance agency.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-04962
Paper Title	**Identifying Attribute Associations in Fatal Speeding Crashes with Latent Class Clustering and Association Rule Mining**
Abstract	Speeding has been distinguished as one of the most frequent and persistent contributing factors and is considered to be a critical contributing factor to the degree of injury severity. In the United States, at least a quarter of nationwide annual fatal crashes during the last decade involved speeding. There is still a need for an overarching look at the crashes involving speeding by considering a wider set of crash, roadway, driver, and vehicle characteristics. This paper mitigates the research gap by investigating the collective impacts of variables in homogenous crash clusters by focusing on fatal crashes with FARS data Using crash data of 2015-2019 from the fatality analysis reporting system (FARS) repository, this study applies latent class clustering (LCC) to obtain homogeneous clusters of fatal speeding crashes addressing the unobserved heterogeneity. Assoication rule mining (ARM) has been applied to the homogeneous clusters to find hidden patterns. The finding of association rules – such as motorcycle speeding single vehicle crashes during weekends and in dark-unlighted condition etc. The results of this research and interpretative findings are expected not only to improve the knowledge of speeding-related crash mechanism and but also to provide important insights on countermeasure development

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-23-01889
Paper Title	**Evaluating University Students' Safety Behavior on Three-Wheel Electric Rickshaw**
Abstract	Three-wheel electric rickshaw (TWER) is an environmental-friendly and energy-efficient mobility option which have gained popularity in recent times. However, the increasing number of TWERs has led to serious concerns about the safety behavior of the passengers. This study is the first research exploring the safety behavior on TWER for university students in Bangladesh. This study synthesizes the theoretical insights from the Theory of Planned Behavior (TPB), Awareness Interest Desire Action (AIDA), and Health Belief Model (HBM) to identify the factors influencing users' safety behavior. Structural equation modeling (SEM) and Bayesian structural equation modeling (BSEM) were used to investigate the safety perception of 798 participants from 5 universities in Gazipur. The two alternative statistical models are used for comparison between results and suggestions for future use. Results reveal safety behavior is directly influenced by perceived severity and perceived susceptibility furthermore safety awareness has a positive significance on the perceived severity and susceptibility of harm related to unsafe behavior. Hence, users' safety behavior is considered indirectly influenced by safety awareness which is further affected only by their attitude. Based on the model fitness and result, BSEM performs better than SEM. This research concludes by discussing implications for transportation planners and policymakers to enhance TWER safety on road.

Lectern Session 3174

The Best of the Best Performance Effects of Geometric Design Paper Submissions
Tuesday, January 10 3:45 PM- 5:30 PM ET
Convention Center, 101
Lectern | *PDH*

Sarah Binkowski, HNTB Corporation

Sponsored by:
Standing Committee on Performance Effects of Geometric Design (AKD10)
Standing Committee on Freeway Operations (ACP20)
Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Kimberly Venegas, UCLA: University of California Los Angeles Brian Taylor, University of California, Los Angeles Severin Martinez, City of Los Angeles
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Freeway Operations (ACP20) Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lectern Session 3174
Session Title	**The Best of the Best Performance Effects of Geometric Design Paper Submissions**
Paper Number	TRBAM-23-01048
Paper Title	**TAKE THE HIGH (VOLUME) ROAD: Analyzing the Safety and Speed Effects of High Traffic Volume Road Diets**
Abstract	Cities nationwide have adopted so-called "road diets" to improve traffic safety, though they are sometimes met with vitriolic opposition from motorists who fear that road diets will increase traffic congestion. Road diets typically convert four-through-traffic lane arterial roadways with no left turn lanes, into streets with a center left-turn lane, two through-through traffic lanes, and (often) bicycle lanes and right turn pockets at intersections. The resulting safety improvements are often dramatic, though most road diets have been on road segments with average daily traffic (ADT) levels below 20,000 vehicles. Indeed, the Federal Highway Administration currently recommends that road diets not be applied to roadways with greater than 20,000 ADT. But there has been little study of high-volume road diets, so it is not at all clear that the safety benefits erode, and traffic delays increase above this threshold. To address this gap in the literature, we examine the safety outcomes of high ADT road diets in Los Angeles. To do this, we compared collisions on five high ADT road diet corridors to 16 similar multi-lane, untreated streets segments. We found safety increased an average of 37 to 200 percent, depending on the measure, while traffic speeds on these high-traffic-volume corridors increased by about 7 to 9 percent. We conclude that road diets, even in higher volume contexts, appear to be an effective means of improving street safety with only minor effects on traffic speeds.

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Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Standing Committee on Freeway Operations (ACP20) Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lectern Session 3174
Session Title	**The Best of the Best Performance Effects of Geometric Design Paper Submissions**
Paper Number	TRBAM-23-01075
Paper Title	**Association between Horizontal Curve Geometry and Single Vehicle Crash Occurrence on Rural Secondary Highways**
Abstract	Single-vehicle crashes are overrepresented on horizontal curves along the rural two-lane undivided highways. While prior work investigated the relationship between crash occurrence and aggregate curve characteristics, several important aspects related to curve geometry remain uninvestigated. To this end, research was undertaken to evaluate the safety impacts associated with several specific horizontal curve-related geometric characteristics (including curve type, curve direction, tangent distance between curves, and curve design speed) on rural two-lane undivided highways, considering non-animal single-vehicle

crashes. Crash data were obtained from the Michigan statewide databases between the years 2011 and 2018 for 277 miles and 557 miles of curved state and county highway segments, respectively. Several mixed-effects negative binomial models, with county- and site-specific random intercepts, were developed separately for state and county highways. The model results indicated that several key geometric factors, including curve type, curve direction, tangent distance approaching the curve, inner-curve tangent distance, and curve design speed, were associated with crash occurrence on rural two-lane highways. Each of the following geometric characteristics was associated with elevated single-vehicle crash occurrence: compound and reverse curves (compared to simple curves), left-turning curves (compared to right-turning), curves with design speeds lower than speed limit (compared to curves with higher design speeds), longer tangent distances leading into a simple curve or the initial curve in a series, and shorter inner-curve distances between successive compound or reverse curves. These results contribute to the limited body of knowledge regarding the safety performance of specific geometric characteristics associated with horizontal curve on rural two-lane highways.

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

Session Number Lectern Session 3174

Session Title **The Best of the Best Performance Effects of Geometric Design Paper Submissions**

Paper Number TRBAM-23-03200

Paper Title **Sightline and Reliability Analysis for Offset Right-Turn Lanes**

Abstract Offset right turn lanes (ORTLs) separate right-turn lanes (RTLs) from the adjacent through lane so that vehicles in the separated RTL do not obstruct the view of the minor-road driver. This is especially critical at minor-road stop-controlled intersections where the RTL is on the uncontrolled approach. A crash analysis of ORTLs shows a trend that ORTLs may reduce intersection-related crashes compared to conventional RTLs; however, the results were not statistically significant. As an alternative to quantifying the crash reduction of ORTLs, a sightline and reliability analysis model was developed to quantify the percentage of time in which a stopped driver on the minor-road approach will have an obstructed view due to right-turning vehicles on the major-road approach. The model takes into account the horizontal and vertical alignment of the major-road approach, major- and minor-road cross sections, type of ORTL (parallel or tapered), turning movement volumes, lane utilization on multilane approaches, design vehicle dimensions, and up to three design vehicles. The model formulation is documented and an example application of the model is presented. Agencies will be able to use the reliability analysis model to prioritize RTLs to convert to ORTLs.

Poster Session 3196

Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others
Tuesday, January 10 3:45 PM- 5:30 PM ET
Convention Center, Hall A
Poster

Karen Dixon, Texas A&M Transportation Institute

Sponsored by:
Standing Committee on Safety Performance and Analysis (ACS20)

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-00574
Paper Title	**A Monitoring Framework for Riding Safety of Delivery Scooters using 100 Naturalistic Riding Study (NRS) Data**
Abstract	A traffic safety issue of two-wheeled delivery scooters is emerging due to the rapid increase in demand for food delivery service. In particular, the strict restriction of delivery time leads to aggressive and dangerous riding behavior that causes a high risk of crash occurrence. Systematic traffic safety management is required to effectively prevent crashes of delivery scooters. The objective of this study is to develop a monitoring framework of riding safety that informs when, where, and how serious safety problems occur. High- resolution riding behavior data obtained by an inertial measurement unit (IMU) sensor installed on delivery scooters, which was a part of the Korean 100 naturalistic riding study (K-100NRS), were used for developing the methodology. The proposed monitoring framework consists of two components: an unsafe riding event detection algorithm and a method to identify the spatial and temporal identification of riding risks. The ratio of frequency of unsafe events to total riding time for each rider is defined as a monitoring index, which is referred to as the riding risk index (RRI) in this study. Approximately 95% detection accuracy was achievable by the developed detection algorithm. In addition, the level of riding safety for each rider was evaluated based on the proposed methodology. As an application, a visualization of detected unsafe events was presented for the purpose of riding safety monitoring.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-00635
Paper Title	**Predicting Pedestrian Crash Occurrence and Injury Severity in Texas Using Tree-Based Machine Learning Models**
Abstract	This study investigates the frequency and injury severity of pedestrian crashes across Texas using tree-based machine learning models. Ten years of police records are used along with roadway inventory and other sources to map more than 78,000 pedestrian crashes over 700,000 road segments along with road design, land use, transit stops, and hospital location and weather information. Methods such as random forests (RF), gradient boosting (LightGBM and XGBoost), and Bayesian additive regression trees (XBART) are applied and compared. The crash frequency models indicate that highway design variables significantly positively impact crash frequencies. Increments in total or fatal crash counts are related to a higher number of lanes, while higher speed and greater median and shoulder widths lead to fewer crash frequencies. Other variables such as proximity to schools, the number of transit stops, and population and job density increased pedestrian crash occurrences. Pedestrian severity models found that a high speed limit significantly increases the likelihood of pedestrian fatalities and severe injuries, and intoxicated drivers and pedestrians lead to more severe injuries. Also, pedestrian crashes are more likely to be severe and fatal at night and in areas with poor lighting conditions. An analysis of the vehicle type found that light-duty trucks

(pickups, SUVs, and vans) also increase pedestrian severity. The comparison of the four models indicates that they performed similarly in predicting crash occurrences, with LightGBM showing significantly lower computational time. While for crash injury severity models, XBART obtained a higher precision value but with a significantly high computational time.

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Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)

Session Number Poster Session 3196

Session Title **Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**

Paper Number TRBAM-23-01246

Paper Title **Investigating Pedestrian Crash Patterns at High-speed Intersection and Road Segments: Findings from unsupervised learning algorithm**

Abstract Pedestrian crashes at high-speed locations are a persistent road safety concern. Driving at high speed essentially indicates that the driver would get considerably less time to react and make evasive maneuvers. On top of this, other crash contributing factors such as humans (pedestrian or driver), vehicles, roadway, and surrounding environmental factors actively interact together to cause a crash at high-speed locations. Moreover, the pattern of pedestrian crashes differs significantly according to the high-speed intersection and segment locations which require further investigation. This study applied Association Rules Mining (ARM), an unsupervised learning algorithm, to reveal the hidden association of pedestrian crash risk factors according to the high-speed intersection and segments separately. The study used Louisiana pedestrian fatal and injury crash data from 2010 to 2019. Any crash location with a posted speed limit of 45 mph or above was classified as a high-speed location. Based on the generated association rules, the results show that pedestrian crashes at the high-speed intersection are associated with left/right turn vehicle movement, older drivers (>64 years), young drivers (15-24 years), pedestrian violations, pedestrian alcohol/drug involvement and so on. Most pedestrian crashes at high-speed segments are associated with roadways with no physical separation, dark-no-streetlight conditions, open country locations, interstate, and so on. The findings of the study are expected to provide a better understanding of the pedestrian crash patterns at high-speed intersections and segments. Highway safety professionals can utilize these findings to conduct a decision-making process for selecting appropriate countermeasures to reduce pedestrian crashes in high-speed locations.

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Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)

Session Number Poster Session 3196

Session Title **Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**

Paper Number TRBAM-23-01415

Paper Title **Behavioral Pathway Analysis of Pedestrian Injury Severity in Pedestrian-Motor Vehicle Crashes**

Abstract Despite the health and environmental benefits of walking as an active and sustainable mode of transport, the increasing number of road crashes involving pedestrians has become a public health concern. This study investigates the direct and indirect effects of various contributing factors on pedestrian injury severity in pedestrian-motor vehicle crashes. Data of pedestrian-vehicle crashes from North Carolina between 2015 and 2019, including the pedestrian pre-crash actions and injury severity, were used. Path analysis was applied to uncover the interrelationship between contributing factors, pedestrian pre-crash behaviors, and injury severity using random parameter ordered logit and mixed logit models. The results indicate that pedestrian intoxication, lighting condition, number of lanes, speed limit, and vehicle type contribute directly and indirectly (through pre-crash behaviors) to increasing injury severity. At an intersection or stop-and-go traffic control, pedestrians are more likely to sustain severe injuries for failing to yield to traffic given a crash. This study provides valuable information about the relationship between various crash factors and pedestrian injury severity. For researchers and agencies interested in pedestrian safety improvements, this study gives valuable insight by uncovering the roles of pedestrians' pre-crash action on injury severity outcomes. For countermeasures, the study recommends better street lighting and reevaluation of posted speed limits on roads with high pedestrian traffic. Also, a regular educational campaign should inform pedestrians about the importance of yielding to traffic on the right of way.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-01435
Paper Title	**What Causes TW Riders Being Run Over During Road Accidents? An Investigation Using Machine Learning and In-depth Accident Survey Data**
Abstract	Objective Insufficient study has been conducted to determine what carries out the run-over accidents (ROAs). The purpose of this study is to identify influence factors for ROAs, which can provide a direction for revealing accident injury mechanism and developing protection implement. Methods Three models based on machine learning and interpretable method are employed. In this study, the dependent variable is whether the accident resulted in a ROA. Moreover, we examine the characteristics of TW vehicles, motor vehicles, and collisions as independent variables. Data for the analysis are taken from the China In-Depth Accident Study database for the period 2017 to 2020. Results All three machine learning models achieve a high level of prediction accuracy (more than 93.2%). Thereinto, LightGBM outperformed the XGBoost and GBDT. This is the first time that the primary factors leading to ROAs have been identified. Longer and wider motor vehicles are more likely to cause ROAs. Further, motor vehicles approaching from the left side of the TW are more likely to crush TW riders. In addition, a panoramic view in the rearview mirror is important for preventing ROAs. Conclusions This study reveals an essential difference between run-over accidents and any other type of TWs' accident. In practice, motor vehicles with larger front wheelbases and/or width should be separated from TWs in areas, due to an increased likelihood of run-over accidents. To prevent run-over accidents from the left side of the two-wheeler, a blind zone warning system is recommended for motor vehicles.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-01748
Paper Title	**Investigating Factors that Affect Conflicts Between Bicyclists and Right Turning Vehicles at Signalized Intersections**
Abstract	Due to the recognition of active transportation as a beneficial alternative to more traditional modes of transportation, there is increasing interest in designing infrastructure systems to promote the safe use of forms of active transportation such as bicycling. Collision data, which are typically used in road safety studies, may be incomplete and the use of such data is reactive as it requires collisions to have already taken place. Additionally, collisions involving bicyclists and vehicles are less common than those between vehicles. As a result, alternative approaches of evaluating the safety effect of various infrastructure attributes, such as the use of surrogate safety measures, specifically traffic conflicts, could be considered. Most collisions between bicyclists and vehicles occur at intersections and of these, collisions between right turning vehicles and bicyclists form the majority. The main objective of this study was to use cross-sectional regression models to investigate various intersection characteristics, including geometry, signal phasing, and bicycle infrastructure, with a view to determining which attributes are associated with a significant effect on right turning conflicts and how this may change with different conflict severity levels. Various intersection attributes were found to be associated with the frequency of right turning conflicts such as exposure levels, the lateral offset of the bicycle facility and the grade of the approach to the intersection. The significance levels of the associated effects of certain attributes were observed to change with the severity level of the conflicts, with effects becoming either more or less significant with increased severity levels.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-02686
Paper Title	**Applying Few-Shot Learning in Classifying Pedestrian Crash Typing**
Abstract	Pedestrian deaths account for 23% of all road traffic fatalities worldwide. After declining for three decades, pedestrian fatalities in the United States have been increasing with 6,941 fatalities in 2020- the highest number in more than two decades, by impeding progress toward a zero-deaths transportation system. The Pedestrian and Bicycle Crash Analysis Tool (PBCAT) was developed to describe the pre-crash actions of the parties involved to better define the sequence of events and precipitating actions that lead to crashes involving motor vehicles and pedestrians or bicyclists. Undoubtedly, police crash data influences decision-making processes for the transportation agencies. Using crash data from three major cities in Texas (during 2018-2020), this study assessed the data quality of police reported crash narratives on pedestrian involved traffic crashes. As the pedestrian crash typing involves many categories, conventional machine learning algorithms will not be sufficient in solving the classification problem from narrative texts. This study used few short learning, an advanced machine learning, to solve this issue. Using the pre-knowledge obtained from five different crash types and a few labeled data points of three unseen new crash types, the proposed model achieved a roughly 40% overall accuracy. Also, four different configurations of crash types were formed and tested which indicates that the model is robust.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-03503
Paper Title	**Investigation of Cyclists Impact in Road Crashes**
Abstract	Cyclists are usually seriously injured when involved in crashes with vehicles. This research aimed to examine the cyclist kinematics and ground effects using video recordings of real-world crash cases. The impact speeds and cyclist kinematics were analyzed for all crashes. The most frequent type of kinematic, forward, accounted for 42.8% of sedan crashes and 53.8% of SUV crashes. The angle of rotation of the cyclist and kinematic relies on the front form and rate of impact of a car. The angle of rotation of cyclists and kinematics are based on the front shape and speed of the impact of a car. The findings of the study would be useful for future research on cyclists' safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-03592
Paper Title	**Identifying Corner Cases in Fatal Pedestrian-involved Crashes: Application of Unsupervised Machine Learning Approach**
Abstract	In recent years, fatal crashes have increased. The number of pedestrian fatalities as vulnerable road users was 6,516 in 2020, indicating a 3.9% increase from 2019. While all fatal pedestrian-involved crashes represent critical cases, some crashes occur in rare and extreme circumstances called “corner cases.” These crashes can potentially challenge the performance of Connected and Automated Vehicles (CAVs) in safety-critical circumstances. Hence, systematically exploring corner cases is critical. This study aims to identify corner cases in fatal pedestrians-involved crashes by analyzing the Fatality Analysis Reporting System (FARS) 2020 data. To this end, a systematic procedure is developed using an unsupervised machine learning approach, K-means clustering. The results indicate that various critical factors trigger corner cases, but all corner cases result from a combination of some crucial events simultaneously. For instance, the presence of certain critical factors, including darkness, a rural context, intoxication of pedestrians and/or drivers, severe weather conditions, and hazardous pedestrian behavior such as crossing expressways, dash/dart out, and pedestrians walking along the roadway on a curve that obscures the pedestrian, can be present simultaneously in the corner cases. Some potential solutions to overcome such extreme scenarios arise from the improvement in CAV technologies. The findings imply that identifying corner cases in fatal pedestrian-involved crashes is critical as they involve performance beyond the capabilities of the CAVs, and auto manufacturers should consider such complex cases to improve the performance of their vehicles.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-03777
Paper Title	**An Experimental Analysis using Automated Trajectory Data to Evaluate Motorcyclist Interaction at Unsignalized Interaction**
Abstract	In a developing country like India, where the share of motorcyclists is increasing exponentially, their accidents are also rising at an alarming rate. Most of these road accidents occur at unsignalized intersections. Therefore, the present study aims to analyze the safety of motorcyclist at unsignalized three-arm intersections under heterogenous traffic environment using a fully automated trajectory data analysis. To do so, firstly the study examines which interactions are more commonly observed between motorcyclists and other road users at unsignalized intersection. Then, the study investigates how motorcyclist are interacting with other vehicles and how other vehicles are interacting with motorcyclists in terms of their speed during an interaction. Finally, as a supervised classification technique, Support vector machine (SVM) was used for categorizing the interactions into severe, moderate and safe on the basis of surrogate safety measures (SSM) and maximum interacting speed of vehicle. The results indicates that rear-end conflict were the most commonly occurring conflict at the unsignalized intersection, followed by crossing conflicts. Further, the results reveal that at an unsignalized intersection, most of the severe interaction occurred during rear-end conflicts between motorcycle-motorcycle and motorcycle-car interaction. Overall, the research provides an essential insight into the motorcyclist safety at an unsignalized three-arm intersection which can be used as a base to implement interventions aimed towards reducing motorcyclist accidents and for evaluating countermeasure effectiveness for motorcyclists at unsignalized intersection.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-04294
Paper Title	**Influence of Built Environment on Micromobility-Pedestrian Accidents**
Abstract	The use of Micromobility(MM), which has been expected effects reducing traffic congestion and greenhouse gas as sustainable urban mobility, has been rapidly increasing across the world. However, this growth has resulted in a considerable number of MM-related accidents. Most of previous studies have explored to MM user injuries to improve the safety of MM user, but it still incompletely understood of the pedestrians who vulnerable road users were threatened by MM. Therefore, this study aims to identify that built environment factors that contribute to MM-pedestrian accidents using MM-pedestrian accident data in Seoul, Korea from 2019 to 2021, and the spatial unit was set as a hexagonal grid with an apothem of 150m. We employed the SZINB(Spatial Zero inflated Negative binomial) model controlling spatial autocorrelation, zero-inflated, overdispersion. As a main result of analysis, we found that road intersection, sidewalk, and bicycle road have a significant correlation with MM-pedestrian accidents. This study suggested that recommended measures: improving of the intersections to be reduced the speed of MM users, sidewalk design that can prevent MM from use of sidewalks, and expansion of completely separated bicycle road.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-04328
Paper Title	**Learning from Moped Crash Data: Safety Factors and Hazardous Scenarios Analysis**
Abstract	Mopeds are light vehicles that provide solutions for short travels, traffic congestion, and environmental pollution issues. However, due to limited physical protection provided by the small vehicle structure, moped riders are more likely to suffer from severe injuries from a crash than vehicle passengers. This study aims to investigate the features and patterns associated with recent moped crashes. This study analyzed the injury severity, and related risk factors to 1,657 moped crashes in Michigan during the recent five years from 2017 to 2021. Two ordered logistic regression models were built to examine the association between crash injury severity levels and 13 variables from three main categories: crash features, rider behaviors/cognitive status, and environmental conditions. The descriptive statistics showed that 79% of moped riders' injuries from crashes were minor or less while the injured riders tend to be younger, male, and not wearing a helmet. According to the model results and odds ratio analysis, the rider injury severity was associated with crash type, riders' mental status (e.g., drinking, careless riding), riders' maneuver behavior (speeding, disregarding traffic control involved), visibility (light condition), and rider age. Head-on crashes and single crashes were two leading crash types resulting in severe/fatal injuries. The results suggested that moped riders should pay more attention to the road, especially when riding at nighttime and should avoid impaired riding. Advanced rider assistance functions, regulations on risky riding behavior (e.g., drinking, speeding, and helmet usage), and additional recommendations on riding age and time are expected to greatly improve moped safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-04347
Paper Title	**Extreme Value Theory Estimation of Vehicle-Pedestrian Safety Surrogates at Intersection with Right-Turn Flashing Yellow Arrow Indication**
Abstract	Traffic conflicts and surrogate safety measures (SSM) have been used as an alternative to crash-based methods to study roadway safety. Extreme value theory (EVT) offers a modeling framework that can be used to expand the use SSM to conduct proactive safety evaluations. This study explores the EVT modeling approach to analyze vehicle-pedestrian interactions and compare safety risks between a site with a right-turn flashing yellow arrow (RT FYA) indication and sites with a permissive circular green indication. Using trajectory data extracted from video using a frame-by-frame analysis approach, post-encroachment-time (PET) values were determined along with an obstructed right turn time (ORTT) measure which is defined as the time it takes a vehicle to complete a right turn maneuver when a conflicting pedestrian is present. At-site univariate and bivariate extreme value theory models were developed using the block maxima (BM) approach and the peak over threshold (POT) approach. Additionally, joint-site univariate and bivariate Bayesian hierarchical models were developed for each approach. Using the resulting estimates, the number of crashes was estimated for each model and compared to the observed crashes. Results showed that models using ORTT produced a better fit model with their covariates indicating that ORTT helps describe traffic interactions objectively. The number of crashes estimated from the Bayesian hierarchical models was found to also be closer to the observed number of crashes than those from other models. Particularly, Bivariate Bayesian hierarchical models outperformed the at-site models (univariate and bivariate) and the univariate joint-site model in terms of crash estimation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-04513
Paper Title	**Estimating Pedestrian Crashes near Bus Stops**
Abstract	Among many potential risk factors, the presence and proximity of transit bus stops are very distinctive in the pedestrian involved crashes, especially in urban areas. Efforts to address pedestrian crashes near bus stop locations should begin with a comprehensive understanding of the characteristics associated with these crashes. The objective of this research study is to develop a pedestrian crash frequency model to identify the significant variables affecting pedestrian crashes near bus stop locations and to estimate pedestrian crashes at bus stop locations which are of prime importance, mainly in large metropolitan cities. To accomplish the study objective, the authors collected pedestrian safety data within the vicinity of 627 bus stop locations in Dallas. The pedestrian crash frequency model developed in this study showed that the variables that had the most influence on pedestrian safety at bus stops are traffic volume on the street, distance to nearest intersection, lane count, median type/width, bus stop design, and land use. The study findings provide important insights to inform future policy decisions related to bus stop design and implementing safety countermeasures at bus stops for improving pedestrian safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-05126
Paper Title	**Using Text Mining and Machine Learning Methods to Automate Pedestrian Crash Typing**
Abstract	Pedestrians are one of the most vulnerable groups involved in traffic crashes. Detailed information is required to understand factors that affect pedestrian crashes. This information, typically available in crash report narratives, requires manual work to extract. Version 3 of the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) provides simplified pedestrian crash types and a user-friendly tool, but still requires manual work to extract the required information. This can be time consuming for states with large numbers of bike/ped crashes. To overcome the manual process, this study explored automated technologies to extract the required data elements for crash typing from crash report narratives. By using text-mining and machine learning, this study automatically classified the pedestrian maneuver, one of the critical data elements necessary to determine the crash type. Using a sample of 500 crash reports from Florida, the report narratives were converted into vectors through text preprocessing, cleaning, and transformation. Then, the vectorized data was enhanced by adding Pre-crash Direction, an essential indicator for identifying the pedestrian maneuver at-crash. Machine learning was then used to obtain pedestrian maneuver information. Among the three machine learning models applied, the Random Forests performed the best, with a prediction accuracy of 82%. A larger sample could be used in the future for better classification results. The study concluded that it is possible to extract the required information and automate the process of pedestrian crash typing. By generating the crash types faster, this approach can support a more streamlined safety analysis and countermeasure development.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-23-05259
Paper Title	**Assessing the Risk of Pedestrian-Involved Crashes at the Link Level Using High-Resolution Location-Based Data**
Abstract	Most existing studies concerning individual pedestrian behavior and crash risk have been focused on a limited number of locations due to the constraints of traditional video or sensor-based data collection methods—thus failing to sufficiently discuss the impact of link-level attributes on pedestrian safety, especially with regard to mid-block crossing behavior. The commonly seen mid-block crossing behaviors, often leading to more severe consequences to vulnerable road users are thus barely accounted for in the analysis of pedestrian-involved crashes. To fill that gap in research, this study has taken advantage of extensive location-based pedestrian data, which enable the identification of individual crossing behavior of a large population regardless of the spatial relation to a crosswalk. The impact of link-level features, including traffic- and geometry-related factors on crossing behavior are then investigated. By controlling for the frequency of mid-block crossing behavior as an innovative independent variable in the analysis, this study identifies the contributing factors to pedestrian-involved crashes at the link level more comprehensively. The results from zero-inflated Negative Binomial and Poisson regression models reveal that links with a higher proportion of mid-block crossing violations are more likely to experience the occurrence of pedestrian-involved crashes, whereas a higher number of all crossings is associated with an increase in the frequency of crashes. Further, the findings indicate that various link features tend to influence crash frequency; however, only link type and free flow speed are found to be associated with the probability of crash occurrence on the link.

Poster Session 3215

Safety Models: New, Evolving, and Refreshed

Tuesday, January 10 6:00 PM- 7:30 PM ET
Convention Center, Hall A
Poster

Karen Dixon, Texas A&M Transportation Institute

Sponsored by:
Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Jinbao Zhang, Central South University Jaeyoung Lee, Central South University Mohamed Abdel-Aty, University of Central Florida Ou Zheng, University of Central Florida Guiming Xiao, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-00512
Paper Title	**Enhanced Index of Risk Assessment of Lane-Change on Expressway Weaving Segments**
Abstract	Vehicles frequently change lanes at weaving segments, and there is a high probability of collision. To assess the risk of lane-change, this study proposes a novel lane-change risk assessment index (LCRAI), which takes both exposure time and conflict severity into consideration. First, the generalized time-tocollision (GTTC) and exposure-to-risk index (ERI) are proposed to evaluate conflicts during lane-change, and then a spatiotemporal overlap analysis is applied to exclude the cases when two vehicles arrive at the conflict area at different time. Second, the change of velocity after a crash occurrence is calculated and used to evaluate the severity risk (SRI). Finally, ERI and SRI are combined to compute the LCRAI. A case study of a weaving segment is conducted, and the weaving segment is divided into four sections to compare their risks. The LCRAI show that the middle section is the most dangerous while the last 100 m section is the safest on the weaving segment.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-00681
Paper Title	**Investigating the exposure-lag-response association of hourly weather and speed variation factors on rural freeway crash risk: A space-time-stratified case-crossover study**
Abstract	Weather condition and speed variation information data are considered to be highly timevarying, and these factors not only have an impact on roadway crash risk during the hour when they occur, but they also have a lasting impact during the several lagged hours. In this study, hourly crash data on rural interstate highways in the state of Texas is used to investigate the exposure-lag-response association between four time-series variables and roadway level crash risk. The four time-series variables are hourly precipitation, hourly visibility, hourly speed standard deviation, and hourly temperature. Distributed lag linear models (DLM) and distributed lag nonlinear models (DLNMs) are applied to perform the analysis. These models are widely used in epidemiology and medical research. The results show that hourly precipitation, hourly visibility, and hourly speed distribution have an apparent exposure-lag-response association pattern on roadway crash risk whereas hourly temperature does not have an adverse impact on roadway crash risk.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-01162
Paper Title	**Crash Risk Prediction on Freeways Using a One-dimensional Convolutional Neural Network: Application to Risky Driving Behavior Data**
Abstract	With the advancement of data collection technology and the widespread use of navigation software, risky driving behaviors data of the vehicles on the road are available to researchers, providing a new perspective on road crash risk prediction. This study attempts to consider the potential local patterns in risky driving behavior data and develops a new crash risk prediction model on freeways by employing a one-dimensional convolutional neural network (1DCNN). Specifically, the crash data and the risky driving behavior data with vehicle-motion parameters on the Nanjing-Hangzhou freeway in China were introduced, and a case-control method was used to construct the sample dataset. Then, this study processed the raw data into multi-channel sequence data rather than traditional tabular data according to spatial relationship and driving behavior type. Moreover, a 1DCNN model was built to predict crash risk based on these sequence data and compared with several benchmark models in terms of performance. The comparison results suggest that the 1DCNN model outperforms others and can accurately identify 71.3% of crash data and 75.1% of non-crash data. The research findings have demonstrated that it is feasible to predict the crash risk on freeways using the 1DCNN model based on risky driving behavior data, which provides a valuable reference for achieving proactive traffic safety risk identification from the perspective of vehicle risky driving behaviors.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-01456
Paper Title	**Conflict Prediction of Merge Process on Roundabouts Based on CNN-LSTM Model with Attention Mechanism**
Abstract	ABSTRACT Conflict risk prediction is expected to play an essential role in traffic accident prevention. However, few related research studies have focused on roundabouts, especially the merger process. Therefore, a detailed analysis was carried out to fill this research gap. Based on microtrajectory data, this study analyzed roundabout merge conflicts from two-dimensional views in normal and tangential directions. A conflict prediction model of CNN-LSTM integrated with a convolutional block attention module (CBAM) attention mechanism is proposed, which can learn multiple features involving distance, speed, acceleration, and angle from merged vehicle groups. Besides, three commonly used models of CNN, LSTM, and CNN-LSTM are used as benchmarks to compare with the proposed model. The results show that the CNN-LSTM embedded with CBAM has excellent prediction performance with an accuracy of 96.48%, which is much higher than benchmark models. This indicates that the attention mechanism effectively captured important features when applied to conflict prediction. In addition, an interesting finding is the performance difference between CNN and LSTM for conflict prediction and crash prediction. In the study, CNN contributes significantly to merging conflict prediction while LSTM plays a less role. However, two models performed oppositely in previous crash prediction studies. The finding provides a meaningful research point for conflict prediction and collision prediction based on deep learning methods. Moreover, the study provides a practical reference for reducing conflicts and improving the traffic safety of roundabouts. Keywords: Conflict Prediction, Roundabout, Attention Mechanism, Deep Learning

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-01557
Paper Title	**Predicting the Duration of Geohazard Incidents on Road Networks Based on KaplanMeier Analysis and Random Survival Forest Model**
Abstract	The mountainous road network with special geological and meteorological characteristics is extremely vulnerable to nonrecurring accidents such as traffic crashes and geohazard breakdowns. Geohazard accidents significantly impact the operation of the road network. Timely and accurate prediction of how long geohazard accidents will last is of significant importance to regional traffic safety management and control schemes. However, none of the existing studies focus on the topic of predicting geohazard accident duration on regional large-scale road networks. To fill this gap, this paper proposes an approach integrated with the Kaplan-Meier (K-M) model and random survival forest (RSF) model for geohazard accident duration prediction based on text data collected from mountainous road networks in Yunnan, China. The results indicate that geohazard accidents in road networks have a strong aggregation in tectonically active, steep mountainous and fragmented areas. Especially the time of the rainy season, and the morning peak brings high incident occurrences. In addition, accident type, secondary accidents, impounded vehicles or personnel, morning rush hour, closed roads and accident management level significantly affect the duration of road geohazards. The RSF model outperformed the traditional hazard model (Cox proportional hazards regression) and other survival machine learning models (survival support vector machine) in terms of the C-index and the average area under the curve. Without censored data, the mean absolute error and mean squared error of the RSF model were 11.32 and 346.99, respectively, which were higher than the machine learning models (random forest and extreme gradient boosting model).

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-01658
Paper Title	**An Analytical Investigation of Traffic Safety and Stability Based on Car-following Model**
Abstract	Road traffic safety has long been a focal issue in the field of transportation research. The theoretical analysis of road traffic safety is still limited. In addition, the previous literature regards traffic string stability as an indicator of traffic safety. However, the detailed relationship between traffic safety and stability is still unclear, and there is a lack of relevant research. This study aims to analytically derive the traffic safety criterion based on a generic car-following (CF) model, and compare the traffic stability criterion and traffic safety criterion. In particular, both the real collision and the potential collision risk which is often quantified by surrogate safety measures (SSM), are adopted to assess traffic safety performance. The results of theoretical analysis are validated by simulations. Moreover, this work also obtains a specific and explicit relationship by comparing the traffic stability and safety criterion. The results show that regarding the infinite-size fleet, traffic string stability criterion is equivalent to non-crash criterion. While string stability is a sufficient but unnecessary condition for the non-crash criterion of a fleet with a finite number of vehicles. This study also demonstrates that string stability is a necessary but insufficient condition for traffic safety when SSMs are adopted as the traffic safety indicator. The findings of this research have the potential to not only improve the theoretical traffic safety analysis, but also provide guidance for automated vehicle design and safety assessment of human driving behaviors.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-02483
Paper Title	**Extensive Hypothesis Testing for Estimation of a Crash Data Count Model**
Abstract	Estimation of crash data count models requires extensive knowledge and significant hypothesis testing to choose the model distribution type, determine likely contributing factors, select transformations that can help capture trends, and find random parameters and associated distributions, among many other modeling decisions. Model development is often time-bound, and an analyst could introduce bias from past experience and knowledge of existing models to save time; potentially overlooking unique specifications. This study proposes a framework to assist during the estimation of crash data count models. The proposed framework includes a mathematical programming formulation that minimizes the Bayesian Information Criterion (BIC) to find potential model specifications. The mathematical program is solved through a range of metaheuristic solution algorithms to provide efficient results over a complex nonconvex search space, including alternative search strategies for unique data sets. Two data sets and three metaheuristics were tested.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-02533
Paper Title	**Freeway Safety Influencing Factors Using Catboost Model and Interpretable Machine Learning Framework SHAP**
Abstract	Exploring and analyzing safety influencing factors can guide to targeted traffic safety management. Traditional traffic safety models are aimed at specific data problems and adjustment to the model structure, which lack focus on predictive ability and have limited information on analysis of influencing factors. In recent years, machine learning methods opened new avenues in modelling, which have higher prediction accuracy, can identify complex nonlinear relationship, and can overcome the over/under dispersion and correlation. However, it also faced with the problem of limited interpretability. The interpretable machine learning framework SHAP can be an effective solution, which can not only reflect the influence of features in each sample but also generate global interpretation. This study utilized electronic toll collection data and used Catboost model to establish a traffic safety model, which was compared with traditional negative binomial regression model. SHAP was used to analyze safety influencing factors from the aspects of geometric design features, traffic operation characteristics, and hour of day. Results confirmed that the Catboost model has better prediction ability and is more suitable for establishing traffic safety model than the traditional NB regression model. The relationships between each of the safety influencing factors and crashes were also concluded, such as, ramp type is the most important factor of freeway crash frequency, curve type has a great positive impact while truck proportion has a great negative impact, traffic volume is highly correlated with truck proportion, etc., which provided theoretical support for safety operation management and targeted improvement measures of freeway.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-02688
Paper Title	**A Method for Short-Term Prediction of Driving Risk Based on LGBM**
Abstract	With the gradual popularization of advanced driver assistance systems, a large amount of refined information such as the vehicle itself and its surrounding environment can be obtained during driving, providing data support for short-term driving risk prediction. This study proposes a threshold update method for risk indicators based on Monte Carlo simulation to further extract risk events; the optimal risk prediction advance time and window width are determined by a variable sliding window method; A short-term risk prediction method integrating combines sample imbalance processing, feature screening, model prediction and risk influencing factor analysis. The method is validated and tested on a dataset of 88 real car driving. The test results show that the optimal risk prediction window advance time and window length are 1.6 seconds and 1.2 seconds respectively; LGBM model has good prediction effect and predicted F1 scores reaches 87.90; the prediction effect of using different data sources is different, and the data containing all the information of the pedestrian, vehicle and surroundings has the best prediction effect. In addition, the SHAP analysis show that speed, TTCi and accelerator are particularly important for perception of driving risks. The method proposed in this paper can well meet the risk prediction requirements of future ADAS. Through various types of vehicle perception data collected in real time, it can identify and predict driving risks in advance in a short time, helping drivers or safety systems to avoid or mitigate earlier risk.

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Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-02764
Paper Title	**Relationship analysis between traffic flow, risky driving behavior, and crash probability in spatiotemporal using a dynamic Bayesian network**
Abstract	Active crash prevention is a challenging problem in traffic safety study. Implementing preventive measures based on the precursory characteristics of crash is crucial to reducing traffic crash rates. The widespread use of in-vehicle navigation terminals enables real-time data collection on risky driving behavior and the traffic status of the entire roadway. Therefore, we used these data and extracted traffic flow and risky driving behavior data for 30 min before a crash in three road segments. A dynamic Bayesian network model was used to determine the relationships between traffic flow, risky driving behavior, and crash probability in time and space. The prior probability and posterior probability of the Bayesian networks were used to obtain the temporal and spatial relationships before the crash. The results showed that the model achieved a crash sensitivity of 83.24% with a false alarm rate of 15.75%, and the crash classification accuracy of 84.16%. The traffic flow and risky driving behaviors had distinct temporal and spatial characteristics before the crash, and their changes led to an increase in the probability of traffic crashes. Temporally, a higher crash probability occurred in the 10 min before the crash. Spatially, changes in the traffic flow and risky driving behavior in the downstream segment were associated with higher crash probabilities. The results show that we can infer the probability of traffic crashes from the temporal and spatial changes of traffic flow and risky driving behavior. And then provide help for the formulation of precise traffic crash prevention measures beforehand.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-03068
Paper Title	**Road Collision Analysis and Accident Prediction Using Neural Networks**
Abstract	Road travel accounts for most traffic accidents that have caused injuries, death, and property damage worldwide. Improvements in road traffic safety education, recent advancements in-vehicle technology, and other environmental factors have decreased the number of road traffic accidents in developed nations. Many provincial and local governments envision the possibility of zero fatalities from road traffic accidents in the near future. Developing a proper accident prediction model to support such a vision is crucial. This study explores determinants of road collisions, emphasizing harsh winter weather. It then compares classical and Machine Learning models for collision prediction. Furthermore, it introduces the most influential factors in crashes concerning severe winter weather. All study parts are performed on the collisions data in Calgary, Alberta, Canada, between 2017 to 2020. It is shown that all the weather attributes are correlated to collisions. It shows the importance of considering the weather attributes in accident analysis and prediction. Based on the nature of the collision dataset, which is tabular and heterogeneous, Neural Networks showed higher performances than the other investigated models, with 92% accuracy. The developed models would allow transportation planners to apply these models for evidence-based policy implementation, including new speed limit recommendations. For instance, Speed limit reduction on one of the busy highways from 100 to 90 km/h resulted in a 5% accident reduction and consequently a 4.8% less daily CO2 emissions, equal to the amount of CO2 emitted by 10 Canadians in their households per year.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-03171
Paper Title	**Accounting for Regional Heterogeneity in Crash Data with Excess Zero Observations: A Grouped Random Parameters Negative Binomial-Lindley Approach**
Abstract	Developing robust and reliable statistical models to estimate, understand, and analyze crash data is a key element in various highway safety evaluation tasks. Crash data have characteristics not found in other data, including but not limited to the excess number of zero responses. The Negative Binomial-Lindley (NB-L) model has been proposed as a method to analyze data with many zero observations. In addition, the differences in various temporal and spatial factors result in variations of model coefficients among different groups of observations. A grouped random parameters model is a strategy to account for such unobserved heterogeneity. In this paper, we proposed the derivations and applications of the grouped random parameters negative binomial-Lindley model (G-RPNB-L) to account for the unobserved heterogeneity in crash data with many zero observations. We first illustrated our proposed model by designing a simulation study. The simulation study showed the ability of the proposed model to correctly estimate the coefficients. Then, we used an empirical dataset in Maine to show the application of the proposed model. We showed that the impact of weather variables denoting “Days with precipitation greater than 1.0 inch”, and “Days with temperature less than 32°F” varies across Maine counties. We also compared the proposed model with the NB, NB-L, and grouped random-parameters NB (GRPNB) models using different goodness-of-fit metrics. The proposed G-RPNB-L model showed a superior fit compared to the other models.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-03482
Paper Title	**Exploring the Impact of Different Parameterizations on Developing Calibration Functions**
Abstract	Crash prediction models play a pivotal role in highway safety evaluations and analyses. In fact, various tasks, instructions, or guidelines documented in Highway Safety Manual (HSM) rely on these models, including but not limited to network screening, or hotspot identifications. The HSM documented crash prediction models to estimate the number and severity of crashes for several facility types. However, since these models were developed using data from select states in the United States and a given period, they should be calibrated to the local conditions when applied to a new jurisdiction, or over time. The HSM recommended using a single scalar calibration factor to calibrate the models. Recently, researchers proposed using a calibration function, instead of a factor, to calibrate the models. The calibration function can also be derived using explanatory variables, such as traffic flow or segment length. However, it is not clear what parameterizations should be considered in developing a calibration function. We considered 12 functional forms to develop calibration functions and compared their performance. We found that with a large and complete sample, a more complex function (with flow, and segment length) could produce a better fit. As the sample size reduces, simpler functions such as those developed with only the segment length as a variable produce better results. Nonetheless, the application and evaluation of most of the functional forms evaluated in this study proved to be useful and should be considered depending on data or sample size.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-03547
Paper Title	**An Enhanced Aggregate Framework to Model Crash Frequency By Crash Type: Accommodating Zero Crashes By Crash Type**
Abstract	In recent years, joint count and fractional split model structure-based approaches have emerged as a credible alternative for multivariate crash frequency dependent variables. However, current approaches in the fractional split theme have a limitation. The fractional split component of these frameworks allocates proportion to all crash configurations. It is possible that across spatial units, several crash configurations might have large share of zero crashes. In the traditional multivariate context, in the presence of high share of zeros, researchers employ zero-inflated or hurdle variants such as zero inflated negative binomial model. The current research effort improves the fractional split based multivariate model systems with an explicit consideration for the potential presence of zeros by crash configuration. The newly included binary component can be employed to identify safer (or riskier) zones by crash configuration. The framework also accommodates for unobserved heterogeneity across the components of the model system. The proposed model structure is estimated using zonal data from Central Florida region for 2010. The model considered 6 crash types including rear-end, angular, sideswipe, single-vehicle, multi-vehicle (3 or more), and nonmotorized crashes. The model estimation is conducted using an exhaustive set of independent variables. The model results clearly highlight the importance of accommodating zero crashes by crash type in the analysis. The model exercise is further augmented with a validation analysis.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-03597
Paper Title	**Comparative Analysis of Negative Binomial and Negative Binomial-Lindley Models in Crash Hotspot Identifications**
Abstract	Identifying hazardous crash sites (or hotspots) is a crucial step in highway safety management. The Negative Binomial (NB) model is the most common model used in safety analyses and evaluations - including hotspot identifications. Recently, the Negative Binomial-Lindley (NB-L) model has been proposed as an alternative to the NB. The NB-L model overcomes several limitations of the NB, such as addressing the issue of excess zero observations. However, it is not clear how the NB-L model compares with the NB regarding the hotspot identifications. In this paper, a simulation protocol was designed to generate a wide range of simulated data characterized by different mean, dispersion, and percentage of zeros. Then, the Full-Bayes NB, and NB-L models were compared for hotspot identifications using several metrics. The results show that for data with higher variations (Coefficient-of-Variation > 1.4), the NB model provides a better false-negative percentage, while the NB-L model provides a better false-positive percentage. For data with lower variations (Coefficient-of-Variation < 1.4), the NB-L model provides a better false-negative percentage, while the NB provides a better false-positive percentage. Considering the metrics of false-negative and false-positive rates, simultaneously, generally the NB-L model performs better in hotspot identifications compared to the NB. Lastly, the results show that NB model provides a better sensitivity, while the NB-L model provides a better specificity in identifying hotspots for highly dispersed data. In other words, while the NB model performs better in identifying hazardous sites, the NB-L model performs better in not picking non-hazardous sites as hazardous.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-03748
Paper Title	**Modeling the Impact of Risky Cut-in and Cut-out Maneuvers on Traffic Platooning Safety with Predictability and Explainability**
Abstract	Investigating the risky lane-changing maneuvers (e.g., risky cut-in and risky cut-out) is crucial for active traffic safety management. However, most past studies have paid primary attention to the impact of risky lane-changing on the immediately following vehicle, ignoring its impact on traffic platooning safety. This study proposed an integrated framework which combined eXtreme Gradient Boosting (XGBoost) model and SHapley Additive exPlanations (SHAP) explainer to investigate the impact of risky cut-in and cut-out maneuvers on traffic platooning safety. A total of 559 risky cut-in events and 319 risky cut-out events were extracted from the highD trajectory dataset to evaluate the proposed framework. Results show that the XGBoost model outperforms Random Forest (RF) regression model, Support Vector Regressor (SVR) model, and Multi-Layer perceptron (MLP) regression model in predicting the impact of risky cut-in and cut-out maneuvers on traffic platooning safety. Using the SHAP explainer, the main and interaction effects of explanatory factors on the safety impact of risky cut-in and cut-out maneuvers can be examined. The key factors that influence the impact of risky cut-in and cut-out on traffic platooning safety were identified. Compared to the traditional black-box machine learning models, the framework proposed in this study provides both predictability and explainability. The findings of this study could be valuable for the design of advanced driving assistance system (ADAS) for alleviating the driving risks caused by risky lanechanging maneuvers, thereby improving traffic safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04032
Paper Title	**Empirical Bayes estimate of the Negative Binomial-Lindley model applicable to all Poisson-compound distributions used in traffic safety**
Abstract	One of the key inputs for systematic safety evaluation of transportation elements is the expected crash frequency. Typically, Full Bayesian (FB) and Empirical Bayesian (EB) approaches are used to estimate the expected crashes. The EB method is an approximation to the FB method in which some of the assumptions are simplified. The EB is known for its computational efficiency and simple implementation as it avoids the time-consuming Markov chain Monte Carlo (MCMC) procedure which is an integral part of the FB approach. The EB approach has been developed for the Negative Binomial (NB) distribution; however, many extensions and alternatives to the NB distribution have been introduced in the literature which the EB approach has not been developed for. The Negative Binomial-Lindley (NB-L) is a mixture of NB and Lindley distribution which has been proven superior to the NB distribution. This study aims to derive the EB approach for the NB-L distribution which can also be applied to any Poisson compound distribution. The proposed EB approach was used to estimate the expected crashes and then, a comparative analysis was performed between the EB and FB estimates to validate the framework. The results showed that the proposed EB approach can successfully approximate its FB counterpart and can be considered a suitable alternative to the traditionally used EB formula derived for the NB model.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04140
Paper Title	**Application of Realistic Artificial Data for Testing Various Crash Safety Analysis: A case Study for Rural Two-Lane Undivided Highways**
Abstract	Traditional crash analysis relies on observed crash data to analyze road safety problems, despite the improved availability of crash data, it is becoming evident that no single crash database will provide a complete picture of road traffic injury or to fully understand the underlying crash mechanism. The research focus has been to develop new modeling approaches that offer superior fit, and it only allows comparisons between different statistical analysis methods. However, there are some drawbacks to solely relying on statistical methods, such as their inability to say how well they mimic the true underlying crash generation process. To meet these safety analysis needs, a high-resolution disaggregate data generating process called realistic artificial data (RAD) was developed, which simulates crash incidence on transportation facilities. The objective of this study was to examine the stability of the dataset across varying sample sizes. To accomplish the objective of this study, ten different datasets was generated from the RAD tool and was estimated with Negative binomial model, the parameter estimates from the model was checked using a revised Wald statistic. The t-statistics estimate showed that the differences among the parameter value across the dataset is within a statiscally acceptable level. This study shows that the RAD tool can be useful in assessing the extent to which a method succeeds in identifying the cause-and-effect relationship in the data which in return can help guide and improve the practical application of statistical methods. Keywords: Crash data, Statistical methods, Realistic artificial data, Negative binomial distribution

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04386
Paper Title	**The Integrated Analysis of Accident Reports and Traffic Flow Data Sets With Early Traffic Disruption Detection and Segmentation**
Abstract	Traffic accidents are often miss-reported with regards to either the exact location or the start and end time of the disruption due to several external factors - communication delays or misreporting, delays in accident clearance and non reporting of exact number of lanes, etc. Misleading information can lead to wrong decisions being made and can also affect the accuracy of any data-driven model that is responsible to predict either the severity or the disruption length. Several studies so far are using the reported incident data logs as truth ground which may wrongly affect any model build on top of this. To address these issues, our paper presents a novel framework that can be used for the early detection and prediction of incident durations. Firstly, we start by mapping and fusing several data sets related to reported traffic incidents (flows, speed, incident locations and incident details). Secondly, we propose several mathematical metrics (including Wesserstein and the Chebyshev metrics) are are fed into an early detection and disruption segmentation algorithm which allows us to choose the best performing metric for future model training. Thirdly, we proposed a modelling interpretation of the traffic speed distributions based to identify between single versus cascade incidents. Last we train and predict using various machine learning models and show that by using our enhanced modelling approach we can reduce the RMSE by 15\% using the best performing model on the task of accident duration prediction as compared to the traditional case of using only historical incident logs.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04499
Paper Title	**Influence of Travel Time Performance Metrics on Road Crashes at the Segment Level**
Abstract	This study explores the relationship between travel time performance metrics and crashes on road segments. The metrics considered are congestion mile hours (CMH), queue mile hours (QMH), and travel time index. The study focuses on fifteen work zones routes in Iowa. This study utilizes 2021 commercial probe vehicle data and crash data. Travel time performance metrics were obtained from the probe vehicle data, and crash counts were gathered from the crash data. The metrics were calculated and analyzed for three periods: all months in 2021, work zone months in 2021, and non-work zone months in 2021. A negative binomial regression model was utilized to establish a relationship between road segment crash counts and travel time performance metrics. This was done for two sets of models. One model set includes CMH as an independent variable, and another uses QMH instead. The study's findings show that CMH and QMH both positively impact crash counts on road segments. CMH was a statistically significant variable for all-year, work zone, and non-work zone periods. However, QMH were statistically significant for all-year analysis, but not for work- and non-work zone periods. Travel time index positively correlated with the crash count for all analysis periods except when included in a CMH model for non-work zone periods. In addition, AADT positively correlated with crash counts for all three analysis periods. These findings can inform decision makers on work zone safety strategies and crash mitigation planning, especially in high traffic volume areas.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04530
Paper Title	**Bayesian Hierarchical based Spatiotemporal Approach for Investigating Effects of Impact Factors on Crash Frequencies in Urban Area**
Abstract	The primary objective of this study is to investigate how to extract the association between spatiotemporal unit traffic crashes and various influencing factors using a spatiotemporal approach considering unobserved heterogeneity. The following seven types of data were collected for New York City during 2019: crash records data, ZCTA map data, NYC taxi trajectory data, road network attributes data, land use data, and social-demographic data. A python program was created to extract the hourly average speed and speed fluctuations in the ZCTAs from taxi trajectory data. Crash data and the extracted spatiotemporal dynamic data are assigned to the corresponding spatiotemporal units according to time periods and ZCTA. The remaining data are processed to obtain various types of regional variables and transformed into time-invariant panel data. Spatial dependency was found to exist from the preliminary analysis of zonal variables. Three models, i.e. model that only accounts for spatial correlation (S-CARar), model that accounts for spatio-temporal correlation (ST-CARar), spatio-temporal model with spatially adaptive smoothing (ST-CARadaptive) were then developed to establish a relationship between crash counts and the contributing factors. Comparative analysis of the models demonstrates that accounting for spatiotemporal correlation can improve the accuracy of parameter estimation, overall model fit, and prediction performance relative to spatial models. ST-CARadaptive model obtained the lowest DIC values and the highest LPML values and was therefore utilised to perform the analysis of the variable's effects. Eleven variables were fount to be significantly related to the crash, and the corresponding recommendations were thereby given.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04758
Paper Title	**Assessing the Relative Importance of Goodness of Fit Measures from the Calibration of Safety Performance Functions**
Abstract	The Highway Safety Manual (HSM) contains Safety Performance Functions (SPFs) that can be calibrated to specific jurisdictions with local safety data. Resources abound to help practitioners with calibration but the multiple existent metrics of calibration fitness do not always agree with each other. This paper uses the calibration results of three datasets: a segment and an intersection datasets from Texas and an intersection dataset from Mississippi to examine and compare the relationships between multiple GOF metrics. The goal is to compare the relative performance of simple index metrics synthesizing the information of correlated GOF metrics from each of the three datasets. The simple indices were developed from factor analyses showing clear similarities and a few differences as well. The key metrics were found to be, in descending order: the deviation of the cumulative residual (CURE) plot from the 95 percent confidence area, the modified R-squared, and the mean absolute deviation. The comparative analysis found that the three developed indices when applied to a single jurisdiction were highly correlated thus convincingly suggesting transferability of the indices, despite the marked differences in the datasets that produced them. Results suggest that any of the simple indices developed for this research can be used to assess the relative quality of multiple calibrated SPFs with results expected to be consistent in other jurisdictions.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-04963
Paper Title	**Investigating random mutation of driving behaviors using wide-range vehicle trajectory data**
Abstract	The random mutation of driving behaviors represents an unusual driving state that the random fluctuations of motion states of the vehicle are significantly different from its surrounding vehicles, which are the precursor to aberrant driving behaviors and may impair local traffic safety. However, existing studies concentrated on statistical features of random driving behaviors, and the fine-grained time-varying characteristics (i.e. amplitude and frequency) were still ambiguous . And abnormal fluctuations of the vehicle relative to the surrounding vehicles have rarely been explored in previous studies. Therefore, this study investigates the random mutation of driving behaviors by combining the time-varying characteristics of motion parameter fluctuations of the individual vehicle and surrounding vehicles. To define the random mutation, Extreme Value Theory (EVT) method was applied to determine the thresholds in terms of frequency and amplitude. Moreover, four algorithms were applied to explore the optimal time window lengths and the influencing factors to identify the random mutation. Based on the wide-range trajectory data which records detailed locational and speed information of road users within the coverage area determined by millimeter wave radar, 2,881 car-following events were collected to test the methodology. Results show that the optimal observation time window length is 3.4s using the Random Forest model. In addition, the features related to the previous random mutation states, acceleration, headway, and speed difference significantly affect random mutation identification. This paper can help to intervene in the random mutation state of driving behaviors in advance to prevent aberrant driving behaviors and improve traffic safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-05058
Paper Title	**The Vehicle Tube Model: A Dynamic Representation and the Theory for Vehicle Accident Analysis**
Abstract	This paper presents a model to represent each vehicle movement, that could be applied to derive the risk probability for accidents at different points in time, as well as the average probability over a period of time. As the speed control of each vehicle is not fully accurate at all points in time, the vehicle influence space with risk densities could be derived and varied with the speed distribution caused by control errors and driving behavior. The proposed vehicle tube model calculates the risk probabilities through the integrals at the overlapping influence spaces around vehicles, in 3-Dimensional time-space volumes. Through the orthogonal decomposition of the influence space, the risk probability of each specific direction can also be determined. Risk analysis with the tube model can be done for hypothetical scenarios as well, which is demonstrated with a no-stop intersection with machine-controlled vehicle movements. Other cases such as stop-and-go movements, and a turning movement with diverging and merging behaviors are also demonstrated. The result includes the average risk probabilities from the parallel and vertical directions, as well as the risk variations over time when vehicles adjust the speeds in rate and direction. Through the simulations, the risk is shown to become greater during vehicles deceleration/acceleration and turning. Interestingly, at a no-stop intersection with constant speed, cross traffic of a conflicting direction bring less risk probability than other vehicles travelling along the same road which is evidently the result of the time-dimension being much shorter for such a conflict.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	TRBAM-23-05093
Paper Title	**Multivariate Poisson-Lognormal Models for Predicting Peak-Period Crash Frequency of Joint On-Ramp and Merge Segments on Freeways**
Abstract	Due to the growing crash occurrence in the conflict areas, the ramp and merge segments on the freeway are a concern for transportation researchers and practitioners. Hence, short-term safety performance functions (SPFs) were proposed to predict the crash frequency at AM and PM peak periods aggregation levels using microscopic traffic detector data. The proposed short-term crash prediction models could achieve more accuracy and flexibility, better understand how safety evaluations change over time and take the appropriate actions. This study contributes to the literature by using the Multivariate Poisson Long-Normal (MVPLN) method via Integrated Nested Laplace Approximation (INLA) approach to investigate the dependency and the correlation between two responses (ramp and merge-related crash frequencies). The models are developed for total crashes (KABCO) and fatal and severe injury crashes (KAB). 70% of a total 239 and 238 for joint ramp and merge segments at AM and PM peaks, respectively, from three states of a freeway (i.e., Florida, Virginia, and Wisconsin) were utilized. The traffic and specific geometric data (e.g., the number of lanes, ramp configuration, the presence of weaving segment, and interchange connector type) for ramp and merge segments were used as independent variables. The significant variables were found to be the exposure parameters and various geometric feature variables for ramp and merge segments. Results on posterior means for the correlation coefficients between the ramp and merge crash frequencies indicate that a significant correlation exists between the two locations.

Poster Session 3216

A Fresh Look at Crash Characteristics

Tuesday, January 10 6:00 PM- 7:30 PM ET
Convention Center, Hall A
Poster

Karen Dixon, Texas A&M Transportation Institute

Sponsored by:
Standing Committee on Safety Performance and Analysis (ACS20)

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-00109
Paper Title	**COPULA-BASED BIVARIATE COUNT DATA REGRESSION MODELS FOR SIMULTANEOUS ESTIMATION OF CRASH COUNTS BASED ON SEVERITY AND NUMBER OF VEHICLES**
Abstract	Statistical models of crash frequency typically apply univariate regression models to estimate total crash frequency or crash counts by various categories. However, a possible correlation between the dependent variables or unobserved variables associated with the dependent variables is not considered when univariate models are used to estimate categorized crash counts—such as different severity levels or numbers of vehicles involved. This may lead to inefficient parameter estimates compared to multivariate models that directly consider these correlations. This paper compares the results obtained from univariate negative binomial regression models of property-damage only (PDO) and fatal plus injury (FI) crash frequencies to models using traditional bivariate and copulabased bivariate negative binomial regression models. A similar comparison was made using models for expected crash frequency of single- (SV) and multi-vehicle (MV) crashes. The models were estimated using two-lane, two-way rural highway segment-level data from an engineering district in Pennsylvania. The results show that all bivariate negative binomial models (with or without copulas) outperformed the corresponding univariate negative binomial models for PDO and FI, as well as SV and MV, crashes. Second, the statistical association between various traffic and roadway/roadside features and PDO and FI, as well as SV and MV crashes, were not the same relative to the univariate models. The bivariate negative binomial model with normal copula outperformed all other models based on the goodness-of-fit statistics. Results suggest that copulabased bivariate negative binomial regression models may be a valuable alternative for univariate models when simultaneously modeling two disaggregate levels of crash counts.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-00165
Paper Title	**Crash classification based on manner of collision: A comparative analysis**
Abstract	Traffic crashes vary in the manner in which the collision occurs (referred to as collision type), and countermeasures to reduce crashes might vary significantly based on this collision type. The inherent complexity in the mechanism of different crashes has motivated this study to identify significant factors influencing collision types, with the goal of better countermeasure deployment by transportation agencies. The objective of this work is to compare the performances of statistical and machine learning (ML) models in classifying vehicle crashes based on collision type, as well as their generalizability and interpretability. Discrete choice models, Bayesian classifiers, treebased ensemble learning algorithms and support vector machines are among the statistical and ML methods offered in this study for comparison. The results indicate that tree-based algorithms perform consistently well in classifying crashes and offer a high level of interpretability. In particular, gradient boosting machine demonstrates consistent predictive performance, even when applied to data that that is characteristically different from that used in the training process. However, while ML models provide a flexible framework for modeling large data volumes and are more generalizable to capture data heterogeneity, statistical models provide additional interpretability on the effect of critical variables on crash mechanisms – which is relevant from a safety management standpoint. In general, the most appropriate type of model depends on the specific use and level of interpretability needed.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-00321
Paper Title	**Crashes involving distracted pedestrians: Exploring association of contributing factors by pedestrian injury severity and modes of distraction**
Abstract	The concept of distracted pedestrians and its potential impact on highway safety has become a growing issue in recent years. Compared to distracted driving, studies focusing exclusively on distracted pedestrian crashes are less pervasive. Most prior studies investigate the harmful effect of cellphone usage during walking instead of considering different forms of distraction associated with pedestrians. This study aims to reveal the chain of contributing factors involved in crashes of distracted pedestrians by injury severity levels and distraction-related tasks. Ten years (2010-2019) of related crashes were extracted from the Louisiana Department of Transportation and Development, and association rule mining (ARM) was applied to identify the meaningful crash patterns. Different distracting activities of pedestrians were introduced from narratives of police-investigated crash reports. The study findings exhibit the complexities of distracted pedestrian crashes by specifying the intricate interrelations between risk factors. Distracted male pedestrians aged 41-64 years are more likely to be fatal/severely injured in the dark-not-lighted conditions at segments. Electronic device usage is found to be frequent while crossing the intersections, whereas distraction by pets/persons/objects is strongly associated with crossing segments in rural settings. Crashes involving in-person conversations are more likely to occur while standing on the roadways of urban residential locations with no traffic controls. The study outcomes are critical in revealing the coexisting crash characteristics associated with distracted pedestrians, which can be helpful in targeting/developing effective educational, design, and enforcement strategies for improving pedestrian safety.

Authors	Le Phan, University of Tennessee, Chattanooga Junxuan Zhao, University of Tennessee, Chattanooga Jeremiah Roland, The University of Tennessee at Chattanooga Michael Baker, Hexagon AB Mina Sartipi, University of Tennessee, Chattanooga
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-00530
Paper Title	**Visualization and Collaboration Platform for Vehicular Crash Hot Spot Prediction in Chattanooga, TN**
Abstract	Vehicle crashes have always been one of many problems that people face everyday. In order to reduce or eliminate the crash fatality and serious injury, predicting crash hot spots is one viable solution. In this work, several machine learning models such as Logistic Regression (LR), Decision Tree (DT), Extreme Gradient Boost (XGB Boost), and Long Short-Term Memory (LSTM) were evaluated to find the best model for this task. These models analyze crashes and their associated weather and roadway geometric characteristics to understand factors contributing to crash occurrence, and are used to produce hot spot predictions for dates not covered by the dataset used for model creation. A collaboration platform was also developed utilizing HxGN® Connect to facilitate the law enforcement resource allocation based on the hot spot prediction map. This platform provides forecast views to help allocate resources for the current day and the future. A historical view was also developed to give insight on historical crashes.

Authors	Xizhi Ding, Central South University Jinjun Tang, Central South University Xinyuan Liu, Central South University Chen Yuan, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-01516
Paper Title	**Jointly Analyzing Freeway Primary and Secondary Crash Severity Using a Copula-Based Approach**
Abstract	This study develops a copula-based model framework to jointly model the severity of freeway primary crashes and secondary crashes. The copula-based model can simultaneously account for the severity levels in the crash and the correlation among primary-secondary crash pairs' severity. The model considers a comprehensive set of exogenous variables including temporal characteristics, crash characteristics, roadway characteristics and real-traffic conditions, and is estimated using traffic crash data from 2016 through 2019 for Los Angeles County, California. The proposed copula model is then compared with the traditional binary probit model and the results show a remarkable superiority of the copula model, which is indicated by better fitting performance and the statistical significance of the spatial term. It is found that road condition, terrain, road weaving, truck involvement and traffic volume have significant effects on primary crash severity propensity and weather, traffic volume and vehicle speed have significant effects on secondary crash severity propensity. In light of the findings, several countermeasures regarding driver education, traffic rule enforcement, vehicle and roadway engineering and emergency services are proposed to mitigate freeway crash severity.

Authors	Zhao Zhang, University of Utah Yaobang Gong, University of Utah Pan Lu, North Dakota State University Xianfeng Yang, University of Maryland, College Park
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-01595
Paper Title	**Secondary Crashes Identification and Modeling along Highways in Utah**
Abstract	The occurrence of secondary crashes on highways would bring many adverse effects, such as traffic congestion, air pollution, leading to more crashes. Accurate identification of secondary crashes is the basis for identifying contributing factors and contributing factors are the cornerstones for incident management system to find effective strategies to reduce the risk of secondary crash. However, secondary crash records are often not recorded correctly. To tackle this issue, this research aims to propose a hybrid method to accurately identify primary and secondary crashes. Based on the identified primary and secondary crashes, this study developed a binary logit model to find contributing factors of secondary crashes and construct a HOPIT model to analyze the crash injury patterns in primary and secondary crashes with identified data of primary and secondary crashes, respectively. This study provides a better understanding of contributing factors as well as crash injury patterns of secondary crashes.

Authors	Reuben Tamakloe, University of Seoul Subasish Das, Texas State University Dongjoo Park, University of Seoul
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-02088
Paper Title	**Risk Factors Affecting Motorcycle-Barrier Crashes and Injury Severities: Insights from an Innovative Cluster-Regression Technique**
Abstract	Although motorcycle crashes into roadside safety barriers are uncommon, they are known to result in particularly severe rider injuries when compared to other types of motorcycle crashes. Currently, very little has been done to understand the factors associated with these crashes and the attributes influencing injury severity outcomes of motorcycle-barrier crashes. This study aims to employ an innovative unsupervised machine learning approach known as Cluster Correspondence Analysis and an ordered probit regression technique to discover latent patterns and associations between key crash contributing attributes in homogeneous clusters of motorcycle-barrier crash data obtained from Massachusetts, and to investigate the effect of risk factors on injury severity outcomes at the cluster level. The results demonstrated significant differences in the factor associations and determinants of fatal/non-fatal injury outcomes in all clusters. While variables such as older riders, minor arterial/collector roads, intersections/roundabouts, rolling/mountainous terrain, daylight, and summer were strongly associated with motorcycle-barrier crashes at no/partial access-controlled segments, attributes, namely interstates, ramps, medians, early mid-aged riders, dark-lighted roads, and winter, were correlated with crashes on full access-controlled segments. Besides, while level terrain, spring, and summer increased the chance of fatalities in motorcycle-barrier crashes on full access-controlled segments, traffic control absence, principal arteries and major collectors increased the likelihood of fatalities on no/partial access-controlled segments. Identifying and controlling all or some factors associated with fatal motorcycle-barrier crashes could help reduce the injury severities on the roads. Based on the insightful findings, policy implications and more targeted countermeasures to improve motorcycle safety have been suggested.

Authors	Shinthia Azmeri Khan, QUT: Queensland University of Technology Amir Afghari, Technische Universiteit Delft Shamsunnahar Yasmin, Queensland University of Technology Shimul (Md. Mazharul) Haque, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-02354
Paper Title	**Applying Random Parameters Negative Binomial Lindley Model to Examine the Effects of Geometric Design Consistency on Run-off Road Crashes Along Two-lane Rural Roadway**
Abstract	Run-off road crashes are one of the leading causes of road death worldwide. Road geometry, driver behaviour, and roadside features are vital factors of run-off road crash risk. The interaction of road geometry and driver's behaviour is critical for run-off road crashes, but this interaction has not been studied well for run-off road crash risks. This study aims to capture the interaction between road geometry and driver behaviour through design consistency measures and investigate its effects on run-off road crashes on two-lane rural roadways. Multiple sourced data from twenty-three highways in Queensland, Australia, have been collected and fused for this study. A wide range of indices under two main geometric design consistency measures: alignment consistency and operating speed consistency, are calculated and applied with other explanatory variables in the Random Parameter Negative Binomial Lindley (accounting for excess zeros and unobserved heterogeneity) count regression models. Results indicate that the alignment and operating speed consistency measures significantly influence the likelihood of run-off road crashes. Alignment consistency captures the effect of sudden changes in the road's geometric alignment while operating speed consistency captures drivers' responses to changes in road geometry. Factors like clear zone width, roadside infrastructures, terrain, roadway remoteness, etc., also contribute to crashes. Overall, the geometric design consistency captures the interaction between driver behaviour and operational factors and contributes to a better prediction of runoff road crashes.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-02552
Paper Title	**A Crash and Violation Analytical Framework for Macro-Level Safety Assessment and Contributing Factors Analysis**
Abstract	During rapid urbanization and motorization, understanding the relationships between traffic safety and risk factors is important in improving crash-prone areas and providing targeted policy recommendations. Previous studies have seldom considered enforcement-related factors because of the endogeneity between crashes and violations. To address this problem, this study developed an analytical framework for the joint modeling of crashes and violations to identify crash and violation hotspots and examine the mechanisms underlying macro-level contributing factors. Socio-economic, road network, public facility, traffic enforcement, and land use intensity data of 115 towns in Suzhou, China, were collected as independent variables. A bivariate negative binomial spatial conditional autoregressive model (BNB-CAR) and the potential for safety improvement (PSI) method were adopted to identify crash-prone and violation-prone areas. An interpretable machine learning framework was applied to explore the factors' effects by area. Results showed that the proposed framework could accurately identify problem areas and quantify the impact of key factors, which, in Suzhou, were the number of traffic police and their daily patrol time. Considering such enforcement-related information provided important insights into reducing crash and violation frequency; for example, keeping the number of traffic police and daily patrol time under certain thresholds (number of police lower than 11 and patrol time lower than 2.3 h in this sample) could potentially reduce the probability of high-crash and high-violation areas. The proposed framework can help traffic administrators identify the key contributing factors in crash-prone and violation-prone areas and provide guidelines for improvement.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-03524
Paper Title	**Do Patterns of Contributing Factors differ Temporarily in Work Zone related Crashes?**
Abstract	Work zones are necessary for maintaining and improving road infrastructure. Work zones, on the other hand, have an impact on traffic safety, and crashes and fatalities associated with work zones have increased significantly in the United States (a 13% increase from 2016 to 2020). Traffic control devices, geometric configurations, traffic operations, and human factors play key roles in work zone crashes and these influencing factors differ by type of work zone such as construction, utility, maintenance, and others. Additionally, the likelihood of being involved in a work zone crash and the factors associated with injury severity differ by the day of the week, and the time of day. To understand the temporal (day of the week and time of the day) and spatial (work zone type and other geometric configurations) impact of work zone crashes, this study collected five years (2016-2020) of fatal crash data from the Fatality Analysis Reporting System (FARS). This study applied association rules mining on five major clusters based on day of the week and time of the day. The findings show that rear-end crashes, and collisions with other vehicle are the key contributing factors. Although some common patterns associated with the most common variables seem recurrent in the rules, the findings some temporal instability. This research helps practitioners develop work zone-specific safety countermeasures to lower crash risk.

Authors	Armana Huq, Bangladesh University of Engineering and Technology (BUET)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-03672
Paper Title	**A Thorough 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. With information synthesized from the studies, we created a probability plot that shows the changes of SC probabilities with every minute increase in primary incident duration. The plot shows that there is a 3% increase in SC probability for every 10-minute increase in duration. This information may be used by incident management programs to set effective and manageable clearance time targets for incidents of different severities.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	TRBAM-23-04001
Paper Title	**Proactive Safety Analysis using Roadside Lidar based Vehicle Trajectory Data: A Study on Rear-end Crashes**
Abstract	This paper presents a methodology to detect rear-end conflicts at signalized intersections with the help of roadside LiDAR sensors. Raw data collected in the point cloud format from the sensors was processed using a series of data processing algorithms to obtain vehicle trajectories. Time-based (MTTC), deceleration-based (SDI) and severity-based (CSI) surrogate safety indices were calculated from the vehicle trajectories to identify the conflict threats at every frame of the dataset, which were further aggregated together to evaluate the risk exposure and risk severity at different temporal segments of the leader/follower car-following period to obtain a rear-end conflict index (RECI). The identified conflicts were compared with the historical crash records using Negative Binomial models. The results indicate correlation between the identified conflicts and the crashes, and further provide new information about the rear-end crash risks at the intersection which could support the proactive approach of traffic safety analysis.

3 Network Screening

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

The subcommittee identified **nine papers** related to network screening, with most research presented at the annual meeting focusing on the use of systemic approaches.

The network screening step in **systemic analysis** is to identify sites with characteristics that are associated with the highest risks. Traditionally, determining the risk scores involve subjective criteria. Paper 23-02861 developed a **data-driven approach** to replace the subjective method used in the past. Paper 23-00991 presented a systemic safety analysis for **pedestrians**. Paper 23-00217 compared the **Road Assessment Program** methodology and the **Australian safe system assessment framework**. Similarly, paper 23-02091 demonstrated a methodology to calibrate the **United States Road Assessment Program** risk assessment formulation when analyzing non-intersection crashes.

Other papers focused on statistical methods aimed at improving network screening. Paper 23-02844 employed a **frequentist approach to finding a joint confidence region of risk** for ranking of locations and identification of hotspots. Papers 23-03597 and 23-04032 focused on **Negative Binomial-Lindley Models**. Paper 23-03597 compared the performances of Negative Binomial and Negative Binomial-Lindley Models in hotspot identification while paper 23-04032 derived the EB approach for the NB-L distribution which can also be applied to any Poisson compound distribution.

Paper 23-00530 compared different **machine learning techniques** such as Logistic Regression, Decision Tree, Extreme Gradient Boost, and Long Short-Term Memory.

Paper 23-03379 investigated the optimal set of **sliding window parameters** by conducting a sensitivity analysis.

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

Authors	Douglas Harwood, Harwood Road Safety LLC Zachary Hans, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-00217
Paper Title	**Comparison of Safe System Assessment Methods**
Abstract	This paper compares two methods for assessing the need for crash countermeasures based on safe system principles. These methods are the Road Assessment Program (RAP) methodology and the Australian safe system assessment framework (SSAF). Both methods were applied to the same set of rural roadways in North Carolina. Comparison of the results from applying the two methods show that both methods can be effective in identifying sites with potential need for crash reduction improvements. However, the SSAF scores do not appear to be useful in distinguishing between sites where the countermeasures identified with the RAP methodology have higher benefit cost-ratios and those with lower benefit-cost ratios. The results indicate that the SSAF method involves subjective judgements, and the ratings from the SSAF methodology may not be repeatable. The SSAF results are dependent on the expertise and interpretations of the individual safety professionals assigned to do the ratings. By contrast, the RAP methodology, while incorporating a few judgement-based ratings, is less subjective and more likely to repeatable. The SSAF results are useful to safety professionals as a guide for identifying countermeasures, while the RAP methodology provides additional output that identifies specific crash countermeasures and estimates their benefits, costs, and benefit-cost ratios. While its lack of repeatability is a limitation in its usefulness, the SSAF methodology appears to be a valuable tool in educating users about the nature of the safe system concept and showing how to understand and utilize safe system principles.

Authors	Le Phan, University of Tennessee, Chattanooga Junxuan Zhao, University of Tennessee, Chattanooga Jeremiah Roland, The University of Tennessee at Chattanooga Michael Baker, Hexagon AB Mina Sartipi, University of Tennessee, Chattanooga
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-00530
Paper Title	**Visualization and Collaboration Platform for Vehicular Crash Hot Spot Prediction in Chattanooga, Tennessee**
Abstract	Vehicle crashes have always been one of many problems that people face everyday. In order to reduce or eliminate the crash fatality and serious injury, predicting crash hot spots is one viable solution. In this work, several machine learning models such as Logistic Regression (LR), Decision Tree (DT), Extreme Gradient Boost (XGB Boost), and Long Short-Term Memory (LSTM) were evaluated to find the best model for this task. These models analyze crashes and their associated weather and roadway geometric characteristics to understand factors contributing to crash occurrence, and are used to produce hot spot predictions for dates not covered by the dataset used for model creation. A collaboration platform was also developed utilizing HxGN® Connect to facilitate the law enforcement resource allocation based on the hot spot prediction map. This platform provides forecast views to help allocate resources for the current day and the future. A historical view was also developed to give insight on historical crashes.

Authors	Wesley Kumfer, University of North Carolina, Chapel Hill Jesse McGowan, Montgomery County Krista Nordback, UNC Highway Safety Research Center Mike Vann, UNC Highway Safety Research Center Bo Lan, UNC Highway Safety Research Center
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3062
Session Title	**Paper Awards: Transportation Safety Management Systems**
Paper Number	23-00991
Paper Title	**A Systemic Predictive Safety Analysis of Pedestrian Crashes for Montgomery County's Vision Zero Program**
Abstract	The goal of Vision Zero is the prevention of all traffic fatalities and serious injuries. While traditional transportation planning has been reactive to locations where these serious crashes occur, some agencies are taking a more proactive approach to safety with the hopes that locations with high expected crashes can be improved before someone is seriously injured or killed. This paper presents the results of a systemic safety analysis that produced two pedestrian-related safety performance functions for Montgomery County, Maryland, including 1) motor vehicle crashes with pedestrians at intersections at night and 2) through-movement motor vehicle crashes with pedestrians traveling along segments. Both models identify key transportation-related exposure variables, including motor vehicle and pedestrian traffic volumes, proximity to transit, and crosswalk locations and also present land use contexts that may explain where pedestrians are likely to walk and be exposed to crash risks. These results build on the existing systemic safety literature and demonstrate the data collection and analysis methods that can be used in a Vision Zero context to improve safety for all who walk. This paper summarizes the analysis approach, including exposure modeling; developing crash models, and applying those models to identify both high-risk locations and potential mitigations. Considerations for equity and long-term planning are also discussed.

Authors	Frank Gross, VHB
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	23-02091
Paper Title	**Calibration of Segment-Level Risk Assessments from usRAP: A Methodology for Systemic Analysis Tools**
Abstract	The United States Road Assessment Program (usRAP) provides a systemic approach to estimate the risk of severe injury and fatal crashes along roadway segments based on expected safety performance dictated by roadway and roadside characteristics. As the adoption of usRAP grows in the U.S., calibration of the methodology and proposed risk assessments is of significant value, not only to identify strengths and limitations within the U.S. context, but also to consolidate usRAP as an additional tool available to roadway agencies. This paper demonstrates a methodology suitable to calibrate the usRAP risk assessment formulation when analyzing non-intersection crashes, including run-off road and head-on crashes. The analysis focuses on the interactions between contributing factors, which by default in usRAP are multiplicative factors with the same weight in the overall crash risk formulation. Relaxation of the functional form to allow for different interactions indicates potential improvements in the risk estimation to match long-term safety performance observed in the field. The methodology presented in this paper opens possibilities for calibration to local conditions beyond those offered by the original usRAP methodology, and is suitable to calibrate other systemic safety analysis tools.

Authors	Reza Aminghafouri, University of Waterloo Liping Fu, University of Waterloo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	23-02844
Paper Title	**A Joint Confidence Region Approach to Ranking Hot Spot Locations Considering Uncertainty in the Expected Risk Estimates**
Abstract	Network screening or crash hotspots identification is an essential task of all road safety improvement programs. The most common approach to network screening is to use statistical models to predict the expected risk at the locations of interest and then rank them on the basis of the predicted risk. The predicted risk used for ranking is mostly in the form of point estimates without any consideration of the inherent uncertainty with the estimates, which could lead to identifying a wrong list of crash hotspots. This study aims to fill this research gap by employing a frequentist approach to finding a joint confidence region of risk for ranking of locations and identification of hotspots. A case study on three-legged stop-controlled intersections in Kitchener, Ontario, is conducted to illustrate the proposed approach. Crash risk is modeled using a combination of a hierarchical full Bayesian negative binomial model and a multinominal Logit model, which are then used to estimate the 95% confidence interval of the expected risk. For each location, the confidence region of rankings is obtained on the basis of the expected risk estimates. The results show that considering uncertainty in the crash hotspots identification process can lead to varied ranking positions with different probabilities since the true value of its estimated crash risk follows a distribution.

Authors	Mohammad Razaur Rahman Shaon, University of Connecticut Shanshan Zhao, University of Connecticut Kai Wang, University of Connecticut Eric Jackson, Connecticut Transportation Institute
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35) City Transportation Issues Coordinating Council (A0030C) Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3010
Session Title	**Moving Safety Research into Practice**
Paper Number	23-02861
Paper Title	**Developing a Data-Driven Network Screening Procedure for Systemic Safety Approach**
Abstract	Systemic analysis is considered an important safety analysis approach that is complementary to the Highway Safety Manual hotspot analysis. The network screening step in systemic analysis is to identify sites with characteristics that are associated with the highest risks. Traditionally, determining the risk scores involve subjective criteria. This research aims to develop a data-driven approach to replace the subjective method used in the past. To obtain the research objective, this study collected roadway and crash data from the Connecticut Department of Transportation. A data-driven crash risk factor categorization methodology was proposed to accurately estimate the performance measures indicating crash risks. Moreover, this study proposed and compared four different risk-scoring matrices to identify an optimal risk-scoring method that attunes with the principles of the systemic approach to safety as well as provides additional insights on justifying the systemic safety analysis results. The proposed methodology was implemented to conduct network screening for severe roadway departure crashes and later validated using severe aggressive driving related crashes. Risk-based network screening results indicated that risk scores derived from normalized crash over-representation provide additional emphasis on sites with low traffic volume that are associated with high severe crash counts. The highest modified crash rate was obtained using normalized overrepresentation based risk scores indicating the proposed network screening methodology can not only identify roadway attributes that are correlated with severe crashes but also account for low-volume roadway sites with severe crashes. The validation analysis indicated proposed method is transferrable to different emphasis areas.

Authors	Flavius Matata, Florida International University Jimoku Salum, Florida International University Priyanka Alluri, Florida International University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-03379
Paper Title	**Exploring the Choice of Sliding Window Parameters for Identifying Hazardous Roadway Segments**
Abstract	A sliding window is one of the three principal network screening methods. Although the methods for segment screening vary depending on the crash data, the sliding window ensures reliable results. The main objective of conducting a sliding window is to identify the hotspot's correct position (begin and endpoints). This study determined the optimal set of sliding window parameters by conducting a sensitivity analysis. The analysis was conducted considering the variation in the built environment (i.e., context class). The 0.1 mi and 0.5 mi were the shortest and longest window lengths, respectively. The optimal sets were chosen based on the value of crashes per mile, a ratio of excess expected average crash frequency to the window length. The higher the value, the more reliable the results. The decrease in window length was observed to be proportional to an increase in the value of crashes per mile. At a 95% confidence level, the Mann-Kendall trend tests indicated the observed trend is significant. For context classes, C1 and C2, a set with a window length of 0.2 mi and an increment length of 0.05 mi was the optimal set for all performance measures used. For C2T through C6 context classes, the optimal set had a window length of 0.1 mi and an increment length of 0.05 mi. The findings could be beneficial to transportation agencies in conducting safety analyses of their transportation networks.

Authors	Jhan Kevin Gil-Marin, University of Maine Mohammadali Shirazi, University of Maine
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-03597
Paper Title	**Comparative Analysis of Negative Binomial and Negative Binomial-Lindley Models in Crash Hot Spot Identifications**
Abstract	Identifying hazardous crash sites (or hotspots) is a crucial step in highway safety management. The Negative Binomial (NB) model is the most common model used in safety analyses and evaluations - including hotspot identifications. Recently, the Negative Binomial-Lindley (NB-L) model has been proposed as an alternative to the NB. The NB-L model overcomes several limitations of the NB, such as addressing the issue of excess zero observations. However, it is not clear how the NB-L model compares with the NB regarding the hotspot identifications. In this paper, a simulation protocol was designed to generate a wide range of simulated data characterized by different mean, dispersion, and percentage of zeros. Then, the Full-Bayes NB, and NB-L models were compared for hotspot identifications using several metrics. The results show that for data with higher variations (Coefficient-of-Variation > 1.4), the NB model provides a better false-negative percentage, while the NB-L model provides a better false-positive percentage. For data with lower variations (Coefficient-of-Variation < 1.4), the NB-L model provides a better false-negative percentage, while the NB provides a better false-positive percentage. Considering the metrics of false-negative and false-positive rates, simultaneously, generally the NB-L model performs better in hotspot identifications compared to the NB. Lastly, the results show that NB model provides a better sensitivity, while the NB-L model provides a better specificity in identifying hotspots for highly dispersed data. In other words, while the NB model performs better in identifying hazardous sites, the NB-L model performs better in not picking non-hazardous sites as hazardous.

Authors	Ali Khodadadi, Texas A&M University Ioannis Tsapakis, Texas A&M Transportation Institute Mohammadali Shirazi, University of Maine Subasish Das, Texas State University Dominique Lord, Texas A&M University, College Station
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-04032
Paper Title	**Empirical Bayes estimate of the Negative Binomial-Lindley model applicable to all Poisson-compound distributions used in traffic safety**
Abstract	One of the key inputs for systematic safety evaluation of transportation elements is the expected crash frequency. Typically, Full Bayesian (FB) and Empirical Bayesian (EB) approaches are used to estimate the expected crashes. The EB method is an approximation to the FB method in which some of the assumptions are simplified. The EB is known for its computational efficiency and simple implementation as it avoids the time-consuming Markov chain Monte Carlo (MCMC) procedure which is an integral part of the FB approach. The EB approach has been developed for the Negative Binomial (NB) distribution; however, many extensions and alternatives to the NB distribution have been introduced in the literature which the EB approach has not been developed for. The Negative Binomial-Lindley (NB-L) is a mixture of NB and Lindley distribution which has been proven superior to the NB distribution. This study aims to derive the EB approach for the NB-L distribution which can also be applied to any Poisson compound distribution. The proposed EB approach was used to estimate the expected crashes and then, a comparative analysis was performed between the EB and FB estimates to validate the framework. The results showed that the proposed EB approach can successfully approximate its FB counterpart and can be considered a suitable alternative to the traditionally used EB formula derived for the NB model.

4 Safety Performance Functions

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

Research related to SPFs can be classified according to the roadway facility type. Multiple papers analyzed the safety performance of intersections (23-00090 and 23-01175), signalized intersections (23-00037 and 23-01237), unsignalized intersections (23-00037), and curves (23-03861 and 23-04101),

On the other hand, many papers focused on developing SPFs for rural roadways (23-00643), major arterials (23-02343), freeways (23-04421), and mountainous freeways (23-02345). In addition, some papers developed macro-level SPFs to predict crashes for a geographic area rather than at a specific segment or intersection site (23-00606, 23-00899, 23-02552, 23-02965, 23-03547, 23-04461, 23-04530)

Furthermore, other papers focused on more specific roadway facilities such as interchanges (23-00090), ramps (23-05093 and 23-00090), and mountainous freeway tunnels (23-02345). Multiple papers conducted safety performance analysis considering active traffic management (ATM) systems such as high occupancy toll lanes (HOT) and high-occupancy vehicle lanes (HOV) (23-01237), congestion mile hours (CMH) (23-04499), queue mile hours (QMH) (23-04499), travel time index (23-04499), and variable/advisory speed limit (VSL/VAS) (23-00037, 23-01237, 23-02354, 23-03861, and 23-04101).

SPFs regarding different crash types and severities have also been widely conducted. The crashes severities investigated were total (23-05093), PDO (23-00109), fatal (23-00109, 23-00643, 23-05093), and severe injury (23-05093). Different crash types were studied such as run off the road (23-02354), rear-end (23-03547, 23-04250), angular (23-03547), sideswipe (23-03547), single-vehicle (23-00109, 23-03547), and multi-vehicles (23-00109 and 23-03547). In addition, SPFs for nonmotorized crashes were developed in papers 23-03547 and 23-04513.

Some studies introduced distinct data sources into the development of SPFs. The objective of paper 23-03861 is to assess the impact of ball bank indicator as an explanatory variable for curve lane departures within an SPF. The paper 23-01175 aims to develop conflict-based SPFs to predict the number of rear-end conflicts at the signal cycle level in mixed traffic conditions with poor lane discipline. In the paper 23-04140, a negative binomial model was developed using realistic artificial data (RAD). In the paper 23-04347, traffic conflicts and surrogate safety measures (SSM) have been used to estimate the number of crashes.

Finally, multiple methodologies were proposed to develop SPFs such as Negative Binomial (23-00037, 23-00062, 23-00090, 23-02533 23-03547 23-03597, and 23-00643) Negative Binomial with Random

Parameters (RP-NBR) (23-00643), Negative Binomial-Lindley (NB-L) (23-03597 and 23-04032) model, Poisson Log-Normal model (23-04421), Conway-Maxwell-Poisson (CMP) (23-00037 and 23-00090), heterogeneous Conway-Maxwell-Poisson (HTCMP)(23-00037), zero-inflated Conway-Maxwell-Poisson (ZI-CMP)(23-00037), and zero-inflated heterogeneous Conway-Maxwell-Poisson (ZI-HTCMP)(23-00037), Poisson Lognormal (PLN) (23-04421), Zero-inflated Logarithmic link for count Time-series (ZILT) (23-04170), Zero-Inflated Negative Binomial (ZINB) (23-01882), Hierarchical Negative Binomial Conditional (HNB-CAR) (23-02343), Spatial Correlation (S-CARar) (23-04530) model, a spatio-temporal correlation (ST-CARar) (23-04530), Spatio-Temporal model with spatially adaptive smoothing (ST-CARadaptive) (23-04530), Multivariate Poisson Long-Normal (MVPLN) method via Integrated Nested Laplace Approximation (INLA) (23-05093), bivariate negative binomial spatial conditional autoregressive model (BNB-CAR) (23-02552). In addition, machine learning techniques were adopted in the safety performance analysis including Catboost model (23-02533), XGBoost (23-01882), LightGBM (23-01882), Artificial Neural Networks (ANN) (22-03731), Random forests (23-01882), abd Bayesian additive regression trees (XBART) (23-01882).

Below, for each of the thirty-three papers involving safety performance functions, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Kirolos Haleem, Western Kentucky University Mehdi Hosseinpour, Western Kentucky University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-00037
Paper Title	**Analyzing Commercial Motor Vehicle Crashes at Signalized and Unsignalized Intersections in Kentucky**
Abstract	This study develops safety performance functions (SPFs) for “fatal and injury” (FI) CMV crashes at each of signalized and unsignalized intersections in Kentucky. Five count-response regression models, including the negative binomial (NB), Conway-Maxwell-Poisson (CMP), heterogeneous Conway-Maxwell-Poisson (HTCMP), zero-inflated Conway-Maxwell-Poisson (ZI-CMP), and zero-inflated heterogeneous Conway-Maxwell-Poisson (ZI-HTCMP) models, were separately developed and compared at each of signalized and unsignalized intersections. Five years of FI CMV intersection-related crashes in Kentucky (from 2015 to 2019) were used. Information regarding road-specific characteristics, e.g., shoulder width, median width and type, and international roughness index (IRI), and traffic volume (including annual average daily traffic “AADT” and heavy vehicle percentage “HVP”), were collected. Additionally, intersection-specific characteristics, e.g., number of through lanes and presence of exclusive left- and right-turn lanes on major and minor roads, were collected using Google Maps’ Street View time slider back to the crash year. For both signalized and unsignalized intersections, the ZI-HTCMP model (with a varying dispersion parameter) was found to outperform the other comparative models. For signalized intersections, major-road speed limit greater than 45 mph, minor-road speed limit greater than 45 mph, and major-road medians wider than 3 feet were significantly associated with increased FI CMV crashes. Regarding unsignalized intersections, higher major-road AADT, four-legged configuration, major-road speed limit greater than 45 mph, and major-road IRI greater than 100 were significantly associated with increased FI CMV crashes. The results of the SPFs (for each of signalized and unsignalized intersections) were then used to identify the top ten hazardous locations for each intersection type.

Authors	Ha Anh Nguyen, Monash University Graham Currie, Monash University David Logan, Monash University Christopher Lowe, Bus Association Victoria Inc.
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-00062
Paper Title	**Safety Performance of US Bus Transit Agencies With/Without Vehicle Ownership: Who Did It Better? An Empirical Study Using the National Transit Database**
Abstract	While risk factors affecting bus safety have been broadly explored, no studies to date have addressed the impact of bus vehicle ownership on safety. Theory from the taxi, trucking and hire car industries suggests those owning the vehicles they operate have better safety performance than those who lease vehicles. Adopting a Negative Binomial regression modelling approach, this paper analysed 8,790 reported bus crashes from the US National Transit Database (2015-2019) to determine whether alternative models of vehicle ownership impact bus safety performance. The results demonstrated that the injury rate (per Vehicle Miles Travelled) among bus transit agencies leasing vehicles was 35% higher than those operating the vehicles they own. Injury rates were found to be higher for: (1) Medium- and small-sized agencies, (2) Private agencies, (3) Daylight operations, (4) Services operating on roads with more signalised intersections/grade crossings, (5) Slippery roads, (6) Clear weather conditions and (7) Higher bus operating speeds. In contrast, lower injury rates were found in relation to: (1) Articulated and double-decker buses, (2) Inclement weather and (3) Higher catchment population and population densities. This is the first study to explore the impact of vehicle ownership on bus safety. Implications for policy and future research are discussed

Authors	Mehdi Hosseinpour, Western Kentucky University Kirolos Haleem, Western Kentucky University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-00090
Paper Title	**Safety Performance Functions for Commercial Motor Vehicle-Related Crashes at Interchange Ramp Segments in Kentucky**
Abstract	Compared to roadway segments and intersections, the safety of interchange ramp segments has rarely been studied, especially when involving commercial motor vehicles (CMVs). The main objective of this study was to develop a safety performance function (SPF) tool for predicting CMV crashes occurring on interchange ramp segments. Four count models, including the negative binomial (NB), heterogeneous NB (HTNB), standard Conway-Maxwell-Poisson (CMP), and heterogeneous Conway-Maxwell-Poisson (HTCMP), were used and compared while fitting CMV crash-specific SPFs along interchange ramp segments. The HTCMP model, which is an extension of the standard CMP model, is a more flexible approach that handles both over-dispersed and under-dispersed crash data while exhibiting varying dispersion parameter. Five-year CMV-related crashes (2015 to 2019), along Kentucky's ramp segments, were used. The model comparison results showed that the HTCMP significantly outperformed the other three models in terms of crash prediction accuracy and goodness-of-fit statistics (e.g., the Akaike information criterion "AIC", Bayesian information criterion "BIC", and McFadden's Pseudo R-squared). The SPF model results using the HTCMP approach indicated that on-ramps (relative to off-ramps), ramp annual average daily traffic (AADT), ramp configuration (diamond and parclo/free-flow-loop ramps), left shoulder width, ramp gore length, absence of left roadside barrier, and presence of other merging or diverging ramps within the ramp of interest were significantly associated with CMV crash frequency on ramp segments. Potential safety countermeasures were proposed, e.g., increasing ramp gore length to be at least 730 feet (since this was associated with a reduction in CMV crashes on ramp segments).

Authors	Nicholas Fiorentini, University of Pisa Massimo Losa, University of Pisa
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-00643
Paper Title	**Investigating Unobserved Heterogeneity in Factors of Severe Crashes across Italian Two-lane Roads: Fixed and Random Parameters Approach**
Abstract	Developing Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) represent one of the leading approaches for determining how infrastructure-related features impact crash likelihood. In Italy, few works investigated the causes of crash occurrences on secondary road networks, i.e., minor rural, suburban, and urban two-lane roads, connecting the primary road network (freeways and highways) with local roads. Furthermore, few or no studies addressed the issue of unobserved heterogeneity of factors contributing to crash occurrence in Italy. To fill this gap and intending to provide an in-depth analysis of causes of Fatal and Injury (FI) crashes that occur on such networks, this paper proposes the development of SPFs and related CMFs across the whole 905-km secondary road network managed by the Tuscany Region Road Administration (TRRA). Incorporating geometrical, functional, and road context information, a Negative Binomial Regression with Fixed Parameters (FP-NBR) and Random Parameters (RP-NBR) to account for unobserved heterogeneity have been adopted for fitting 5,802 FI crashes that occurred within 2008-2016. Capturing unobserved heterogeneity affecting factors, outcomes show that the RP-NBR markedly outperforms the FP-NBR in terms of predictive performance. Conversely, the latter shows a higher level of interpretation; elasticities and CMFs indicate that traffic flow, carriageway width, driveway density (especially in urban areas), the density of intersections, and road area type are the most influential ones, whereas longitudinal gradient and road alignment have a weaker effect on FI occurrences. These SPFs and related CMFs can improve planning activity, as well as monitoring and maintenance duties of road authorities.

Authors	Numan Ahmad, The Pennsylvania State University Vikash Gayah, Pennsylvania State University, University Park Eric Donnell, Pennsylvania State University, University Park
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-00109
Paper Title	**COPULA-BASED BIVARIATE COUNT DATA REGRESSION MODELS FOR SIMULTANEOUS ESTIMATION OF CRASH COUNTS BASED ON SEVERITY AND NUMBER OF VEHICLES**
Abstract	Statistical models of crash frequency typically apply univariate regression models to estimate total crash frequency or crash counts by various categories. However, a possible correlation between the dependent variables or unobserved variables associated with the dependent variables is not considered when univariate models are used to estimate categorized crash counts—such as different severity levels or numbers of vehicles involved. This may lead to inefficient parameter estimates compared to multivariate models that directly consider these correlations. This paper compares the results obtained from univariate negative binomial regression models of property-damage only (PDO) and fatal plus injury (FI) crash frequencies to models using traditional bivariate and copulabased bivariate negative binomial regression models. A similar comparison was made using models for expected crash frequency of single- (SV) and multi-vehicle (MV) crashes. The models were estimated using two-lane, two-way rural highway segment-level data from an engineering district in Pennsylvania. The results show that all bivariate negative binomial models (with or without copulas) outperformed the corresponding univariate negative binomial models for PDO and FI, as well as SV and MV, crashes. Second, the statistical association between various traffic and roadway/roadside features and PDO and FI, as well as SV and MV crashes, were not the same relative to the univariate models. The bivariate negative binomial model with normal copula outperformed all other models based on the goodness-of-fit statistics. Results suggest that copulabased bivariate negative binomial regression models may be a valuable alternative for univariate models when simultaneously modeling two disaggregate levels of crash counts.

Authors	Shahrior Pervaz, University of Central Florida Tanmoy Bhowmik, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-00606
Paper Title	**An Econometric Framework for Integrating Aggregate and Disaggregate Level Crash Analysis**
Abstract	Traditionally, aggregate crash frequency and disaggregate severity analysis are conducted independently in the transportation research. The current research effort contributes to the safety literature by bridging the gap between these two different streams of research by using both aggregate and disaggregate level crash data simultaneously. To be specific, the study proposes a framework that integrates aggregate and disaggregate level models. The proposed framework allows for the influence of independent variables at the crash record level to be incorporated within the aggregate level propensity estimation. The empirical analysis is based on the crash data drawn from the city of Orlando, Florida for the year 2019. The disaggregate level analysis uses 20,204 crash records that contain crash specific, temporal, roadway, vehicle, driver, and road environmental factors for each record. For aggregate level model analysis, the study aggregated the crash records by severity class over 300 TAZs. An exhaustive set of independent variables including roadway, traffic, land-use, built environment, and sociodemographic characteristics are considered in this analysis. The empirical analysis is further augmented by employing several goodness of fit and predictive measures. A validation exercise is also performed using a holdout sample to highlight the superiority of the proposed integrated model over non-integrated model. The proposed model can also accommodate common unobserved spatial correlation among crash records within the same zone. The model results illustrate the benefits of developing an integrated model system for crash frequency and severity

Authors	Jonathan Aguero-Valverde, University of Costa Rica Darío Vargas Aguilar, Universidad de Costa Rica
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-00899
Paper Title	**Incorporating Road Network Connectivity in Neighboring Structures for Crash Prediction Models at Area Level**
Abstract	Spatial correlation models have been traditionally used in road safety to account for spatial effects resulting from unmeasured or unknown risk factors that induce spatial correlation between neighboring areas. In transportation, the interaction between neighboring areas is highly influenced by the number of roads that connect those areas and the importance of those roads. This paper proposes an approach in which the spatial interaction (and therefore the spatial correlation) between areas depends on the number of road connections between those areas and the importance of those connections. The results using districts in Costa Rica show that the inclusion of road network connectivity in the models of spatial correlation significantly improve model fit, even after accounting for model complexity using the DIC and WAIC. The inclusion of higher weights to national roads compared to municipal o local roads further improved model fit. The best three models in terms of posterior deviance, DIC and WAIC are those that give at least three times more weight to national roads compared to local roads. In terms of site ranking, those three models present similar results, which also highlights the consistence among those models.

Authors	Shahana A, Indian Institute of Technology, Bombay Vedagiri Perumal, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-01175
Paper Title	**Safety Modeling for Signalized Intersection at Approach-level Using Mixed Traffic Trajectory Data**
Abstract	The majority of accidents observed at signalized intersections comprise rear-end collisions resulting from a diversity of vehicle interactions happening during signal change. This study aims to develop conflict-based safety performance functions (SPFs) to predict the number of rear-end conflicts at the signal cycle level in mixed traffic conditions with poor lane discipline. More than 9000 vehicle trajectory data was extracted from traffic video data collected from four signalized intersections in various cities in India. Interacting leader-follower pairs were identified using a methodology suitable for mixed traffic conditions i.e., by considering the width and the lateral gap between vehicles. Time to Collision (TTC) was used to identify the rear-end conflicts. The variation in TTC value with respect to the deceleration rate of vehicles showed that the lower TTC values are obtained for motorized two-wheelers and motorized three-wheelers indicating that smaller vehicle types contribute to more critical vehicle interactions. The SPFs are developed at varying TTC thresholds suitable for mixed traffic conditions which help to address different conflict severity levels. The results show that higher conflict occurrence is expected during signal cycles with more traffic volume, vehicle arrival speed, delay, and lower platoon ratio. Several goodness-of-fit measures used show that the SPFs developed in this study can provide a better prediction of rear-end conflicts at signalized intersections. These results can be most beneficially used for optimizing safety at signalized intersections in mixed traffic conditions.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-01237
Paper Title	**Safety Modeling for Signalized Intersection at Approach-level Using Mixed Traffic Trajectory Data**
Abstract	Time-specific Safety Performance Functions (SPFs) were proposed to achieve accurate and dynamic crash frequency predictions. This study contributes to the literature by developing time specific SPFs for freeways that include reversible lanes (RL) and freeways that include High-Occupancy Vehicle (HOV) lanes using Microwave Vehicle Detection System (MVDS) data from Virginia, Arizona and Washington States. Variables that capture the time-specific traffic turbulence were prepared and considered in the developed SPFs. Moreover, two different hierarchical models were proposed to identify factors associated with the different crash types or severity in crash frequency prediction. The results indicated that the variables representing the volume difference between reversible and general purpose lanes (GPL) were positively associated with crash frequency. Further, the variable that indicated the design of the access point of the reversible lane was positively associated with crash frequency. The models comparison results showed that the hierarchical models outperformed the corresponding Poisson lognormal model with lower AIC and MAE values. This study also tested the proposed hierarchical models on High-Occupancy Vehicle freeway sections and reached the same conclusion on model comparison results. The significant variables representing the logarithm of volume was found to be significant and positive with crash frequency. Moreover, the difference in average speed between the HOV lanes and GPL was also found to be positive and significant with the crash frequency. In general, this study successfully identified the factors associated with the different crash types or severity in crash frequency prediction models.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-01882
Paper Title	**Predicting Crash Occurrence at Intersections in Texas: an Opportunity for Machine Learning**
Abstract	This paper studies the frequency of traffic crashes at intersections across Texas by employing zero-inflated negative binomial (ZINB) models using the MLE method, and various tree-based ML methods, namely random forests (RF), XGBoost, LightGBM, and Bayesian additive regression trees (XBART) to predict the frequency of crashes at intersections. Official records of traffic crashes from 2010 to 2019 were used in addition to the roadway inventory database and other sources to map more than 700k intersections. The performances of the MLE and ML models were computed and compared, using R-square and Root Mean Square Error as the metrics. Results indicated that RF had the best model performance in predicting crash frequency. Resampling the data led to better prediction performances for all the models and was useful in dealing with highly imbalanced crash data. Road design variables had the highest feature importance on the ML models to predict crash occurrence. Sensitivity analysis showed that the effects of several predictors have different directions across different ML models making interpreting their contribution in predicting crash occurrences difficult. The findings suggest that machine learning models are better at predicting crash occurrences, whereas statistical models are better at investigating the contributing factors of a crash event.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02343
Paper Title	**Safety Analysis of Major Arterials: An Investigation into the Safety Impacts of Road Network Characteristics**
Abstract	With the construction of high-density roadway networks, neither macro- nor micro- level safety analysis can provide a comprehensive interpretation of the safety impacts of network characteristics. This study employed a meso-level analysis unit which combined the intersections with adjacent segments to investigate the safety impacts of intersection spacing and network connection characteristics. Three main intersection spacing characteristics, including the density of intersection spacing (DOIP), the standard deviation of intersection spacing (SDIP), and the variation of intersection spacing (VOIP) were extracted to represent the interaction between arterials in the network. Additionally, this study introduced the concept of hierarchical differences to quantitatively analyze the safety effects of road connection with different functions. To illustrate the hierarchical structure of the model, a two-level hierarchical negative binomial conditional autoregressive (HNB-CAR) model was adopted to examine the safety effects of network characteristics at the meso level. The results showed the existence of unobserved heterogeneities among the selected arterials. DOIP was negatively associated with crashes, while SDIP and VOIP were found to have positive effects on crash occurrences. Combining all the three intersection spacing characteristics, long and uniform signal spacing could achieve more efficient safety improvement. As for network connection, the units with moderate connection were found to have more crashes than those with appropriate connection, while the meso units with the highest hierarchical difference instead had fewer crashes. The results are expected to provide suggestions on potential safety hazard screening and crash prevention.

Authors	Zeke Ahern, Queensland University of Technology Paul Corry, Queensland University of Technology Alexander Paz, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-02483
Paper Title	**Extensive Hypothesis Testing for Estimation of a Crash Data Count Model**
Abstract	Estimation of crash data count models requires extensive knowledge and significant hypothesis testing to choose the model distribution type, determine likely contributing factors, select transformations that can help capture trends, and find random parameters and associated distributions, among many other modeling decisions. Model development is often time-bound, and an analyst could introduce bias from past experience and knowledge of existing models to save time; potentially overlooking unique specifications. This study proposes a framework to assist during the estimation of crash data count models. The proposed framework includes a mathematical programming formulation that minimizes the Bayesian Information Criterion (BIC) to find potential model specifications. The mathematical program is solved through a range of metaheuristic solution algorithms to provide efficient results over a complex nonconvex search space, including alternative search strategies for unique data sets. Two data sets and three metaheuristics were tested.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-02533
Paper Title	**Freeway Safety Influencing Factors Using Catboost Model and Interpretable Machine Learning Framework SHAP**
Abstract	Exploring and analyzing safety influencing factors can guide to targeted traffic safety management. Traditional traffic safety models are aimed at specific data problems and adjustment to the model structure, which lack focus on predictive ability and have limited information on analysis of influencing factors. In recent years, machine learning methods opened new avenues in modelling, which have higher prediction accuracy, can identify complex nonlinear relationship, and can overcome the over/under dispersion and correlation. However, it also faced with the problem of limited interpretability. The interpretable machine learning framework SHAP can be an effective solution, which can not only reflect the influence of features in each sample but also generate global interpretation. This study utilized electronic toll collection data and used Catboost model to establish a traffic safety model, which was compared with traditional negative binomial regression model. SHAP was used to analyze safety influencing factors from the aspects of geometric design features, traffic operation characteristics, and hour of day. Results confirmed that the Catboost model has better prediction ability and is more suitable for establishing traffic safety model than the traditional NB regression model. The relationships between each of the safety influencing factors and crashes were also concluded, such as, ramp type is the most important factor of freeway crash frequency, curve type has a great positive impact while truck proportion has a great negative impact, traffic volume is highly correlated with truck proportion, etc., which provided theoretical support for safety operation management and targeted improvement measures of freeway.

Authors	Xuesong Wang, Tongji University Yesihati Azati, Tongji University Mohammed Quddus, Imperial College London Bowen Cai, Tongji University Xuefang Zhang, Tongling University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02345
Paper Title	**Statistical Analysis of Traffic Crashes on the Sections of Mountainous Freeway Tunnels**
Abstract	Tunnels on mountainous freeways are affected by the abrupt changes in brightness, complex geometrical alignments, heavy traffic flow, bad weather, and other factors, some of which contribute toward tunnels having more traffic crashes than other sections of the freeway. Previous research has given limited attention to tunnel length and heterogeneity in the sections of the tunnels, such as at the tunnels' entrances and exits. This paper utilizes 36 tunnels of Guidu Freeway in China's Guizhou Province as spatial entity, collects data on crashes and their influencing factors over two years (2020-2021), constructs a negative binomial panel random effect model, and analyzes single-vehicle crashes, multi-vehicle crashes and total crashes. The results show that: 1) multi-vehicle crashes occur in most of the tunnel sections, 2) crashes are more likely to occur in long tunnel sections, 3) the crash risk from the tunnel entrance zone to the mid zone is higher than other areas of the tunnel, 4) the crash risk is higher for circular curve/easy curve sections than for straight sections in the flat curve type, 5) the crash risk is higher for downhill and concave curve sections than for flat sections in the vertical curve type, 6) the crash risk increases with heavy traffic flows and adverse weather conditions, and finally 7) the crash risk increases as road surface skidding resistance and ride quality decrease. These findings can provide theoretical support for engineering improvement and specification revision formulation of freeway tunnel sections, especially in mountainous areas.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02354
Paper Title	**Applying Random Parameters Negative Binomial Lindley Model to Examine the Effects of Geometric Design Consistency on Run-off Road Crashes Along Two-lane Rural Roadway**
Abstract	Run-off road crashes are one of the leading causes of road death worldwide. Road geometry, driver behaviour, and roadside features are vital factors of run-off road crash risk. The interaction of road geometry and driver's behaviour is critical for run-off road crashes, but this interaction has not been studied well for run-off road crash risks. This study aims to capture the interaction between road geometry and driver behaviour through design consistency measures and investigate its effects on run-off road crashes on two-lane rural roadways. Multiple sourced data from twenty-three highways in Queensland, Australia, have been collected and fused for this study. A wide range of indices under two main geometric design consistency measures: alignment consistency and operating speed consistency, are calculated and applied with other explanatory variables in the Random Parameter Negative Binomial Lindley (accounting for excess zeros and unobserved heterogeneity) count regression models. Results indicate that the alignment and operating speed consistency measures significantly influence the likelihood of run-off road crashes. Alignment consistency captures the effect of sudden changes in the road's geometric alignment while operating speed consistency captures drivers' responses to changes in road geometry. Factors like clear zone width, roadside infrastructures, terrain, roadway remoteness, etc., also contribute to crashes. Overall, the geometric design consistency captures the interaction between driver behaviour and operational factors and contributes to a better prediction of runoff road crashes.

Authors	Xuesong Wang, Tongji University Xueyu Zhang, Tongji University School of Transportation Engineering Yingying Pei, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02552
Paper Title	**A Crash and Violation Analytical Framework for Macro-Level Safety Assessment and Contributing Factors Analysis**
Abstract	During rapid urbanization and motorization, understanding the relationships between traffic safety and risk factors is important in improving crash-prone areas and providing targeted policy recommendations. Previous studies have seldom considered enforcement-related factors because of the endogeneity between crashes and violations. To address this problem, this study developed an analytical framework for the joint modeling of crashes and violations to identify crash and violation hotspots and examine the mechanisms underlying macro-level contributing factors. Socio-economic, road network, public facility, traffic enforcement, and land use intensity data of 115 towns in Suzhou, China, were collected as independent variables. A bivariate negative binomial spatial conditional autoregressive model (BNB-CAR) and the potential for safety improvement (PSI) method were adopted to identify crash-prone and violation-prone areas. An interpretable machine learning framework was applied to explore the factors' effects by area. Results showed that the proposed framework could accurately identify problem areas and quantify the impact of key factors, which, in Suzhou, were the number of traffic police and their daily patrol time. Considering such enforcement-related information provided important insights into reducing crash and violation frequency; for example, keeping the number of traffic police and daily patrol time under certain thresholds (number of police lower than 11 and patrol time lower than 2.3 h in this sample) could potentially reduce the probability of high-crash and high-violation areas. The proposed framework can help traffic administrators identify the key contributing factors in crash-prone and violation-prone areas and provide guidelines for improvement.

Authors	Jeff Gooch, VHB Ian Hamilton, VHB Catherine Chestnutt, VHB Tal Cohen, VHB
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02965
Paper Title	**Municipal-Level Analysis of Behavioral Crashes in Massachusetts**
Abstract	Systemic safety analysis is a useful tool for identifying factors associated with the risk of a severe crash. MassDOT elected to use systemic safety analysis to select risk factors for severe behavioral crashes, including alcohol impaired driving, distracted driving, and unbelted occupants. The analysis was performed at the municipality level for Massachusetts to prioritize communities for education interventions. Risk factors were identified using negative binomial regression. Several forms of data were tested to identify risk factors. Ultimately, the analysis showed correlations between citation data, equity data, and infrastructure data and the frequency of severe behavioral crashes.

Authors	Madeline Blair, The University of Maine Mohammadali Shirazi, University of Maine Srinivas Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-03482
Paper Title	**Exploring the Impact of Different Parameterizations on Developing Calibration Functions**
Abstract	Crash prediction models play a pivotal role in highway safety evaluations and analyses. In fact, various tasks, instructions, or guidelines documented in Highway Safety Manual (HSM) rely on these models, including but not limited to network screening, or hotspot identifications. The HSM documented crash prediction models to estimate the number and severity of crashes for several facility types. However, since these models were developed using data from select states in the United States and a given period, they should be calibrated to the local conditions when applied to a new jurisdiction, or over time. The HSM recommended using a single scalar calibration factor to calibrate the models. Recently, researchers proposed using a calibration function, instead of a factor, to calibrate the models. The calibration function can also be derived using explanatory variables, such as traffic flow or segment length. However, it is not clear what parameterizations should be considered in developing a calibration function. We considered 12 functional forms to develop calibration functions and compared their performance. We found that with a large and complete sample, a more complex function (with flow, and segment length) could produce a better fit. As the sample size reduces, simpler functions such as those developed with only the segment length as a variable produce better results. Nonetheless, the application and evaluation of most of the functional forms evaluated in this study proved to be useful and should be considered depending on data or sample size.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-03547
Paper Title	**An Enhanced Aggregate Framework to Model Crash Frequency By Crash Type: Accommodating Zero Crashes By Crash Type**
Abstract	In recent years, joint count and fractional split model structure-based approaches have emerged as a credible alternative for multivariate crash frequency dependent variables. However, current approaches in the fractional split theme have a limitation. The fractional split component of these frameworks allocates proportion to all crash configurations. It is possible that across spatial units, several crash configurations might have large share of zero crashes. In the traditional multivariate context, in the presence of high share of zeros, researchers employ zero-inflated or hurdle variants such as zero inflated negative binomial model. The current research effort improves the fractional split based multivariate model systems with an explicit consideration for the potential presence of zeros by crash configuration. The newly included binary component can be employed to identify safer (or riskier) zones by crash configuration. The framework also accommodates for unobserved heterogeneity across the components of the model system. The proposed model structure is estimated using zonal data from Central Florida region for 2010. The model considered 6 crash types including rear-end, angular, sideswipe, single-vehicle, multi-vehicle (3 or more), and nonmotorized crashes. The model estimation is conducted using an exhaustive set of independent variables. The model results clearly highlight the importance of accommodating zero crashes by crash type in the analysis. The model exercise is further augmented with a validation analysis.

Authors	Jhan Kevin Gil-Marin, University of Maine Mohammadali Shirazi, University of Maine
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-03597
Paper Title	**Comparative Analysis of Negative Binomial and Negative Binomial-Lindley Models in Crash Hotspot Identifications**
Abstract	Identifying hazardous crash sites (or hotspots) is a crucial step in highway safety management. The Negative Binomial (NB) model is the most common model used in safety analyses and evaluations - including hotspot identifications. Recently, the Negative Binomial-Lindley (NB-L) model has been proposed as an alternative to the NB. The NB-L model overcomes several limitations of the NB, such as addressing the issue of excess zero observations. However, it is not clear how the NB-L model compares with the NB regarding the hotspot identifications. In this paper, a simulation protocol was designed to generate a wide range of simulated data characterized by different mean, dispersion, and percentage of zeros. Then, the Full-Bayes NB, and NB-L models were compared for hotspot identifications using several metrics. The results show that for data with higher variations (Coefficient-of-Variation > 1.4), the NB model provides a better false-negative percentage, while the NB-L model provides a better false-positive percentage. For data with lower variations (Coefficient-of-Variation < 1.4), the NB-L model provides a better false-negative percentage, while the NB provides a better false-positive percentage. Considering the metrics of false-negative and false-positive rates, simultaneously, generally the NB-L model performs better in hotspot identifications compared to the NB. Lastly, the results show that NB model provides a better sensitivity, while the NB-L model provides a better specificity in identifying hotspots for highly dispersed data. In other words, while the NB model performs better in identifying hazardous sites, the NB-L model performs better in not picking non-hazardous sites as hazardous.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-04032
Paper Title	**Empirical Bayes estimate of the Negative Binomial-Lindley model applicable to all Poisson-compound distributions used in traffic safety**
Abstract	One of the key inputs for systematic safety evaluation of transportation elements is the expected crash frequency. Typically, Full Bayesian (FB) and Empirical Bayesian (EB) approaches are used to estimate the expected crashes. The EB method is an approximation to the FB method in which some of the assumptions are simplified. The EB is known for its computational efficiency and simple implementation as it avoids the time-consuming Markov chain Monte Carlo (MCMC) procedure which is an integral part of the FB approach. The EB approach has been developed for the Negative Binomial (NB) distribution; however, many extensions and alternatives to the NB distribution have been introduced in the literature which the EB approach has not been developed for. The Negative Binomial-Lindley (NB-L) is a mixture of NB and Lindley distribution which has been proven superior to the NB distribution. This study aims to derive the EB approach for the NB-L distribution which can also be applied to any Poisson compound distribution. The proposed EB approach was used to estimate the expected crashes and then, a comparative analysis was performed between the EB and FB estimates to validate the framework. The results showed that the proposed EB approach can successfully approximate its FB counterpart and can be considered a suitable alternative to the traditionally used EB formula derived for the NB model.

Authors	Oluwaseun Olufowobi, D-Q University John Ivan, University of Connecticut Shanshan Zhao, University of Connecticut Kai Wang, University of Connecticut
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-04140
Paper Title	**Application of Realistic Artificial Data for Testing Various Crash Safety Analysis: A case Study for Rural Two-Lane Undivided Highways**
Abstract	Traditional crash analysis relies on observed crash data to analyze road safety problems, despite the improved availability of crash data, it is becoming evident that no single crash database will provide a complete picture of road traffic injury or to fully understand the underlying crash mechanism. The research focus has been to develop new modeling approaches that offer superior fit, and it only allows comparisons between different statistical analysis methods. However, there are some drawbacks to solely relying on statistical methods, such as their inability to say how well they mimic the true underlying crash generation process. To meet these safety analysis needs, a high-resolution disaggregate data generating process called realistic artificial data (RAD) was developed, which simulates crash incidence on transportation facilities. The objective of this study was to examine the stability of the dataset across varying sample sizes. To accomplish the objective of this study, ten different datasets was generated from the RAD tool and was estimated with Negative binomial model, the parameter estimates from the model was checked using a revised Wald statistic. The t-statistics estimate showed that the differences among the parameter value across the dataset is within a statiscally acceptable level. This study shows that the RAD tool can be useful in assessing the extent to which a method succeeds in identifying the cause-and-effect relationship in the data which in return can help guide and improve the practical application of statistical methods. Keywords: Crash data, Statistical methods, Realistic artificial data, Negative binomial distribution

Authors	Bowen Cai, Tongji University Mohammed Quddus, Imperial College London Yu Miao, University of Georgia
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-04170
Paper Title	**A New Modelling Approach for Predicting Disaggregated Time-Series Traffic Crashes**
Abstract	Short window crash prediction is a fundamental step in proactive traffic safety management that can monitor traffic conditions in real time, identify unsafe traffic dynamics, and implement suitable interventions for traffic conflicts. Short window (e.g. hourly) traffic collision count data, however, exhibits excessive zeros and serial autocorrelation. Most of the commonly used regression-based models fail to address excessive zeros and temporal structure simultaneously in hourly traffic collision prediction. For example, hurdle models and zero-inflated models can address the overdispersion issue caused from excessive zeros but lack of the power to control the significant spatio-temporal characteristics inherent in the time-based collision data. To overcome these issues simultaneously, this paper develops a novel statistical model termed as Zero-inflated Logarithmic link for count Time-seriess (ZILT) based on the framework of zero-inflated models. Covariates (e.g. speed, vehicle types, and traffic volumes) were extracted through deep learning computer vision methods in vehicle detection and tracking on the image space. This new statistical model (i.e. ZILT) performs well in solving the issues of excessive zeros and serial dependences. The prediction accuracy of the ZILT model improved around 5% in relation to ZIP and hurdle models. Results show that traffic crashes happened in the previous hour and other covariates such as truck-to-car ratio, holiday effect, traffic flow, and speed have significant influence on the collision occurrences. Findings from this study could be utilized by relevant transport agencies in developing engineering interventions and countermeasures to proactively manage road safety.

Authors	Heesub Rim, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Nada Mahmoud, University of Central Florida
Sponsoring Committee	Standing Committee on Traffic Flow Theory and Characteristics (ACP50)
Session Number	4027
Session Title	**Traffic Flow Theory, Part 4: Traffic Modeling, Monitoring, and Control**
Paper Number	23-04421
Paper Title	**Developing Safety Performance Functions for Freeway Weaving Segments using Lane-level Traffic Data: Focusing on Multi-vehicle Crashes**
Abstract	This study developed the Safety Performance Functions (SPFs) for freeway weaving segments using lane-level traffic data. Due to the coexistence of three different movements including through, merging, and divering traffic, the probavility of crashes in weaving segments is higher compared to other segment types. Further, the traffic flow in this section is the most unstable. Hence, to analyze detailed traffic conditions, this study utilized lane-level traffic data. The SPFs were developed using Poisson Lognormal (PLN) regression model. The results showed that different traffic parameters were selected based on the types of crashes. For the rear-end crashes model, more general traffic conditions of the weaving segment were found to be significantly associated with the crash frequency such as the natural logarithm of average speed of through lanes. Nevertheless, for the sideswipe and angle crashes models, the traffic variables which are directly related to the weaving movements were selected as significant factors such as the off-ramp volume ratio, and standard deviation of speed of the rightmost lane. The results presented in this study can be meaningful in that they can serve as a basis for the weaving segments related safety evaluation studies. In addition, the developed models' results can be a great source to establish operational strategies to improve traffic safety on freeway weaving segments.

Authors	Maria Valencia-Cardenas, University of California, Davis Carlos Gonzalez-Calderon, Universidad Nacional de Colombia John Jairo Posada-Henao, Universidad Nacional de Colombia Manuela Córdoba-Misas, Universidad Nacional de Colombia Alejandro Fernández-Cadavid, Universidad Nacional de Colombia Ivan Sanchez-Diaz, Chalmers University of Technology Miguel Jaller, University of California, Davis
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-04461
Paper Title	**Analyses of Traffic Crashes Involving Trucks in Medellin, Colombia**
Abstract	This paper analyzes and provides a general approach of freight truck-related crashes and the influence variables in those events; where the spatial distribution of freight-truck-related crashes is presented, considering multiple special variables as well as spatial units. The study is conducted using a time series data set covering the crash data registered between 2014 and 2019, in the city of Medellin, Colombia. Data were collected by the Medellin Department of Transportation and include information crashes characteristics, road network and land use. Those variables are tested for spatial autocorrelation with good result and statistically analyzed using hotspots technique to identify zones with higher rate of crashes. Hotspots differ according to the influence of every variable. Facility type and land-use hotspots, with similar patter to frequency distribution, present high precision and consistency which means that are strongly correlated to crashes.

Authors	Dorcas Okaidjah, Iowa State University Christopher Day, Iowa State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-04499
Paper Title	**Influence of Travel Time Performance Metrics on Road Crashes at the Segment Level**
Abstract	This study explores the relationship between travel time performance metrics and crashes on road segments. The metrics considered are congestion mile hours (CMH), queue mile hours (QMH), and travel time index. The study focuses on fifteen work zones routes in Iowa. This study utilizes 2021 commercial probe vehicle data and crash data. Travel time performance metrics were obtained from the probe vehicle data, and crash counts were gathered from the crash data. The metrics were calculated and analyzed for three periods: all months in 2021, work zone months in 2021, and non-work zone months in 2021. A negative binomial regression model was utilized to establish a relationship between road segment crash counts and travel time performance metrics. This was done for two sets of models. One model set includes CMH as an independent variable, and another uses QMH instead. The study's findings show that CMH and QMH both positively impact crash counts on road segments. CMH was a statistically significant variable for all-year, work zone, and non-work zone periods. However, QMH were statistically significant for all-year analysis, but not for work- and non-work zone periods. Travel time index positively correlated with the crash count for all analysis periods except when included in a CMH model for non-work zone periods. In addition, AADT positively correlated with crash counts for all three analysis periods. These findings can inform decision makers on work zone safety strategies and crash mitigation planning, especially in high traffic volume areas.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-04530
Paper Title	**Bayesian Hierarchical based Spatiotemporal Approach for Investigating Effects of Impact Factors on Crash Frequencies in Urban Area**
Abstract	The primary objective of this study is to investigate how to extract the association between spatiotemporal unit traffic crashes and various influencing factors using a spatiotemporal approach considering unobserved heterogeneity. The following seven types of data were collected for New York City during 2019: crash records data, ZCTA map data, NYC taxi trajectory data, road network attributes data, land use data, and social-demographic data. A python program was created to extract the hourly average speed and speed fluctuations in the ZCTAs from taxi trajectory data. Crash data and the extracted spatiotemporal dynamic data are assigned to the corresponding spatiotemporal units according to time periods and ZCTA. The remaining data are processed to obtain various types of regional variables and transformed into time-invariant panel data. Spatial dependency was found to exist from the preliminary analysis of zonal variables. Three models, i.e. model that only accounts for spatial correlation (S-CARar), model that accounts for spatio-temporal correlation (ST-CARar), spatio-temporal model with spatially adaptive smoothing (ST-CARadaptive) were then developed to establish a relationship between crash counts and the contributing factors. Comparative analysis of the models demonstrates that accounting for spatiotemporal correlation can improve the accuracy of parameter estimation, overall model fit, and prediction performance relative to spatial models. ST-CARadaptive model obtained the lowest DIC values and the highest LPML values and was therefore utilised to perform the analysis of the variable's effects. Eleven variables were fount to be significantly related to the crash, and the corresponding recommendations were thereby given.

Authors	Abdulrahman Faden, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Nada Mahmoud, University of Central Florida Tarek Hasan, University of Central Florida Heesub Rim, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-05093
Paper Title	**Multivariate Poisson-Lognormal Models for Predicting Peak-Period Crash Frequency of Joint On-Ramp and Merge Segments on Freeways**
Abstract	Due to the growing crash occurrence in the conflict areas, the ramp and merge segments on the freeway are a concern for transportation researchers and practitioners. Hence, short-term safety performance functions (SPFs) were proposed to predict the crash frequency at AM and PM peak periods aggregation levels using microscopic traffic detector data. The proposed short-term crash prediction models could achieve more accuracy and flexibility, better understand how safety evaluations change over time and take the appropriate actions. This study contributes to the literature by using the Multivariate Poisson Long-Normal (MVPLN) method via Integrated **Nested Laplace Approximation (INLA)** approach to investigate the dependency and the correlation between two responses (ramp and merge-related crash frequencies). The models are developed for total crashes (KABCO) and fatal and severe injury crashes (KAB). 70% of a total 239 and 238 for joint ramp and merge segments at AM and PM peaks, respectively, from three states of a freeway (i.e., Florida, Virginia, and Wisconsin) were utilized. The traffic and specific geometric data (e.g., the number of lanes, ramp configuration, the presence of weaving segment, and interchange connector type) for ramp and merge segments were used as independent variables. The significant variables were found to be the exposure parameters and various geometric feature variables for ramp and merge segments. Results on posterior means for the correlation coefficients between the ramp and merge crash frequencies indicate that a significant correlation exists between the two locations.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-03861
Paper Title	**Ball Bank Indicator's Impact in Rural Curve Crash Prediction**
Abstract	Ball bank indicator (BBI) measures the lateral forces on a vehicle. It is used to establish advisory speed limit in the AASHTO Greenbook (1). BBI values respond to roadway geometry and driver behavior. However, BBI has not been used in a safety performance function (SPF) (i.e., a crash prediction model). Engineers use SPFs to proactively assess safety. As BBI becomes widely available, there is an opportunity to utilize it in SPFs. Therefore, the objective of this paper is to assess the impact of BBI as an explanatory variable for curve lane departures within an SPF. To accomplish this objective, a case study is conducted on rural curves within Georgia DOT districts 1, 2 and 6. BBI is integrated in an SPF alongside other common explanatory variables used in the Highway Safety Manual (HSM). This SPF with BBI is compared to a baseline SPF without it. BBI is a statistically significant variable under a 99.9% threshold. Additionally, it was found that the model with BBI has 1.3 and 1.35 percent less mean absolute error and route mean squared error respectively. This finding is notable because these data may already be available to leverage in a transportation agency. Furthermore, BBI may allow for changes in driver behavior (i.e., anticipation of curves) to be assessed in a prediction model.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-04101
Paper Title	**Safety Performance Analysis of Horizontal Curves on Urban Roads**
Abstract	While numerous studies have examined horizontal curve risk factors in rural areas, there is only one study in urban areas. Moreover, previous studies have used limited datasets, which tend to generate an intrinsic bias on results either by the sample size or due to a lack of understanding of all the risk factors associated with curve safety. This study aims to narrow this knowledge gap in three aspects: it focuses in urban areas; it uses a large novel GIS dataset of 25,000 urban curves; and expands the traditional curve risk factor pool by examining the spatial relationship of curves to adjacent curves and intersections. Using this curve dataset and six years of statewide fatal and injury crash data in the state of Florida, the study develops customized safety performance functions (SPFs) for urban curves based on different spatial relations of curves to intersections. The results confirm that the traditional risk factors for curves, such as, traffic volume, curve radius and length, speed limit, functional classification, and number lanes, are also applicable to curves in urban areas. However, the new finding is that curve safety in urban areas is affected by the proximity of curves to adjacent curves and intersections. The curves with intersections and the curves that are isolated (have no adjacent nearby curves) are at high risk. There are also risk factor differences between single and dual-centerline roads. We also observed differences between the travel bounds on divided roadway curves, but this will require further research.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-04347
Paper Title	**Extreme Value Theory Estimation of Vehicle-Pedestrian Safety Surrogates at Intersection with Right-Turn Flashing Yellow Arrow Indication**
Abstract	Traffic conflicts and surrogate safety measures (SSM) have been used as an alternative to crash-based methods to study roadway safety. Extreme value theory (EVT) offers a modeling framework that can be used to expand the use SSM to conduct proactive safety evaluations. This study explores the EVT modeling approach to analyze vehicle-pedestrian interactions and compare safety risks between a site with a right-turn flashing yellow arrow (RT FYA) indication and sites with a permissive circular green indication. Using trajectory data extracted from video using a frame-by-frame analysis approach, post-encroachment-time (PET) values were determined along with an obstructed right turn time (ORTT) measure which is defined as the time it takes a vehicle to complete a right turn maneuver when a conflicting pedestrian is present. At-site univariate and bivariate extreme value theory models were developed using the block maxima (BM) approach and the peak over threshold (POT) approach. Additionally, joint-site univariate and bivariate Bayesian hierarchical models were developed for each approach. Using the resulting estimates, the number of crashes was estimated for each model and compared to the observed crashes. Results showed that models using ORTT produced a better fit model with their covariates indicating that ORTT helps describe traffic interactions objectively. The number of crashes estimated from the Bayesian hierarchical models was found to also be closer to the observed number of crashes than those from other models. Particularly, Bivariate Bayesian hierarchical models outperformed the at-site models (univariate and bivariate) and the univariate joint-site model in terms of crash estimation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-04513
Paper Title	**Estimating Pedestrian Crashes near Bus Stops**
Abstract	Among many potential risk factors, the presence and proximity of transit bus stops are very distinctive in the pedestrian involved crashes, especially in urban areas. Efforts to address pedestrian crashes near bus stop locations should begin with a comprehensive understanding of the characteristics associated with these crashes. The objective of this research study is to develop a pedestrian crash frequency model to identify the significant variables affecting pedestrian crashes near bus stop locations and to estimate pedestrian crashes at bus stop locations which are of prime importance, mainly in large metropolitan cities. To accomplish the study objective, the authors collected pedestrian safety data within the vicinity of 627 bus stop locations in Dallas. The pedestrian crash frequency model developed in this study showed that the variables that had the most influence on pedestrian safety at bus stops are traffic volume on the street, distance to nearest intersection, lane count, median type/width, bus stop design, and land use. The study findings provide important insights to inform future policy decisions related to bus stop design and implementing safety countermeasures at bus stops for improving pedestrian safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-04898
Paper Title	**Investigating the Safety Effects of Median Separation Layout on 2+1 Roads**
Abstract	Evaluations of 2+1 roads focus mainly on the comparison between two-lane rural roads and three-lane configurations, indicating all the safety benefits of the latter. In Poland, several solutions are currently adopted for separating traffic directions, which include only horizontal marking, horizontal marking with additional measures to improve safety (low or high safety devices), and physical separation using cable barriers. However, the literature lacks studies about the impact of all the above-mentioned median separations on safety. When the target of the investigation is the safety performance of 2+1 roads, their contribution cannot be ignored. Based on this assumption, the aim of the present research work is to investigate the safety performance of 2+1 roads, considering various solutions for separating traffic directions, considering the accident' costs. The methodological approach includes the statistical inference by means of regression models quantifying the predicted number of crashes considering exposure and other variables. The quantification is carried out by calibrating the Safety Performance Functions (SPFs) for total crashes, based on the traffic flows, inventory and crash data. To develop the SPF model the generalized linear regression modeling (GLM) approach was used by calibrating the model on homogeneous segments. Crash Modification Factors (CMFs) for 2+1 roads were estimated to evaluate the influence on the safety of the various solutions of separating. The lowest cost of crashes is expected for cable barrier separation, although the greatest number of crashes but mainly non-injured is observed.

5 Crash Severity Prediction

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The subcommittee identified **eighty-two papers** dealing with crash severity prediction. Indeed, the identification of factors contributing to crash severity is crucial for planning, designing, and managing a safer transport system. The large number of papers dealing with crash severity prediction highlighs how this issue is becoming important for the scientific community. Great emphasis is given to fatal and injuries crashes also at political level. The UN General Assembly Resolution 74/299 declares the period 2021–2030 as the Second Decade of Action for Road Safety, with the target of decreasing road traffic deaths and injuries by at least 50 per cent from 2021 to 2030. Furthermore, the EU set the goal of halving the number of serious injuries in the EU by 2030 from the 2021 baseline using a common definition based on the MAIS 3+ trauma scale.

The papers are distributed across seventeen different sessions:

- 2046 Research Supporting Advancements in Roadside Safety (Monday, January 09 8:00 AM- 9:45 AM ET);
- 2053 Building Resilient and Sustainable Communities (Monday, January 09 8:00 AM- 9:45 AM ET);
- 2099 Truck and Bus Safety Research (Monday, January 09 10:15 AM- 12:00 PM ET);
- 2149 Innovations in Traffic Law Enforcement (Monday, January 09 1:30 PM- 3:15 PM ET);
- 2150 Occupant Protection Posters (Monday, January 09 1:30 PM- 3:15 PM ET);
- 3093 Toward the Next Generation of Intelligent Transportation Systems (Tuesday, January 10 10:15 AM- 12:00 PM ET);
- 3097 TRB Minority Student Fellows Poster Session (Tuesday, January 10 10:15 AM- 12:00 PM ET);
- 3149 Transportation Safety Management Systems from Start to Finish (Tuesday, January 10 1:30 PM- 3:15 PM ET);
- 3158 Highway-Rail Crossing Research (Tuesday, January 10 1:30 PM-3:15 PM ET);
- 3196 Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others (Tuesday, January 10 3:45 PM- 5:30 PM ET);
- 3206 Quantitative Methods for Understanding Travel and Traffic Behavior: Implications for Transport Practitioners in Developing Countries (Tuesday, January 10 3:45 PM- 5:30 PM ET);
- 3216 A Fresh Look at Crash Characteristics (Tuesday, January 10 6:00 PM-7:30 PM ET);
- 4059 Investigating Pedestrian Safety and Accessibility (Wednesday, January 11 10:15 AM- 12:00 PM ET);
- 4060 Bicycling and Micromobility Research Omnibus Session (Wednesday, January 11 8:00 AM- 9:45 AM ET);
- 4065 Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling (Wednesday, January 11 10:15 AM- 12:00 PM ET);
- 4072 Current Research in Transportation Equity (Wednesday, January 11 10:15 AM- 12:00 PM ET); and
- 4080 Artificial Intelligence Applications in Transportation Planning (Wednesday, January 11 3:45 PM- 5:30 PM ET).

Twenty-seven papers investigated vulnerable road users highlighting how the safety of pedestrian, cyclist and powered two-wheelers is a growing concern for transportation planners and safety engineers:

- Pedestrians (23-00321, 23-00635, 23-00978, 23-01089, 23-01246, 23-01415, 23-01449, 23-01847, 23-02917, 23-03617, 23-03653, 23-03804, 23-04198);
- Cyclists (23-00526, 23-00749, 23-01748, 23-03617, 23-03880, 23-04154); and
- Powered Two-Wheelers (23-00194, 23-04631, 23-00709, 23-00749, 23-02088, 23-02428, 23-03994, 23-04154, 23-04325, 23-04328).

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:

- Autoregressive Integrated Moving Average (ARIMA) model (23-04741);
- Bayesian multinomial logit model (23-01323);
- Binary Probit model (23-01516);
- Copula-based model (23-01516);
- Cross-sectional regression model (23-01748);
- Geographically Weighted Logistic Regression (23-01847, 23-02786, 23-04333);
- Hierarchical Bayesian heterogeneity-based model (23-04932);
- Latent Class Cluster analysis (23-03617, 23-04962);
- Logit model (23-00978, 23-02610, 23-02917, 23-03061, 23-03804, 23-02238, 23-03228, 23-04255);
- Multivariate Poisson Log-normal model (23-04036);
- Negative binomial model (23-02610),
- Partial Proportionality Odds model (23-03128);
- Proportional Regression Connection model (23-03913);
- Random binary Bayesian logit model (23-04635, 23-04738);
- Random Parameter Logit model (23-00145, 23-00287, 23-00289, 23-00691, 23-00749, 23-23-0242800904, 23-01415, 23-01574, 23-02170, 23-02428, 23-02917, 23-03012, 23-03061, 23-03732, 23-03880, 23-03994, 23-04255, 23-04639, 23-04894);
- Random Parameters Hazard-Based Duration model (23-04469);
- Regression model (23-00194, 23-02087);
- Zero-inflated negative binomial model (23-00338, 23-01993, 23-04010).

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

- Binary and Bivariate Ordered Probit model (23-00132, 23-00709);
- Hierarchically Ordered Probit model (23-05001);
- Ordered Logit model (23-02115, 23-03913, 23-04154, 23-04328);
- Ordered Probit Regression model (23-02088);
- Random parameters Ordered Logit model (23-01415, 23-02352, 23-02003, 23-04570);
- Random parameters Ordered Probit model (23-01089).

Some papers used **machine learning approach**, such as:

- Artificial Neural Networks (23-00417);
- Association Rule (23-00321, 23-01246, 23-02153, 23-04962);
- Bayesian additive regression trees (23-00635);
- Bayesian Networks (23-04325, 23-04476);
- Bidirectional Encoder Representations from Transformers (23-02697);
- Cluster Correspondence Analysis (23-02088);
- Convolutional Neural Networks (23-00417);
- eXtreme Gradient Boosting (23-00978, 23-02981, 23-04894);
- Gradient boosting (23-00635);
- K-means clustering (23-03592, 23-04265);
- Random Forest (23-00635, 23-01993; 23-03617);
- ResNet-50 (23-03583);
- SHapely Additive exPlanations (23-02981).

One paper (23-00526) used a simultaneous econometric approach to estimate the effect of proximity to a school on cyclist injuries at signalized intersections while accounting for endogeneity. Another paper (23-04631) applied machine learning technique to evaluate the most important factors for injury severity and total hospitalization cost.

One paper (23-00606) proposed an econometric framework that uses both aggregate and disaggregate level crash data simultaneously. The used model can also accommodate common unobserved spatial correlation among crash records.

One paper (23-01013) compared fatal crashes in the United States during the COVID-19 pandemic to quantify the involvement of specific crash, vehicle, and driver-related factors in fatal crashes during May-December 2020 relative to what would have been expected in the absence of the pandemic based on models of pre-existing trends. Another paper (23-01104) utilized several state-of-the-art text mining tools including word cloud analysis, word frequency analysis, word co-occurrence network analysis, rapid automatic keyword extraction, and topic modeling to identify crash contributing factors and patterns associated with fatal truck-involved crashes in Bangladesh. Another paper (23-04198) provided a comprehensive review of data collection, analysis, contributing factors, and crash prevention methods to enhance pedestrian safety.

Paper 23-01449 conducted a comprehensive study on pedestrian injury severity at urban intersections in Hong Kong from 2010 to 2019 by constructing a refined spatial correlation form according to the road network structure, and established two different spatial treatments, four kinds temporal trends, and various spatial and temporal combinations. Another paper (23-02059) identified crash severity contributors from text narratives using Natural Language Processing (NLP) showing the feasibility of leveraging state-of-the-art NLP techniques for the analysis of crash narratives to devise safety countermeasures.

One paper (23-03297) calculated yearly driver and occupant fatality rates per 100,000 population for each race and ethnicity from 2010 through 2019 to understand the racial discrepancies that exist in motor vehicle traffic fatalities. Another paper (23-03653) examined the incidence of injurious and fatal

pedestrian crashes for lower-income and affluent communities in Broward and Palm Beach Counties, Florida, finding notable differences in the environmental risk factors for these populations.

One paper (23-03771) analyzed the factors contributing to varying injury severity outcomes for child vehicle occupants less than 8 years old involved in road crashes in Ghana from 2014-2020. Another paper (23-03913) developed a multilevel discrete outcome modeling framework to estimate crash counts by severity for California rural four lane divided highways by estimating and combining three models: a univariate count model for total crashes at the site-level predicted total crash counts, an ordered logit discrete outcome crash severity prediction model at the crash-level predicted proportion of crashes by severity, and a proportional regression connection model that predicted proportion of groups of drivers and vehicles to connect the other two models.

One paper (23-04265) applied K-means clustering to develop the severity clustering model and developed a severity clustering validation model after investigating nine machine learning techniques to validate the developed severity clustering model. Another paper (23-04806) used a deterministic approach to calculate the effects of different AV levels on each of the fatal crashes.

Below, for each of the forty papers involving crash severity prediction, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Brendan Russo, Northern Arizona University Fan Yu, Northwestern University Edward Smaglik, Northern Arizona University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-00132
Paper Title	**Examination of Factors Associated with Fault Status and Injury Severity in Intersection Related Rear-End Crashes: Application of Binary and Bivariate Ordered Probit Models**
Abstract	Rear-end crashes are a relatively common crash type and often occur at or near intersections. Although rear-end crashes are generally less severe than some other crash types, there were still 2,346 fatal and 595,000 injury rear-end crashes in the US in 2019 alone. These crashes are generally caused by one atfault driver who strikes a leading vehicle, and it may be useful to assess factors associated with a driver being at-fault. Additionally, it is important to analyze factors associated with injury severity outcomes in order to develop countermeasures aimed at preventing severe injuries. As such, this study investigates factors related to fault status and injury severity (and the interrelation between the two) in two-vehicle intersection-related rear-end crashes using data from a southwestern US state. A binary probit model was estimated to assess factors associated with fault status, while a bivariate ordered probit model was estimated to assess factors associated with driver injury severity by fault status. Importantly, by modelling the injury severity of both crash-involved drivers jointly, potential within-crash correlation can be accounted for. The results of the fault status model indicated numerous factors were associated with a fault status including vehicle type, driver age, and driver impairment or distraction. The results of the bivariate injury severity model indicated numerous factors were significantly associated with injury severity and importantly, differences were observed between at-fault and not-at-fault drivers. Ultimately, the results of this study may assist in development of targeted countermeasures aimed at reducing both crash occurrence and severe injury outcomes.

Authors	Dongdong Song, Beijing Jiaotong University Xiaobao Yang, Beijing Jiaotong University Panagiotis Anastasopoulos, University at Buffalo, SUNY
Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-00145
Paper Title	**Temporal Stability Analysis of Fixed-Objects Crashes on Mountainous Regions Accounting for Unobserved Heterogeneity**
Abstract	This paper explores different effects of factors determining the driver injury-severity of crashes involving three different types of fixed-objects: w-beam barriers, cable barriers, and roadside trees. How these factors change over the years is leveraging through a random parameters logit modeling approach with heterogeneity in the means and variances (RPLHMV). Using injury-severity data from 2016 to 2019 in Guiyang City, China, three injury-severity categories are determined as outcome variables: severe injury (SI), minor injury (MI), and no injury (NI), while the potential influencing factors including drivers-, vehicle-, road-, and environment-specific characteristics are statistically analyzed. Findings indicate that the RPLHMV model provides a superior statistical fit and offers additional insights as compared to the traditional lower order logit model counterparts. In addition, the results of temporal effects analysis show that some variables present relative stability, which are likely more important for formulating long-term strategies to enhance traffic safety. More importantly, the effects of the explanatory factors that exhibit a relatively temporal stability are found to vary across different fixed-objects crashes. The results from this study are expected to help policymakers take necessary actions in reducing fixed-objects crashes by targeting appropriate strategies and proper resource allocation.

Authors	Arjun Ganga, Warren Alpert Medical School of Brown University Eric Kim, Warren Alpert Medical School of Brown University Oliver Tang, Warren Alpert Medical School of Brown University Joshua Feler, Warren Alpert Medical School of Brown University Rahul Sastry, Warren Alpert Medical School of Brown University Matthew Anderson, Warren Alpert Medical School of Brown University Sharonda Keith, Warren Alpert Medical School of Brown University Jared Fridley, Warren Alpert Medical School of Brown University Ziya Gokaslan, Warren Alpert Medical School of Brown University Deus Cielo, Warren Alpert Medical School of Brown University Steven Toms, Warren Alpert Medical School of Brown University Patricia Sullivan, Warren Alpert Medical School of Brown University
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-00194
Paper Title	**The Cost of Unhelmeted Motorcycle Injury: a Nationwide Scoring-based Analysis of Helmet Safety Legislation**
Abstract	Motorcycle collisions comprise a large portion of motor vehicle injuries and fatalities. Unhelmeted riders have worse outcomes and generate billions of dollars in costs. Despite helmets having been shown to lower the risk of injury and death, legislation concerning helmet use varies widely across the US. In this study, we reviewed statutes to evaluate the stringency of helmet policies across the country using a legislative scoring system termed the Helmet Safety Score (HSS) ranging from 0-7 points, with higher scores denoting more stringent statutes. Regression modeling was used to predict unhelmeted mortality in all jurisdictions using our safety scores. The mean score across all jurisdictions was 4.73. We found that states with higher helmet safety scores generally had lower percentages of unhelmeted fatalities in terms of total fatalities as well as lower unhelmeted fatalities per 100,000 people and registered motorcycles. In contrast, some lower-scoring states had over 100 times more unhelmeted fatalities than higher-scoring states. Our helmet safety scores significantly predicted unhelmeted motorcycle fatalities per 100,000 people (β = -0.228 per 1-point HSS increase, $p < .0001$) and per 100,000 registered motorcycles (β = -6.17 per 1-point HSS increase, $p < .0001$). Aspects of our score concerning helmet exemptions for riders and motorcycle-type vehicles independently predicted fatalities ($p < .0001$). Universal helmet laws are an effective mechanism for maximally decreasing unhelmeted mortality. We advocate for a federal, universal helmet law to decrease motorcycle-related injury and fatality burden. In states with existing helmet laws, we advocate for elimination of exemptions.

Authors	Nawaf Alnawmasi, University of Hail College of Engineering
Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-00287
Paper Title	**A Statistical Assessment of Temporal Instability in Factors Affecting Driver-injury Severities During Wet-Pavement Conditions**
Abstract	This study explores the effect of pavement skid resistance values on the crash injury severity outcomes during wet pavement conditions. The temporal shifts in the effects of explanatory variables on the injury severity outcomes of wet-pavement crashes are also explored. Using data from wet-pavement crashes on Florida State highways over a four-year period (from 2016 to 2019 inclusive), separate yearly models of driver-injury severities (with possible outcomes of severe injury, minor injury, and no injury) were estimated by the random parameters logit with possible heterogeneity in the means and variances of random parameters. Likelihood ratio tests were conducted to examine the overall stability of model estimates across years and marginal effects of each explanatory variable were also considered to investigate the temporal stability of the effect of individual parameter estimates on wet-pavement crashes injury-severity probabilities. A wide range of variables potentially affecting injury severities was considered including diver characteristics, vehicle characteristics, environmental conditions, temporal characteristics, roadway attributes, and combinations of driver characteristics and pavement conditions. The findings show statistically significant temporal instability was found, which likely results from the evolution of the influence of factors that affect wet-pavement condition driving behaviors over time.

Authors	Renteng Yuan, Southeast University Xin Gu, Beijing University of Technology Zhipeng Peng, Chang'an University Qiaojun Xiang, Southeast University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-00289
Paper Title	**Exploring differences in injury severity between occupant groups involved in fatal rear-end crashes: A correlated random parameter logit model with mean heterogeneity**
Abstract	Rear-end crashes are one of the most common crash types. Passenger cars involved in rear-end crashes frequently produce severe outcomes. However, no study investigated the differences in the injury severity of occupant groups when cars are involved as following and leading vehicles in rear-end crashes. Therefore, the focus of this investigation is to compare the key factors affecting the injury severity between the font- and rear-car occupant groups in rear-end crashes. First, data is extracted from the Fatality Analysis Reporting System (FARS) for two types of rear-end crashes from 2017 to 2019, including passenger cars as rear-ending and rear-ended vehicles. Significant injury severity difference between font- and rear-car occupant groups is found by conducting likelihood ratio test. Moreover, the font- and rear-car occupant groups are modelled by the correlated random parameter logit model with heterogeneity in means (CRPLHM) and the random parameter logit model with heterogeneity in means (RPLHM), respectively. Overall, significant differences in the factors affecting the injury severity of different occupant groups are found in rear-end crashes, such as occupant positions, driver age, overturns, vehicle type, etc. For instance, the driving and front-right positions significantly increase the probability of severe injury when struck by another vehicle. Large truck-strike-car tends to cause severe outcomes compared to car-strike-large truck. This study provides an insightful knowledge of mechanism of occupant injury severity in rear-end crashes, and could help traffic managers implement effective countermeasures to mitigate the crash severity.

Authors	Md Mahmud Hossain, Auburn University Huaguo Zhou, Auburn University Ahmed Hossain, University of Louisiana, Lafayette Subasish Das, Texas State University Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-00321
Paper Title	**Crashes involving distracted pedestrians: Exploring association of contributing factors by pedestrian injury severity and modes of distraction**
Abstract	The concept of distracted pedestrians and its potential impact on highway safety has become a growing issue in recent years. Compared to distracted driving, studies focusing exclusively on distracted pedestrian crashes are less pervasive. Most prior studies investigate the harmful effect of cellphone usage during walking instead of considering different forms of distraction associated with pedestrians. This study aims to reveal the chain of contributing factors involved in crashes of distracted pedestrians by injury severity levels and distraction-related tasks. Ten years (2010-2019) of related crashes were extracted from the Louisiana Department of Transportation and Development, and association rule mining (ARM) was applied to identify the meaningful crash patterns. Different distracting activities of pedestrians were introduced from narratives of police-investigated crash reports. The study findings exhibit the complexities of distracted pedestrian crashes by specifying the intricate interrelations between risk factors. Distracted male pedestrians aged 41-64 years are more likely to be fatal/severely injured in the dark-not-lighted conditions at segments. Electronic device usage is found to be frequent while crossing the intersections, whereas distraction by pets/persons/objects is strongly associated with crossing segments in rural settings. Crashes involving in-person conversations are more likely to occur while standing on the roadways of urban residential locations with no traffic controls. The study outcomes are critical in revealing the coexisting crash characteristics associated with distracted pedestrians, which can be helpful in targeting/developing effective educational, design, and enforcement strategies for improving pedestrian safety.

Authors	Aemal Khattak, University of Nebraska, Lincoln Muhammad Farooq, University of Nebraska-Lincoln
Sponsoring Committee	AR080
Session Number	3158
Session Title	**Highway-Rail Crossing Research**
Paper Number	23-00338
Paper Title	**The Effects of Inaccurate and Missing Highway-Rail Grade Crossing Inventory Data on Crash Model Estimation and Crash Predictions**
Abstract	Most highway-rail grade crossing (HRGC) crash models in the US rely on the Federal Railroad Administration's (FRA) highway/rail crossing inventory database. Any errors and/or incomplete information in this database affects the estimated crash model parameters and subsequent crash predictions. Using 560 HRGCs in Nebraska, this study illustrates differences in crash predictions obtained from the FRA's new (2020) Accident Prediction and Severity (APS) model when: 1) using the unaltered, original FRA HRGC inventory dataset as input, and 2) using a field-validated inventory dataset for those 560 HRGCs as input to the new APS model. Results showed that the predictions using the two different input datasets were statistically significantly different. HRGC hazard rankings from the two predictions as well as FRA's Web Accident Prediction System (WBAPS) were different from each other. Estimation of new zero-inflated negative binomial models using 5-year reported HRGC crashes and the two inventory datasets for the 560 HRGCs enabled model parameter estimate and marginal value comparisons showing differences in estimated coefficients' expected-magnitudes and average marginal effects. The conclusions were that erroneous and missing data in the unaltered FRA HRGC inventory dataset led to statistically different crash predictions compared to corrected and complete (field validated) HRGC inventory dataset and estimated crash prediction model parameters and their respective marginal values were different for comparative models based on the two different HRGC inventory datasets.

Authors	SINA SHAFFIEE HAGHSHENAS, University of Calabria: Universita della Calabria Giuseppe Guido, University of Calabria Alessandro Vitale, University of Calabria Vittorio Astarita, University of Calabria: Universita della Calabria
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-00417
Paper Title	**A Comparison Between the Models' Performance of ANN and Deep Learning to Predict the Level of Road Crash Severity**
Abstract	In measuring road safety, accident severity is a key concern. Crash severity prediction models show researchers how severe an accident was depending on different parameters. To date, an enormous amount of research has been done on crash severity, and several models have been suggested to forecast crash severity utilizing existing test data or simulated datasets created using regression or classification analysis. In this study, a new approach was developed to determine the level of road crash severity (LRCS) using a large amount of real-existing data (1627 cases) by applying machine learning methods to the roads of Calabria in southern Italy. This study has three main goals: building prediction models based on classification approaches with the highest accuracy; comparing the performance of two machine learning methods, including artificial neural networks (ANN) and convolutional neural networks (CNN), for predicting the LRCS; as well as determining the role of each of the contributing parameters in the LRCS and presenting a ranking by performing a sensitivity analysis. Finally, based on the accuracy values, it has been found that there isn't a salient difference between the predicted models. But it should be noted that 68.4% accuracy for the testing dataset implies the CNN model was superior than the ANN model, which scored 61.74% accuracy. This is acceptable if the minor variation in modeling accuracy is desired. Also, the results of the sensitivity analysis showed that the number of vehicles and the road element had the highest and lowest effect rates on the LRCS, respectively.

Authors	Michael Forrest, University of Southampton Shahram Heydari, University of Southampton
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-00526
Paper Title	**Estimating the Effect of Proximity to School on Cyclist Injury Frequencies**
Abstract	The safety of cyclists is a universal concern and identifying factors which affect the frequency of cycling injuries is crucial in understanding how to target interventions to improve cycling safety. Safety around schools is a particular point of concern and as such these locations are often the subject of safety interventions. However, it is difficult to estimate the impact of proximity to school on traffic safety due to an inherent endogeneity of the presence of a school which might be associated with safety (e.g., cyclist injury frequencies) and other site characteristics at the same time. This paper uses a simultaneous econometric approach to estimate the effect of proximity to a school on cyclist injuries at signalised intersections while accounting for endogeneity. It was found that a number of exposure and built environment factors had a significant association with cyclist injury frequency and the presence of schools at intersections. We found that the presence of a school was associated with an increase in cyclist injuries and this association was stronger when endogeneity was accounted for in the model, confirming the importance of considering endogeneity in studies of school safety interventions. This research offers policy implications based on the findings of the analysis including the need for safety interventions at intersections with high turning vehicle counts and those in proximity to public transport stops. A safety-in-numbers effect is also found for cyclists in the study area and period, suggesting that as volume increases the rate of injuries per cyclist decreases.

Authors	Roumen Vesselinov, University of Maryland Kartik Kaushik, University of Maryland Mark Scarboro, University of Maryland, School of Medicine Elizabeth Karpinski, The MITRE Corporation Kimberly Auman, University of Maryland, Baltimore County Joseph Kufera, University of Maryland, Baltimore County Bridget Lewis, MITRE Corporation Tracy Sanders, The MITRE Corporation
Sponsoring Committee	AME80
Session Number	2053
Session Title	**Building Resilient and Sustainable Communities**
Paper Number	23-04631
Paper Title	**Analysis of Micromobility Injuries in Maryland**
Abstract	This is a study of 173 e-scooter riders who were injured and treated between 2016 and 2021 at a busy Level 1 trauma center in the US, located at Baltimore, Maryland. Patient data were analyzed in terms of injury severity, cost of hospitalization, and the use of illicit drugs, marijuana, and alcohol prior to the injury, along with their interactions, and compared with patient injury data from bicyclists, motorcyclists, and pedestrians. With the help of a machine learning technique, the most important factors for injury severity and total hospitalization cost were evaluated. The results indicate strong need for interventions involving policies, community education, and enforcement to control the factors that cause increased morbidity among micromobility users.

Authors	Shandhana Rashmi B, NIT-Trichy: National Institute of Technology Tiruchirappalli Sankaran Marisamynathan, National Institute of Technology, Calicut
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-00600
Paper Title	**Identifying the Factors Affecting Truck Driver Behavior on a Road Safety Context: A Critical Systematic Review**
Abstract	Road traffic injuries and crashes are one of the major public concerns contributing to mortality and morbidity figures across the globe. Researchers estimated that around 90% of all causative factors for crashes are attributed to road users in which drivers are the principal controlling elements. Therefore, understanding complex driver behavior and their possible violations or errors are necessary to control and prevent accident occurrence to a considerable extent. This is even more imperative for truck drivers who are more prone to engage in unsafe driving behaviors given their tight delivery schedules, irregular sleep-wake patterns, and monotonous driving environment. Studies on truck driver behavior are scattered widely and scarcely explored hindering the possibility of road safety outcomes. These underscores lead to the need to excavate and synthesize the past studies for an effective understanding of human factors causing truck crashes. In this paper, an attempt has been made to systematically review the pieces of literature and to identify the causative factors affecting truck driver behavior. The upward trend of studies shows a promising framework for improving truck driver safety by taking care of human factors influencing crashes. Most kinds of literature have cited human factors and unsafe behavior of drivers as a predominant source of truck crashes. The outcomes of this research can be utilized by transportation firms and stakeholders for identifying the possible lags to develop pragmatic and possible effective preventive measures featuring truck driver safety.

Authors	Shahrior Pervaz, University of Central Florida Tanmoy Bhowmik, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-00606
Paper Title	**An Econometric Framework for Integrating Aggregate and Disaggregate Level Crash Analysis**
Abstract	Traditionally, aggregate crash frequency and disaggregate severity analysis are conducted independently in the transportation research. The current research effort contributes to the safety literature by bridging the gap between these two different streams of research by using both aggregate and disaggregate level crash data simultaneously. To be specific, the study proposes a framework that integrates aggregate and disaggregate level models. The proposed framework allows for the influence of independent variables at the crash record level to be incorporated within the aggregate level propensity estimation. The empirical analysis is based on the crash data drawn from the city of Orlando, Florida for the year 2019. The disaggregate level analysis uses 20,204 crash records that contain crash specific, temporal, roadway, vehicle, driver, and road environmental factors for each record. For aggregate level model analysis, the study aggregated the crash records by severity class over 300 TAZs. An exhaustive set of independent variables including roadway, traffic, land-use, built environment, and sociodemographic characteristics are considered in this analysis. The empirical analysis is further augmented by employing several goodness of fit and predictive measures. A validation exercise is also performed using a holdout sample to highlight the superiority of the proposed integrated model over non-integrated model. The proposed model can also accommodate common unobserved spatial correlation among crash records within the same zone. The model results illustrate the benefits of developing an integrated model system for crash frequency and severity

Authors	Bo Zhao, UT Austin: The University of Texas at Austin Natalia Zuniga-Garcia, Argonne National Laboratory Lu Xing, UT Austin: The University of Texas at Austin Kara Kockelman, University of Texas, Austin
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-00635
Paper Title	**Predicting Pedestrian Crash Occurrence and Injury Severity in Texas Using Tree-Based Machine Learning Models**
Abstract	This study investigates the frequency and injury severity of pedestrian crashes across Texas using tree-based machine learning models. Ten years of police records are used along with roadway inventory and other sources to map more than 78,000 pedestrian crashes over 700,000 road segments along with road design, land use, transit stops, and hospital location and weather information. Methods such as random forests (RF), gradient boosting (LightGBM and XGBoost), and Bayesian additive regression trees (XBART) are applied and compared. The crash frequency models indicate that highway design variables significantly positively impact crash frequencies. Increments in total or fatal crash counts are related to a higher number of lanes, while higher speed and greater median and shoulder widths lead to fewer crash frequencies. Other variables such as proximity to schools, the number of transit stops, and population and job density increased pedestrian crash occurrences. Pedestrian severity models found that a high speed limit significantly increases the likelihood of pedestrian fatalities and severe injuries, and intoxicated drivers and pedestrians lead to more severe injuries. Also, pedestrian crashes are more likely to be severe and fatal at night and in areas with poor lighting conditions. An analysis of the vehicle type found that light-duty trucks (pickups, SUVs, and vans) also increase pedestrian severity. The comparison of the four models indicates that they performed similarly in predicting crash occurrences, with LightGBM showing significantly lower computational time. While for crash injury severity models, XBART obtained a higher precision value but with a significantly high computational time.

Authors	Sheikh Shahriar Ahmed, University at Buffalo, SUNY Francesco Corman, Eidgenossische Technische Hochschule Zurich (ETH Zurich) Panagiotis Anastasopoulos, University at Buffalo, SUNY
Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-00691
Paper Title	**Addressing unobserved heterogeneity and spatial instability in the analysis of highway-rail grade crossing crashes: A random parameters with heterogeneity in means and variances approach**
Abstract	Crashes at highway-rail grade crossings often result in higher proportion of injury and fatality of the vehicle occupants as compared to other crash types. In this study, injury-severity outcomes from highway-rail grade crossing crashes are analyzed using crash data from Texas and California, which are the most vulnerable states in the United States, in terms of highway-rail grade crossing crash occurrences. The data are collected from the Federal Railroad Administration's (FRA) Office of Safety Analysis, covering a period between 2012 and 2020. Such data often suffer from out-of-date or missing information due to cost and available resources limitations, which inevitably may lead to unobserved characteristics varying systematically across the dataset. To address these limitations, the random parameters multinomial logit modeling framework with heterogeneity in the means and variances is employed. Spatial instability of the factors affecting different injury-severity levels is investigated as well. The results indicate that the factors are not spatially stable across Texas and California, leading to the estimation of two separate state-specific models. The model estimation results help identify several vehicle-, train-, vehicle driver-, weather- and crossing-specific factors affecting different injury severity outcomes. Moreover, the results also demonstrate the varying magnitude of the identified factors on injury-severity across the two states, indicating the presence of spatial instability. The findings of this study highlight the importance of accounting for unobserved heterogeneity and spatial instability to avert critical methodological issues and misleading inferences from the simple aggregation used in most econometric analysis of highway-rail grade crossing crashes.

Authors	Steve Lee, The University of Tennessee Knoxville Numan Ahmad, The Pennsylvania State University Jerry Everett, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-00709
Paper Title	**Strategies for Reducing Motorcyclist Injuries in Tennessee: Relevance of Evidence-Based Countermeasures that Work**
Abstract	One of the recent issues in transportation safety is the rise in fatalities and severe injuries among motorcyclists. Since motorcyclists are far more vulnerable than enclosed vehicle users on the road, they are substantially more likely to be injured given a crash. While countermeasures against motorcycle crashes are available, this study aims to shorten the implementation cycle by thoroughly investigating motorcyclist injury severity, exploring flashpoint locations, and relating the findings from this study to countermeasures that are based on recent evidence from quality studies. According to recent motorcycle crash data (N=14,677) in Tennessee, 73.4% of motorcycle crashes resulted in rider injuries, with 5.1% causing fatalities. Statistical analysis with an ordered probit model reveals that improper use of a DOT-compliant helmet is associated with severer injuries, compared with properly wearing a DOT-compliant helmet. Not wearing a helmet and wearing a non-compliant helmet are also associated with higher injury risk, given a crash. Other injury risk factors include impaired riding and riding on undivided two-way roads. The provision of lighting in the dark could help mitigate the severity of motorcyclist injuries. High-frequency motorcycle crash flashpoints are located in large cities, but also on the Great Smoky Mountains National Park with tight curves and elevation changes. The findings from this study are a valuable reference to help prepare and apply evidence-based countermeasures that can deal with rider-related and environmental risk factors to prevent motorcyclist injuries in the future.

Authors	Tao Wang, Guilin University of Electronic Technology Jin Yu, Guilin University of Electronic Technology Yuzhi Chen, Guilin University of Electronic Technology
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-00749
Paper Title	**Factors Associated with The Severity of Motor Vehicle Crashes Involving Electric Motorcycles and Electric Bicycles: A Random Parameters Logit Approach with Heterogeneity in Means**
Abstract	China has more electric motorcycle crashes and electric bicycle crashes, exploring the heterogeneity of factors influencing the severity of the two types of crashes can help to target the development of accident prevention policies to improve traffic safety. Therefore, this paper established a mean heterogeneity random parameter Logit model using crash data from 2016 to 2020 in Guangxi to explore the different factors influencing the severity of electric motorcycle crashes and electric bicycle crashes. The results showed that the likelihood of serious crashes was greater for electric motorcycles involving indicators: drunk drivers, driver violations, large trucks, peak time, and no street lighting at night. The likelihood of serious crashes was greater for electric bicycles involving indicators: drunk drivers, driver violations, riders aged 41-64, large trucks, and no street lighting at night. The likelihood of serious crashes was lower for drivers with college or higher education and riders with college or higher education. In the electric motorcycle crashes, the likelihood of serious crashes decreased when both street lighting at night and vehicle left turn were involved, and decreased when both street lighting at night and no signal control were involved. In the electric bicycle crashes, the likelihood of serious crashes increased when both large trucks and motor vehicle lights not turned on were involved, and increased when both large trucks and visibility less than or equal to 200 meters were involved. The results provide a basis for improving the road safety of electric motorcycles and electric bicycles.

Authors	Sahima Nazneen, HNTB Khaled Ksaibati, University of Wyoming
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-00904
Paper Title	**Investigating Commercial Motor Vehicles Injury Crashes in Wyoming: Mixed logit model**
Abstract	Wyoming is ranked 1 st in terms of highest percentage of truck involvement in fatal crashes recording 25 percent truck related crashes, more than twice as national average. Understanding the factors contributing to Commercial Motor vehicle (CMV) crashes is crucial to develop appropriate countermeasures in reducing such crashes. This study offers a contribution to the literature by providing an extensive exploratory analysis and analyzing the variability in factors that contribute to CMV fatality/injury crashes based on seasons. The mixed logit model was employed to model.

Authors	Diana Cortes, Tennessee State University Hellen Shita, Tennessee State University Deo Chimba, Tennessee State University Bahati Chimba, Tennessee State University
Sponsoring Committee	AJE00, ACH10, AEP60, AED30, AV010, AME80, AP025, AKP00, AME50, ACS20, AMS20, AKD80, ACP55, ACH20, AKM80, AKT50, ACP20, AEP50, AP010, ACO20
Session Number	3097
Session Title	**TRB Minority Student Fellows Poster Session**
Paper Number	23-00978
Paper Title	**Invited Student Paper: Machine Learning and Regression Based Modeling of Pedestrian Crash Injury Severity Prediction: A comparative study**
Abstract	Significant percentage of traffic crashes in the United States involve pedestrians. This value has been at undesired level for the past decade and thus indicate how pedestrians are a class of vulnerable road users that are over-represented in fatal or incapacitating injury crash statistics. This study therefore utilized 20-year of pedestrian crash data in Tennessee to evaluate different factors that influence the severity of pedestrian crashes. Two different methodologies were applied, (1) XGBoost, a now popular machine learning algorithm and (2) binary logit, a regression model, were used to correlate significant variables and features that dictate injury severity. XGBoost results indicate that the highest influencing predictors include location of the crash, presence or absence of street illumination, number of lanes and land use at the crash site. It was found that pedestrians crossing non junction areas (along road segments) have a 0.61% higher chance of sustaining an injury compared to those crossing at junction-related locations such as intersections or grade crossings. On the other hand, binary logit results indicated that speed limit, crash locations, crash time and peak hour percentage are the leading factors in influencing pedestrian crash injury severity. Moreover, the two models showed a slight difference in their prediction accuracy levels, as XGBoost showed an accuracy level of 90% while the binary logit model showed an accuracy level of 93%. Location of the crash was found to be the common highest influencing variable among the two models.

Authors	Meng Wang, University of Massachusetts, Amherst Brian Tefft, AAA Foundation for Traffic Safety
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-01013
Paper Title	**Comparing Fatal Crashes in the United States During the COVID-19 Pandemic to Forecasts Based on Pre-Existing Trends**
Abstract	After initial reductions early in the COVID-19 pandemic, traffic fatalities in the U.S. surged in 2020 to their highest levels in over a decade. The purpose of the current study was to quantify the involvement of specific crash, vehicle, and driver-related factors in fatal crashes during May-December 2020 relative to what would have been expected in the absence of the pandemic based on models of pre-existing trends. Data from all fatal crashes in the U.S. from January 1, 2011 through December 31, 2020 were used to develop Seasonal Autoregressive Integrated Moving Average models of monthly counts of fatal crashes through December 2019, which were used to forecast how many fatal crashes would have occurred in May-December 2020 had the pandemic not occurred. The main outcome measures were the difference and ratio of the actual versus forecasted counts. Separate models were developed for total fatal crashes and for categories of crash, vehicle, and driver factors. Total fatalities in May-December 2020 exceeded the forecast by 3,083 (12.1%). The increase was not uniform across factors examined. Actual counts exceeded forecasts by large amounts in both difference and ratio for late night/early morning crashes, single-vehicle crashes, speeding drivers, drivers aged 25-34, drivers with suspended/revoked/no license, drivers of vehicles registered to others, and vehicles 15+ years old. Crashes during hours 6-10AM and involvements of drivers aged 55+ were fewer than forecast. Results can inform deployment of countermeasures intended to slow or reverse the increase in traffic fatalities that occurred during the COVID-19 pandemic.

Authors	Muhammad Farooq, University of Nebraska-Lincoln Aemal Khattak, University of Nebraska, Lincoln
Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-01089
Paper Title	**A Heterogeneity-Based Temporal Stability Assessment of Pedestrian Crash Injury Severity Using an Aggregated Crash and Hospital Dataset**
Abstract	This study utilized a unique approach to crash data analysis by examining the temporal stability of pedestrian crash injury severity and its contributory factors. Police-reported crash data and EMS-related injury data from Nebraska were obtained from 2014 to 2018, and random parameter ordered probit models for injury severity were estimated for each year to account for unobserved heterogeneity. Four discrete levels of injury severity were considered for model estimation: fatality, disabling injury/suspected serious injury, visible injury/possible injury, and no injury. Data were filtered based on several important variables of interest, such as pedestrian characteristics, crash characteristics, environmental and weather characteristics, road surface characteristics, pedestrian location of crash, pre-crash pedestrian conditions, contributory circumstances of a crash, presence of work zones, and time gap between actual crash-time and police-reported time. A series of likelihood ratio tests were used to determine the temporal stability of factors over the course of two consecutive years and then over all individual time periods. The likelihood ratio tests showed temporal instability among explanatory variables for different time periods as well as for consecutive years. The random-parameters ordered probit models estimated a random distribution for the following indicators: old pedestrian indicator, pedestrian not visible due to dark clothing indicator, marked crosswalk at intersection indicator, time gap of 10-30 minutes between actual crash-time and police-reported time, chest area injury, work zone indicator, and ice on road indicator. This exploratory research suggests significant policy implications to help improve pedestrian safety.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette Shah Alam, Rajshahi Science and Technology University Subasish Das, Texas State University
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-01104
Paper Title	**Crash Contributing Factors and Patterns Associated with Fatal Truck-involved Crashes in Bangladesh: Findings from Text Mining Approach**
Abstract	Despite extensive research on traffic injury severities, relatively little is known about the factors contributing to truck-involved crashes in developing countries, especially in the context of Bangladesh. Due to the unavailability of authentic crash data sources, this study collected data from alternative sources such as online English news media reports. The current study prepared a database of 144 fatal truck-involved crash reports during the period of twelve months (January 2021 to December 2021). The crash reports contain a bag of 15,300 words. To identify crash patterns, several state-of-the-art text mining tools were utilized including word cloud analysis, word frequency analysis, word co-occurrence network analysis, rapid automatic keyword extraction, and topic modeling. The analysis revealed several important crash contributing factors such as type of vehicle involved (auto-rickshaw, bus, van, motorcycle), manner of collision (head-on), time of the day (morning, night), driver behavior (speeding, overtaking, wrong-way driving), and environmental factors (dense fog). In addition, 'coming from opposite direction' and 'head-on collision' are identified as two important sequences of events in truck involved crashes. Truck drivers are also involved in crashes with trains at the rail crossing. The findings of this research are expected to assist transportation experts and policymakers in identifying crash avoidance strategies to lower truck-related crashes in Bangladesh.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Niaz Zafri, Bangladesh University of Engineering and Technology Xiaoduan Sun, University of Louisiana, Lafayette Julius Codjoe, Louisiana Department of Transportation and Development
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-01246
Paper Title	**Investigating Pedestrian Crash Patterns at High-speed Intersection and Road Segments: Findings from unsupervised learning algorithm**
Abstract	Pedestrian crashes at high-speed locations are a persistent road safety concern. Driving at high speed essentially indicates that the driver would get considerably less time to react and make evasive maneuvers. On top of this, other crash contributing factors such as humans (pedestrian or driver), vehicles, roadway, and surrounding environmental factors actively interact together to cause a crash at high-speed locations. Moreover, the pattern of pedestrian crashes differs significantly according to the high-speed intersection and segment locations which require further investigation. This study applied Association Rules Mining (ARM), an unsupervised learning algorithm, to reveal the hidden association of pedestrian crash risk factors according to the high-speed intersection and segments separately. The study used Louisiana pedestrian fatal and injury crash data from 2010 to 2019. Any crash location with a posted speed limit of 45 mph or above was classified as a high-speed location. Based on the generated association rules, the results show that pedestrian crashes at the high-speed intersection are associated with left/right turn vehicle movement, older drivers (>64 years), young drivers (15-24 years), pedestrian violations, pedestrian alcohol/drug involvement and so on. Most pedestrian crashes at high-speed segments are associated with roadways with no physical separation, dark-no-streetlight conditions, open country locations, interstate, and so on. The findings of the study are expected to provide a better understanding of the pedestrian crash patterns at high-speed intersections and segments. Highway safety professionals can utilize these findings to conduct a decision-making process for selecting appropriate countermeasures to reduce pedestrian crashes in high-speed locations.

Authors	Anthony Forcades, Florida International University John Kodi, Florida International University Priyanka Alluri, Florida International University
Sponsoring Committee	AJE00, ACH10, AEP60, AED30, AV010, AME80, AP025, AKP00, AME50, ACS20, AMS20, AKD80, ACP55, ACH20, AKM80, AKT50, ACP20, AEP50, AP010, ACO20
Session Number	3097
Session Title	**TRB Minority Student Fellows Poster Session**
Paper Number	23-01323
Paper Title	**Invited Student Paper: Exploring Work Zone Crash Risk for Different Highway Functional Classifications**
Abstract	Traffic safety and the safety of workers in work zones have drawn the attention of several transportation agencies due to a recent increase in the number of work zone-related crashes. Although a number of strategies have been implemented to improve work zone safety, the frequency and severity of work zone-related crashes are still substantially high. The effect of work zones on traffic safety can be aggravated by different factors, including spatial-temporal characteristics and the functional classification of the roadway. Thus, understanding the factors associated with work zone-related crashes on different roadway functional classifications is essential in improving traffic safety and the safety of workers. This study explored the factors influencing the work zone-related crashes based on roadway functional classification using ten years (2012-2021) of crash data from Florida's roadways using a Bayesian multinomial logit model. The findings indicated that work zone area types, rear-end, sideswipes, and run-off-road crashes were associated with a higher likelihood of work zone-related crashes on freeways than on arterials. Also, compared to collector roads, results revealed that work zone-related crashes are more severe on arterials than on freeways. Other contributing factors, such as dark lighting conditions, adverse weather conditions, wet road surface conditions, weekend, and rural areas, were associated with an increase in the likelihood of work zone-related crashes, both on freeways and arterials. The study's findings may help transportation agencies develop guidelines for improving the safety of work zones specific to a given roadway.

Authors	Sunday Okafor, University of Alabama, Tuscaloosa Jun Liu, University of Alabama Emmanuel Adanu, Alabama Transportation Policy Research Center Steven Jones, The University of Alabama
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-01415
Paper Title	**Behavioral Pathway Analysis of Pedestrian Injury Severity in Pedestrian-Motor Vehicle Crashes**
Abstract	Despite the health and environmental benefits of walking as an active and sustainable mode of transport, the increasing number of road crashes involving pedestrians has become a public health concern. This study investigates the direct and indirect effects of various contributing factors on pedestrian injury severity in pedestrian-motor vehicle crashes. Data of pedestrian-vehicle crashes from North Carolina between 2015 and 2019, including the pedestrian pre-crash actions and injury severity, were used. Path analysis was applied to uncover the interrelationship between contributing factors, pedestrian pre-crash behaviors, and injury severity using random parameter ordered logit and mixed logit models. The results indicate that pedestrian intoxication, lighting condition, number of lanes, speed limit, and vehicle type contribute directly and indirectly (through pre-crash behaviors) to increasing injury severity. At an intersection or stop-and-go traffic control, pedestrians are more likely to sustain severe injuries for failing to yield to traffic given a crash. This study provides valuable information about the relationship between various crash factors and pedestrian injury severity. For researchers and agencies interested in pedestrian safety improvements, this study gives valuable insight by uncovering the roles of pedestrians' pre-crash action on injury severity outcomes. For countermeasures, the study recommends better street lighting and reevaluation of posted speed limits on roads with high pedestrian traffic. Also, a regular educational campaign should inform pedestrians about the importance of yielding to traffic on the right of way.

Authors	Qiang ZENG, South China University of Technology Qianfang WANG, South China University of Technology Pengpeng Xu, University of Hong Kong
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-01449
Paper Title	**Analyzing The Severity Of Vehicle-Pedestrian Crashes At Urban Intersections Based On The Refined Spatial Configuration**
Abstract	This paper conducted a comprehensive study on pedestrian injury severity at urban intersections in Hong Kong from 2010 to 2019. The authors argue that accounting for spatial correlation between adjacent intersections can contribute to both unbiased parameter estimations in identifying the exogenous variables and improved model performance. Different from existing studies that mostly considered the spatial correlated effect at the zone level, we constructed a refined spatial correlation form according to the road network structure, and established two different spatial treatments, four kinds temporal trends, and various spatial and temporal combinations.

Authors	Xizhi Ding, Central South University Jinjun Tang, Central South University Xinyuan Liu, Central South University Chen Yuan, Central South University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-01516
Paper Title	**Jointly Analyzing Freeway Primary and Secondary Crash Severity Using a Copula-Based Approach**
Abstract	This study develops a copula-based model framework to jointly model the severity of freeway primary crashes and secondary crashes. The copula-based model can simultaneously account for the severity levels in the crash and the correlation among primary-secondary crash pairs' severity. The model considers a comprehensive set of exogenous variables including temporal characteristics, crash characteristics, roadway characteristics and real-traffic conditions, and is estimated using traffic crash data from 2016 through 2019 for Los Angeles County, California. The proposed copula model is then compared with the traditional binary probit model and the results show a remarkable superiority of the copula model, which is indicated by better fitting performance and the statistical significance of the spatial term. It is found that road condition, terrain, road weaving, truck involvement and traffic volume have significant effects on primary crash severity propensity and weather, traffic volume and vehicle speed have significant effects on secondary crash severity propensity. In light of the findings, several countermeasures regarding driver education, traffic rule enforcement, vehicle and roadway engineering and emergency services are proposed to mitigate freeway crash severity.

Authors	Amjad Pervez, Central South University Jaeyoung Lee, Central South University Helai Huang, Central South University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-01574
Paper Title	**What Factors Would Make Freeway Tunnel Crashes More Severe? Empirical Evidence from China**
Abstract	Crashes in freeway tunnels can be more severe than those on the open road sections due to their closed driving environment. Despite the higher crash severity, very few studies have attempted to investigate the severity of injuries in freeway tunnel crashes. Also, the existing studies on the injury severity analysis of tunnels did not fully consider the unobserved heterogeneity and its interactive effects. To address these issues, the present study first collected a comprehensive dataset containing five-year of police-reported tunnel crashes from Hunan province, China. A random parameters model with heterogeneity in means and variances was then developed to explore the influence of different variables related to the environment, drivers, crashes, vehicles, and tunnels. The study observed that the presence of curves and speeding indicators produce random parameters with heterogeneity in means and variances for freeway tunnels, which is influenced by the young drivers and outside exit zone variables. Also, the results reveal that factors, including weekdays, daytime, speeding, fatigue driving, rear-end collisions, collisions with fixtures, large passenger vehicles, and downgrades increase, while rain reduces the probability of severe injury outcomes in freeway tunnel crashes. More importantly, considering the unique tunnel driving environment, the summer, young drivers, novice drivers, presence of curves, and different tunnel sections (access, entrance, and outside exit zones) also significantly affect the risk of severe injury outcomes. Finally, the study's findings could be used as a basis for developing plans and technologies to minimize the severity of crash injuries in freeway tunnels.

Authors	Robert Mansell, Ryerson University Bhagwant Persaud, Toronto Metropolitan University Craig Milligan, MicroTraffic Inc. Amanda Pushka, MicroTraffic Inc.
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-01748
Paper Title	**Investigating Factors that Affect Conflicts Between Bicyclists and Right Turning Vehicles at Signalized Intersections**
Abstract	Due to the recognition of active transportation as a beneficial alternative to more traditional modes of transportation, there is increasing interest in designing infrastructure systems to promote the safe use of forms of active transportation such as bicycling. Collision data, which are typically used in road safety studies, may be incomplete and the use of such data is reactive as it requires collisions to have already taken place. Additionally, collisions involving bicyclists and vehicles are less common than those between vehicles. As a result, alternative approaches of evaluating the safety effect of various infrastructure attributes, such as the use of surrogate safety measures, specifically traffic conflicts, could be considered. Most collisions between bicyclists and vehicles occur at intersections and of these, collisions between right turning vehicles and bicyclists form the majority. The main objective of this study was to use cross-sectional regression models to investigate various intersection characteristics, including geometry, signal phasing, and bicycle infrastructure, with a view to determining which attributes are associated with a significant effect on right turning conflicts and how this may change with different conflict severity levels. Various intersection attributes were found to be associated with the frequency of right turning conflicts such as exposure levels, the lateral offset of the bicycle facility and the grade of the approach to the intersection. The significance levels of the associated effects of certain attributes were observed to change with the severity level of the conflicts, with effects becoming either more or less significant with increased severity levels.

Authors	Niaz Zafri, Bangladesh University of Engineering and Technology Asif Khan, Bangladesh University of Engineering and Technology
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-01847
Paper Title	**Using Geographically Weighted Logistic Regression (GWLR) for Pedestrian Crash Severity Modeling: Exploring Spatially Varying Relationships with Natural and Built Environment Factors**
Abstract	Although a large number of studies tried to explore the relationship between built environment and pedestrian crash severity in developed countries, there is a lack of similar studies in the context of developing countries. Methodologically, the contributory factors influencing pedestrian crash severity are commonly identified through global logistic regression (GLR) models. However, these models are unable to capture the spatial variation in the relationships between the dependent and independent variables. The local logistic regression model, such as Geographically Weighted Logistic Regression (GWLR), can potentially overcome this issue. Therefore, this study aimed to apply the GWLR technique to explore spatially heterogeneous relationships between the natural and built environment-related factors with pedestrian crash severity in Dhaka, the capital city of a developing country: Bangladesh. First, using secondary pedestrian crash data, a GLR model was developed to identify significant contributory factors influencing pedestrian crash severity. Results of the model showed that the probability of fatal pedestrian crash occurrence increased at night, in unlit locations, and during adverse weather conditions. In addition, the chance of occurring fatal crash reduced when medians exist on roads and around institutional land use. Also, the likelihood of fatal crashes increased on straight and flat roads and at locations with more bus stops. Finally, this study explored spatial variation in the effect intensity of these significant variables across the study area using the GWLR technique. This technique can be applied in any area and the results would be helpful to provide insights in the spatial dimension of traffic safety.

Authors	Pouya Jalali Khalilabadi, The University of Arizona Abolfazl Karimpour, State University of New York (SUNY) Yao-Jan Wu, University of Arizona
Sponsoring Committee	ACS30
Session Number	2149
Session Title	**Innovations in Traffic Law Enforcement**
Paper Number	23-01993
Paper Title	**Severity Analysis of Red-Light Running Behavior at Signalized Intersections**
Abstract	Red-Light Running (RLR) is one of the riskiest behaviors at signalized intersections. According to the report published by AAA Foundation for Traffic Safety, in 2019, more than two people were killed each day as a result of disregarding red signal indications. This study aims to utilize intersection and corridor-level characteristics to identify variables that impact the frequency and severity of RLR violations. The severity of RLR is defined based on the time when the violations happened. That is, less severe violations are the ones that happen within three seconds of the signal light turning red (RLR3), and more severe violations happen between three to ten seconds of the signal light turning red (RLR10). As RLR data are non-negative integers, a conventional parametric model, zero-inflated negative binomial, and a nonparametric model, random forest, were utilized to calibrate the violation models. Results of the ZINB model showed that an increase in intersection delay and split failure increases the frequency of both types of RLR severities. An increase in the yellow interval, cycle length, and the number of lanes, reduces the frequency of RLR3 but increases the frequency of RLR10. Furthermore, based on the factor importance analysis conducted through the random forest, it was shown split failure is one of the most predictive variables for RLR3 and RLR10. The founding of this research could help transportation agencies in different geographic jurisdictions utilize the calibrated models to understand the impact of different intersection and corridor-based characteristics on the frequency and severity of RLR.

Authors	Ye Dong, Iowa State University Maroa Mumtarin, Iowa State University Jonathan Wood, Iowa State University
Sponsoring Committee	AKD20
Session Number	2046
Session Title	**Research Supporting Advancements in Roadside Safety**
Paper Number	23-02003
Paper Title	**Impacts of Traffic Barrier Types on Crash Severity**
Abstract	Traffic barriers are known as one of the most popular safety countermeasures to minimize severe collisions from crossing medians and run-off-road at locations with non-traversable roadsides. This paper examines the impact of different traffic barrier types on crash severity with five years (2016-2020) crash data from Iowa using a causal inference framework. This includes genetic matching to reduce selection bias and the use of random parameters ordinal logistic regression to estimate the impacts of the barrier types on crash severity. Barriers were classified into three groups for the analysis: guardrails (i.e., semi-rigid), cable barriers (i.e., flexible) and concrete barriers (i.e., rigid). In order to make comparisons across barrier types, genetic matching was performed for paired comparisons (e.g., concrete vs. cable barrier) and then marginal effects were estimated to determine the differences in crash severity. According to the results, the cable barrier is associated with the lowest injury while the concrete barrier is associated with the highest injury levels. Guardrails are safer than concrete barriers and less safe than cable barriers. It is also found that if concrete barrier or guardrail is involved in the crash, there is 12.09% and 7.69% increased probability of an injury compared to cable barriers, respectively.

Authors	Cristian Arteaga, University of Nevada, Las Vegas Jee Woong Park, University of Nevada, Las Vegas Alexander Paz, Queensland University of Technology
Sponsoring Committee	AED50
Session Number	4080
Session Title	**Artificial Intelligence Applications in Transportation Planning**
Paper Number	23-02059
Paper Title	**Enhanced Identification of Crash Severity Contributors from Text Narratives Using Natural Language Processing**
Abstract	To develop traffic safety countermeasures, analysts must account for likely contributing factors to crash severities. Current traffic safety practices focus on the analysis of quantitative data contained in historical crash reports without using crash narratives, which can include insightful information with details and context. A few past studies have attempted to use crash narratives for the identification of likely severity contributors. However, methods of analysis remain at a superficial level using word frequency while leaving rich language semantics and their potential unexplored. To address this limitation and take advantage of available and valuable data that is mostly underutilized, this study evaluates whether a modern Natural Language Processing (NLP) approach with superior semantic modeling can enhance the identification of crash severity likely contributors from narratives. Specifically, this study investigated the ability of a modern NLP text classifier to enable the identification of crash severity contributors using phrases instead of individual words. The investigation used 1,131 narratives for crashes that occurred in Massachusetts between 2018 and 2020. The results obtained indicate that modern NLP techniques provide superior modeling of language semantics and thus enable an enhanced identification of crash severity likely contributors in the form of phrases, which word-frequencybased analysis cannot naturally reveal. Examples of the identified phrases include descriptions of collisions with objects, pedestrian involvement, driving under the influence of alcohol, airbag deployment, weather conditions, and injury types. These results show the feasibility of leveraging state-of-the-art NLP techniques for the analysis of crash narratives to devise safety countermeasures.

Authors	Kwaku Boakye, Arcadis Shashi Nambisan, University of Nevada, Las Vegas
Sponsoring Committee	ACS40
Session Number	2150
Session Title	**Occupant Protection Posters**
Paper Number	23-02087
Paper Title	**The Risk of Seatbelt Non-use among Unlicensed and Licensed Drivers**
Abstract	In the United States, about one in five fatal crashes, as well as traffic fatalities involve unlicensed drivers. The exact reasons for the overrepresentation of unlicensed drivers in fatal crashes remain unclear, however, there is growing evidence linking unlicensed driving to a cluster of high-risk behaviors including alcohol-impaired driving, speeding, and seatbelt non-use. The contribution of unlicensed drivers to the frequency of traffic crashes is well documented in the literature, yet minimal research has been conducted to investigate the effect of unlicensed driving on restraint use. Against this background, this study explored the risk of seatbelt non-use among unlicensed and licensed drivers using a 10-year (2011-2019) crash data from the Fatality Analysis Reporting System (FARS). In a relative risk analysis, the results showed that the risk of seatbelt non-use among unlicensed drivers was almost twice as that of licensed drivers. In addition, unlicensed drivers significantly showed a higher risk of not wearing seatbelts when driver demographics (age, gender), roadway/ environment (urban/rural, jurisdictional seatbelt law, region, road type), vehicle type, and collision characteristics (injury outcome, time/day/season of crash) were accounted for in a z-test comparison analysis. Adjusting for the above predictor variables in a logistic regression model, unlicensed drivers were 60% more likely than licensed drivers to be unrestrained in motor vehicle crashes. These findings are critical to addressing a myriad of policy questions related unlicensed drivers' behavior toward seatbelt use. The results highlight a risk effect that has significant implications for highway safety and injury prevention programs.

Authors	Reuben Tamakloe, University of Seoul Subasish Das, Texas State University Dongjoo Park, University of Seoul
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02088
Paper Title	**Risk Factors Affecting Motorcycle-Barrier Crashes and Injury Severities: Insights from an Innovative Cluster-Regression Technique**
Abstract	Although motorcycle crashes into roadside safety barriers are uncommon, they are known to result in particularly severe rider injuries when compared to other types of motorcycle crashes. Currently, very little has been done to understand the factors associated with these crashes and the attributes influencing injury severity outcomes of motorcycle-barrier crashes. This study aims to employ an innovative unsupervised machine learning approach known as Cluster Correspondence Analysis and an ordered probit regression technique to discover latent patterns and associations between key crash contributing attributes in homogeneous clusters of motorcycle-barrier crash data obtained from Massachusetts, and to investigate the effect of risk factors on injury severity outcomes at the cluster level. The results demonstrated significant differences in the factor associations and determinants of fatal/non-fatal injury outcomes in all clusters. While variables such as older riders, minor arterial/collector roads, intersections/roundabouts, rolling/mountainous terrain, daylight, and summer were strongly associated with motorcycle-barrier crashes at no/partial access-controlled segments, attributes, namely interstates, ramps, medians, early mid-aged riders, dark-lighted roads, and winter, were correlated with crashes on full access-controlled segments. Besides, while level terrain, spring, and summer increased the chance of fatalities in motorcycle-barrier crashes on full access-controlled segments, traffic control absence, principal arteries and major collectors increased the likelihood of fatalities on no/partial access-controlled segments. Identifying and controlling all or some factors associated with fatal motorcycle-barrier crashes could help reduce the injury severities on the roads. Based on the insightful findings, policy implications and more targeted countermeasures to improve motorcycle safety have been suggested.

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Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-02115
Paper Title	**Understanding Severity of Truck-involved Crashes on Mountainous Expressway Considering Vehicle Types and Road Alignment Specifications**
Abstract	Truck involved accidents have long been a big concern for transportation sectors and has brought huge property loss as well as casualties. In the present work, influencing factors of the severity of truck-involved crashes is analyzed taking the crash data on a mountainous expressway in China as an example. With this data set, an ordered logistics model is built considering the specification of vehicle types and more detailed classification of road alignment condition. The modelling results show that vehicle types involved in the crash is proved to have significant effect on the severity of truck-truck crashes. Moreover, it is observed that although the probability for truck-involved crashes with higher severity gradually decreases with the increase of the curve radius, a flat curved section is not always safer than that of a smaller curve. While for grade considerations, flat grade sections are observed to have higher probability of severe crashes than that of upgrade sections. Conclusions obtained in the present work could provide important implications for both road de-signer and transportation management agencies to further improve traffic safety for mountainous expressway with high truck mix rate.

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Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-02153
Paper Title	**Using association rule mining in investigating animal-related injury and non-injury crashes on Louisiana roadways**
Abstract	Animal vehicle crash is a critical yet often under-emphasized safety concern of Louisiana. During 2014-2018, over 14,000 animal-related crashes cost Louisiana more than $520 million. To identify multiple key contributing factors and their association patterns, this study applied association rules mining in the dataset of animal-related roadway crashes that occurred during 2014-2018. Since high proportions of animal-related crashes involve complaint and no injury of vehicle occupants, separate analyses were performed for KAB (fatal, severe, and moderate injury) and CO (possible/complaint and no injury) crashes. Top rules ordered by higher lift values were interpreted and compared to implicate the quantified likelihood of crash patterns. KAB rules presented the likelihood of associations of characteristics such as unlighted dark conditions, interstate and parish roads, a wide range of speed limits, residential and open country locations, normal and rainy weather conditions, light trucks, young drivers, etc. The majority of CO crash patterns were associated with interstates, straight segments, normal driver conditions, clear weather, unlighted dark conditions, open country locations, a speed limit of 97 km/h or higher, etc. Findings in this study and their implications supported by prior studies are expected to be beneficial in strategic planning for identifying implementable countermeasures for animal-vehicle crashes.

Authors	Raul Pineda-Mendez, Purdue University Qiming Guo, Purdue University Andrew P. Tarko, Purdue University
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-02170
Paper Title	**Risk-Based Highway Safety Management Systems: A Case Study for Rural Interstate Freeways in Indiana**
Abstract	In highway safety management, road hazards are methodically identified and reduced to reflect a lower crash frequency and diminish the severity of crash-related injuries. For this purpose, aggregate count-based crash models, e.g., safety performance functions, have been widely adopted in engineering practice. This study evaluates the potential use of disaggregate safety analysis combined with emerging high-resolution data sources to supplement conventional count-based crash models used by safety management systems. A methodology is proposed to identify and assess time-dependent safety issues such as weather conditions and operational speed characteristics, which are typically omitted in traditional safety management systems. This methodology is illustrated in a case study on rural interstate freeways in Indiana. In addition to fixed safety factors, the effect of time-dependent variables on the hourly crash probability and injury severity is estimated. For this purpose, a sequential binary logit model with random effects was used to assess the impact of multiple contributing factors on crash occurrence and injury severity. Results from the sequential binary mixed logit model are then used to illustrate a group of analytical safety dashboards for implementing risk-based safety management. Finally, other applications in various highway safety management tasks are discussed.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02238
Paper Title	**Animal-related Crash Severity Analysis on Urban and Rural Roads by Multinomial Logit Model**
Abstract	The presence of animals on the road has long been considered a risk factor because a collision between a vehicle and an animal can lead to serious traffic accidents. This paper studies the vehicle-animal crashes on urban and rural roads in the State of Washington based on five-year crash collected during 2015-2019. Separate multinomial logit (MNL) models were established to analyze the factors that affect the severity of driver injury based on over all crashes, rural crashes and urban crashes, separately, and pseudo-elasticity analysis was applied to quantify the marginal effects of these influencing factors. Important influencing factors are: Season, surface wet, daylight, dark without light, straight and curve road, diver age, gender, seatbelt and airbag not ejected. The results showed differences and similarities in risk factors across different roads. In particular, each model has its unique heterogeneity parameters. Findings from this work help highlight injury risk factors in each configuration and develop injury prevention strategies for vehicle-animal crashes.

Authors	Sunday Okafor, University of Alabama, Tuscaloosa Emmanuel Adanu, Alabama Transportation Policy Research Center Abhay Lidbe, University of Alabama Steven Jones, The University of Alabama
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02352
Paper Title	**Analysis of Left and Right Run-Off-Road Single Vehicle Crash Severity using Random Parameter Ordered Logit Model**
Abstract	Single vehicle (SV) run-off-road crashes are a major cause of severe injury and fatality. Such crashes can result in different levels of severity depending on the direction (i.e., left or right) in which the vehicle runs off the road. This paper explored the factors contributing to the severity outcomes of right run-off-road (R-ROR) and left run-off-road (L-ROR) SV crashes. The study used SV crash data from the City of Charlotte, North Carolina, covering 2014 to 2017. Two separate random parameter ordered logit (RPOL) models were developed to estimate the contributing factors to R-ROR and L-ROR SV crash severities. The impact of the explanatory variables on the crash severity outcomes was quantified using the model direct pseudo-elasticities. From the results, male drivers, Driving Under Influence (DUI), motorcycle, and dry road surface were identified as the significant contributing factors to R-ROR and L-ROR SV crash severities. Specifically for the R-ROR model, speeding, reckless driving, 1-2 lanes, and older drivers increased crash severity. For the L-ROR model, phone distraction, crossing the center line, 3-4 lanes, rain, and dark unlighted roadway increased crash severity. Based on common significant variables in the two models, it was inferred that L-ROR SV crashes are more likely to result in severe crashes than R-ROR SV crashes. Hence, this study contributes to the literature on ROR SV crashes by providing insight into additional explanatory factors influencing R-ROR and L-ROR crash outcomes.

Authors	Chenzhu Wang, Southeast University School of Transportation Muhammad Ijaz, Southeast University School of Transportation Fei Chen, Southeast University Yunlong Zhang, Texas A&M University Jianchuan Cheng, Southeast University
Sponsoring Committee	ACS40
Session Number	2150
Session Title	**Occupant Protection Posters**
Paper Number	23-02428
Paper Title	**Evaluating gender differences in injury severities of non-helmet wearing motorcyclists: accommodating temporal shifts and unobserved heterogeneity**
Abstract	With a rapid motorcycle growth and relatively low helmet-wearing rate, the motorcycle crashes result to severe injuries and fatalities in Pakistan. To investigate the temporal instability and nontransferability of contributors determining the male and female non-helmeted motorcycle crashes, this paper simulates two groups of random parameters logit model with heterogeneity in means and variances based on the non-helmeted motorcycle crashes data in Rawalpindi city across 2017-2019. With four possible crash injury severity categories of no injury, minor injury, severe injury, and fatal injury, various types of multiple explanatory variables determining the injury severity including the characteristics of rider, vehicle, roadway, environment, crash, and temporal conditions are examined in the analysis. A comprehensive temporal instability is observed through the likelihood ratio tests while several variables still illustrate relatively temporal stability such as above 50 years and distraction indicator. Moreover, the out-of-sample predictions are undertaken to further confirm the temporal instability and non-transferability. Concerning such temporal stability, several recommendations including effective enforcement countermeasures and relevant educational campaigns can be developed by administrators and decision-makers for a long-term perspective. The non-transferability between male and female non-helmeted motorcycle crashes is also revealed, based on which several differentiated measurements should be raised targeted at different gender groups. This paper makes some suggestions to prevent non-helmeted motorcycle crashes targeted male and female motorcyclists and develop safety recommendations accordingly.

Authors	Yaobang Gong, University of Utah Pan Lu, North Dakota State University Xianfeng Yang, University of Maryland, College Park
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-02610
Paper Title	**Investigating the Impact of COVID-19 on Traffic Safety: From "Lockdown" to the "New Normal"**
Abstract	COVID-19 pandemic has placed pronounced and prolonged impacts on traffic safety. Many studies found the crash frequency reduced but the severity level increased during the earlier "Lockdown" period. However, there is a lack of studies investigating the pandemic's impact on traffic safety during the later stage of the pandemic. Therefore, this study employs statistical methods to investigate whether the impact of COVID-19 on traffic safety differs during the different stages. Pairwise t-tests were conducted to compare the crash frequency and crash severity levels before, during the earlier stage, and the later stage of the pandemic. Negative binomial models and binary logit models were utilized to study the effects of the pandemic on the crash frequency and severity respectively while accounting for the exposure, environmental and human factors. The results show that the crash frequency is significantly less than that of the pre-pandemic during the whole course of the pandemic. However, it significantly increases during the later stage due to the relaxed restrictions and possibly drivers' behavioral changes. Crash severity levels increased during the earlier pandemic due to the prevalence of risky driving behavior and increased presence of commercial vehicles, but it reduced to a level comparable to the pre-pandemic later. Statistical models show that the impacts of the pandemic on drivers' behavior are decaying, leading to the insignificance of all pandemic quantifiers during the later stage of the pandemic when accounting for the exposure, weather, and economic factors.

Authors	Subasish Das, Texas State University Amir Hossein Oliaee, Texas A&M University Valerie Vierkant, Texas A&M Transportation Institute Jinli Liu, Texas State University
Sponsoring Committee	AED50
Session Number	4080
Session Title	**Artificial Intelligence Applications in Transportation Planning**
Paper Number	23-02697
Paper Title	**Using Bidirectional Encoder Representations from Transformers (BERT) to Classify Traffic Crash Severity Types**
Abstract	Traffic crashes are a critical safety concern. Many studies have attempted to improve traffic safety by performing a wide range of studies on safety topics with the application of diverse statistical and machine learning models. The data elements contained in police-reported crash narrative information are not routinely analyzed with coded and structured crash data. In the recent years, unstructured textual contents in traffic crash narratives have been investigated by many researchers. However, most of these studies are basic text mining applications and often the dataset is limited in size. This study applied an advanced language model Bidirectional Encoder Representations from Transformers (BERT) to classify traffic injury types by using a dataset of over 750,000 unique crash narrative reports. The models have an 84.2% ±0.5 predictive accuracy and an Area Under the receiver operating Curve (AUC) of 0.93 ±0.06 per class. Overall, the findings can assist safety engineers and analysts in determining the causes of a crash. The classification of crash injury types using a language model like BERT is a valuable tool for identifying additional factors that contribute to crashes, which can identify new areas for safety countermeasures and support the development of new safety strategies.

Authors	Soyoung Jung, Dongyang University Xiao Qin, University of Wisconsin, Milwaukee
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02786
Paper Title	**Identifying the Local Impacts of Speed-Related Factors on Tunnel Entrance Crash Severity**
Abstract	According to crash statistics, higher injury severity rates are observed near the entrance zone of a freeway tunnel than the other sections. The concentration of traffic injuries is a combination of higher speed and lower driver alertness. One of the safety countermeasures the Korean government has deployed to mitigate the consequence of tunnel entrance crashes is the variable speed limit (VSL). However, the VSL facilities implemented have not gone through a review of tunnel safety conditions and crash analysis, and therefore, the effectiveness of the implementation is unknown. This study intended to predict the injury severity of crash occurred at the tunnel entrance zone given the nature of a collision, the size of a tunnel, the roadway geometric characteristics, and environmental factors. It was hoped that a statistical model calibrated with historical crash data and tunnel features can be used to justify the current locations of VSL facilities and prioritize new VSL implementations. Considering the varying geographic locations of freeway tunnel entrances, the geographically weighted logistic regression was employed and benchmarked by the conventional logistic regression model. The geographically weighted logistic regression model presented consistent findings and slightly better statistical goodness-of-fit than the conventional logistic model. Moreover, the geographically weighted regression captured the local impact of low-level traffic speed on crash injury severities. The findings in this study could help researchers and practitioners to evaluate site-specific traffic safety improvement strategies.

Authors	Dipanjan Mukherjee, SaveLIFE Foundation Mohamed Abdel-Aty, University of Central Florida Amrita Goswamy, University of Central Florida
Sponsoring Committee	ACH10
Session Number	4059
Session Title	**Investigating Pedestrian Safety and Accessibility**
Paper Number	23-02917
Paper Title	**A Comprehensive Analysis of Pedestrian Fatalities and Severe Injury Crashes in Florida**
Abstract	Pedestrian safety has been a major concern in Florida. Although pedestrian fatalities show a downward trend in many states in the US, Florida constitutes a significant share of national total pedestrian fatalities and serious injuries. Using 9-year crash data (2012-2020) from the Florida Department of Transportation, the present study examines the impact of crash timing and crash location, environmental factors, traffic exposure, and operational parameters, alcohol, and drugs involvements, pedestrian-vehicular involvement in a crash, road infrastructure on the possibility of pedestrian fatal and serious injury crashes in Florida. Both fixed and random parameter binary logit models are established to identify the important factors influencing pedestrian safety issues. This approach allows the incorporation of unobserved heterogeneity across the observations in the modeling process. Variables representing crash timing (nighttime), crash locations (intersection, rural roads), adverse weather condition, inadequate visibility, over-speeding, alcohol and drug consumption by pedestrians, annual average daily vehicle volume, impacting vehicle category (commercial vehicle, truck, non-motorized vehicle), hit-and-run collision, absence of paved shoulder, and pavement surface condition are found to be statistically significant in the estimated models. Also, the current study has identified two parameters as random (i.e., crashes due to lane departure, and the number of vehicles involved in a crash) demonstrating their heterogeneous influences on the risk of fatal and serious injury crashes. The paper has further confirmed the statistical superiority of the random-parameter logit model compared to the fixed-parameter model. Overall, these findings and the modelling approach can help frame better policies to improve pedestrian safety.

Authors	Panick Kalambay, University of North Carolina, Charlotte Hardik Gajera, University of North Carolina, Charlotte Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	ACP15
Session Number	3093
Session Title	**Toward the Next Generation of Intelligent Transportation Systems**
Paper Number	23-02981
Paper Title	**Are Risk Factors Associated with Fatal Crashes Involving Level 0 Vehicles and Level 1 and Level 2 AVs the Same?**
Abstract	Research on the safety effects of automated vehicles (AVs) is mainly conducted at specific AV testing sites or virtual environments through simulation. This research complements previous findings by identifying factors contributing to the occurrence of fatal crashes using reported crash data. Moreover, it compares these factors by type of the crash and level of automation through the application of eXtreme Gradient Boosting and SHapely Additive exPlanations. The levels of automation were identified according to the Society of Automotive Engineers (SAE) classification by joining vehicle identification number of vehicles involved in fatal crashes from the Fatality Analysis Reporting System database with the vehicle data from the National Highway Traffic Safety Administration database. The occurrence of fatal head-on crashes involving L0 vehicles is higher on minor arterials. In contrast, fatal head-on crashes involving L1&2 AVs are higher at non-intersection locations, 2-lane roadways, and other principal arterials. Fatal rear-end crashes involving L0 vehicles are associated with 4-lane roads, whereas fatal rear-end crashes involving L1&2 AVs occur more at non-intersection locations, straight roadway segments, and urban areas. Poor light conditions favor the occurrence of fatal sideimpact crashes involving L0 vehicles and L1&2 AVs. This research concludes with the need to improve the quality of the crash data. Police should report more accurate information to make research findings more reliable; guide the development of crash reduction strategies through planning and improvement of embedded vehicle smart features; help better vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-everything communication; and allow a smooth transition to fully AVs.

Authors	Mahyar Madarshahian, University of South Carolina Aditya Balaram, University of South Carolina Fahim Ahmed, South Carolina Department of Transportation Nathan Huynh, University of South Carolina Chowdhury Siddiqui, South Carolina Department of Transportation Mark Ferguson, University of South Carolina
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-03012
Paper Title	**Analysis of Injury Severity of Truck-Involved Crashes in Work Zones in South Carolina for Different Speed Limits**
Abstract	This study investigates factors contributing to the injury severity of truck-involved work zones crashes in South Carolina (SC). The outcome of interest is injury or property damage only crashes, and the explanatory factors examined include the occupant, vehicle, collision, roadway, temporal and environmental characteristics. Two mixed (random parameter) logit models are developed, one for speed limit less than 60 miles per hour (mph) and one for speed limit greater than or equal to 60 mph using South Carolina statewide truck-involved work zone crash data from 2014 to 2020. Results of log-likelihood ratio tests indicate that separate speed models are warranted. The factors that are found to contribute to injury at the 90\% confidence level for both models include dark lighting condition, female (at-fault) drivers, and driving too fast for roadway conditions. Significant factors that apply only when speed limit is less than 60 mph are SC or US primary roadways, activity area of work zone, at-fault drivers under 35, sideswipe collision, presence of workers in work zone, and collision with fixed objects. Significant factors that apply only when speed is greater than or equal to 60 mph are three or more vehicles, rear-end collision, location before the first work zone sign, and weekdays. Lastly, two random parameters are found to be significant for both speed limit categories: exactly two vehicles involved in crashes and crashes occurring in the shoulder or median of the roadway.

Authors	Difei Jing, Tongji University Cancan Song, Tongji University Zhongyin Guo, Tongji University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-03061
Paper Title	**Single-vehicle Crash Severity Analysis with Decomposed Traffic Volumes and Space-time Variations**
Abstract	Existing literatures mainly focus on the effect of the prevalence of trucks on the severity of single-vehicle crashes, leaving the effects of other vehicle types unveiled. This study aims to investigate the role of the presence and prevalence of vehicles of various types on the severity of single-vehicle crashes, considering the space-time-varying heterogeneities. Binary logit models with grouped fixed and random parameters are developed with a four-year comprehensive traffic and crash dataset from 2016 to 2019 on five freeway segments in Shandong Province of China. Space-time panels are defined based on 5 road segments across 4 years for the random parameters model. Model comparison results indicate that the grouped random parameters model is superior to the fixed counterpart. The prevalence of trailer trucks has a significant space-time varying random effect on the severity of single-vehicle crashes. The prevalence of other vehicle types (passenger car, bus and light truck) and hitting fixtures have different degrees of positive effects on the possibility for a single-vehicle crash to be severe, whereas average speed and heavy traffic are less likely to incur severe single-vehicle crashes. Moreover, the prevalence of trailer trucks is associated with higher likelihood of more severe single-vehicle crashes of passenger cars. This paper provides insightful understandings of the impacts of traffic volume composition on severity of single-vehicle crashes and beneficial references for developing effective countermeasures for improving road safety.

Authors	Sonu Mathew, Kittelson & Associates, Inc. (KAI) Srinivas Pulugurtha, University of North Carolina, Charlotte Sarvani Duvvuri, University of North Carolina, Charlotte
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-03128
Paper Title	**Evaluating Crash Risk Factors Associated with Weather-Related Crash Injury Severity**
Abstract	The focus of this research is to identify the crash risk factors associated with the injury severity of weather-related crashes. Weather-related crashes include crashes that occurred during weather conditions such as rain, snow, fog, sleet, hail, freezing rain, drizzle, severe crosswinds, and blowing sand. Crash data obtained from the Highway Safety Information System (HSIS) for the entire state of North Carolina for years 2015 to 2017 was used for analysis and modeling. A total of 238,252 weather-related crashes were identified and analyzed. A partial proportionality odds model was developed to identify factors contributing to injury severity of weather-related crashes. The results indicate a higher likelihood of moderate injury in crashes occurring on high-speed roads during adverse weather conditions. Weather-related crashes involving motor scooters, mopeds, pedal cycles, or motorcycles are more likely to result in moderate injury when compared to passenger cars. Similarly, driving on road with no lighting in weather conditions increases the likelihood of severe injury crash as compared to driving on roads during daylight hours in weather conditions. The findings from the analysis could be utilized to enhance highway safety in adverse weather conditions. The results suggest that it is helpful to install more warning signals on selected roads to remind drivers of the need to be vigilant and cautious during adverse weather conditions.

Authors	Alainie Sawtelle, Kimley-Horn and Associates, Inc. Mohammadali Shirazi, University of Maine Per Garder, University of Maine Jonathan Rubin, University of Maine
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-03228
Paper Title	**Severity of Lane Departure Crashes in Maine: Examining the Impact of Driver, Roadway, and Weather Factors**
Abstract	In Maine, lane departure crashes account for over 70% of roadway fatalities. Maine has aging infrastructure, houses the oldest population in the United States (U.S.), and experiences the third coldest weather in the U.S. This study analyzes the impact of roadway, driver, and weather factors on the severity of single-vehicle lane departure crashes occurring from 2017 to 2019 on rural roadways in Maine. Rather than using police reported weather, weather station data was utilized. Four facility types: Interstates, minor arterials, major collectors, and minor collectors are considered for analysis. The Multinomial Logistic Regression model was used for the analysis. The property damage only (PDO) outcome was used as the reference (or base) category. Given a crash, the modeling results show that the odds of a crash leading to major injury or fatality (KA outcome) increases by 330%, 150% 243% and 266% for older drivers (65 or above), compared to young drivers (29 or less), on Interstates, minor arterials, major collectors, and minor collectors respectively. In Maine, factors such as older drivers, operating under the influence, speeding, precipitation and not wearing a seatbelt showed higher odds of leading to injury. This study provides safety analysts and practitioners in Maine a comprehensive study of factors that influences the severity of crashes in Maine at different facilities to improve maintenance strategies, enhance safety using proper safety countermeasures, or increase awareness across the state.

Authors	Jacqueline Chavez Orellana, Virginia Tech: Virginia Polytechnic Institute and State University Miguel Perez, Virginia Tech: Virginia Polytechnic Institute and State University
Sponsoring Committee	AME10
Session Number	4072
Session Title	**Current Research in Transportation Equity**
Paper Number	23-03297
Paper Title	**Motor Vehicle Traffic Fatalities by Race and Ethnicity (2010 – 2019)**
Abstract	Motor vehicle traffic fatalities (MVTFs) are a public health issue that substantially affects the increasing BIPOC (Black, Indigenous, and People of Color) population. To further understand the racial discrepancies that exist in MVTFs, data from Fatality Analysis Reporting System (FARS) and US Census was utilized to explore factors such as rurality, urbanicity, restraint use, and alcohol-impairment by calculating yearly driver and occupant fatality rates per 100,000 population for each race and ethnicity from 2010 through 2019. Results demonstrate that American Indian population is the most overrepresented group in fatality rates across all factors explored. Additionally, the Black and Hispanic populations were the only groups that had increases in fatality rates when accounting for factors such as unrestrained vehicle driver/occupants and alcohol-impaired fatality rate while the Native Hawaiian or Pacific Islander population has consistently experienced one of the largest reductions in driver and occupant fatality rates. Further analysis is necessary to develop and implement the countermeasures that may reduce increasing fatality rates the most vulnerable populations while continuing to decrease the rates for others. However, despite limitation of FARS and population data, these results can provide a pathway towards reducing MVTFs and associated racial inequities that exist in the nation, particularly as the BIPOC population continues to grow.

Authors	Md Nasim Khan, Texas State University Anik Das, Texas A&M Transportation Institute Mohamed Ahmed, University of Cincinnati
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-03583
Paper Title	**Prediction of Truck-Involved Crash Severity on Rural Mountainous Freeway Using Transfer Learning with ResNet-50 Deep Neural Network**
Abstract	The primary objective of this study was to develop a robust model capable of accurately predicting fatal and injury crashes involving heavy trucks on rural mountainous freeways. A wide range of variables related to environmental, roadway, crash, occupant, and vehicle characteristics was extracted from the crash database of Interstate-80 in Wyoming. This study applied a cutting-edge deep neural network architecture named ResNet-50 using transfer learning to develop the crash severity prediction models. To apply the proposed deep learning model, the numeric crash data were converted to images leveraging a unique method, called DeepInsight. Considering the imbalanced nature of the crash severity data, this study leveraged two data balancing techniques, namely Random Under Sampling (RUS) and Synthetic Minority Oversampling Technique (SMOTE); and experimented with several data sampling ratios. A ratio of 1:2:2 (Fatal:Injury:PDO) combined with both RUS and SMOTE produced the best performance with recall values of 99.7%, 79.7%, and 79.3% for fatal, injury, and PDO crashes, respectively. This study also leveraged Boruta, and Extreme Gradient Boosting for investigating the importance of variables on crash severity, which revealed that deployment of airbags, use of seatbelts, driver distraction, driver conditions, such as inattentiveness and fatigue, vehicle type, vertical grades, weather, and road surface conditions were the most important variables contributing to the severity of crashes involving heavy trucks. The proposed deep neural network model can provide a timely and accurate prediction of fatal and injury crashes involving heavy trucks, which is beneficial for ensuring efficient collision management and facilitating prompt medical assistance.

Authors	Nastaran Moradloo, University of Tennessee Iman Mahdinia, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville Mohammad SafariTaherkhani, University of Tennessee
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-03592
Paper Title	**Identifying Corner Cases in Fatal Pedestrian-involved Crashes: Application of Unsupervised Machine Learning Approach**
Abstract	In recent years, fatal crashes have increased. The number of pedestrian fatalities as vulnerable road users was 6,516 in 2020, indicating a 3.9% increase from 2019. While all fatal pedestrian-involved crashes represent critical cases, some crashes occur in rare and extreme circumstances called “corner cases.” These crashes can potentially challenge the performance of Connected and Automated Vehicles (CAVs) in safety-critical circumstances. Hence, systematically exploring corner cases is critical. This study aims to identify corner cases in fatal pedestrians-involved crashes by analyzing the Fatality Analysis Reporting System (FARS) 2020 data. To this end, a systematic procedure is developed using an unsupervised machine learning approach, K-means clustering. The results indicate that various critical factors trigger corner cases, but all corner cases result from a combination of some crucial events simultaneously. For instance, the presence of certain critical factors, including darkness, a rural context, intoxication of pedestrians and/or drivers, severe weather conditions, and hazardous pedestrian behavior such as crossing expressways, dash/dart out, and pedestrians walking along the roadway on a curve that obscures the pedestrian, can be present simultaneously in the corner cases. Some potential solutions to overcome such extreme scenarios arise from the improvement in CAV technologies. The findings imply that identifying corner cases in fatal pedestrian-involved crashes is critical as they involve performance beyond the capabilities of the CAVs, and auto manufacturers should consider such complex cases to improve the performance of their vehicles.

Authors	Chunwu Zhu, Texas A&M University, College Station Bahar Dadashova, Texas A&M Transportation Institute
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-03617
Paper Title	**Investigation on the Driver-Victim Pairs in Pedestrian and Bicyclist Crashes by Latent Class Clustering and Random Forest Algorithm**
Abstract	Both driver and pedestrian/bicyclist play an important part in the occurrence of a roadway crash, while the existing literature tend to investigate the crashes from one party. Drivers and victims from similar socioeconomic backgrounds might be more likely involved in a crash due to the similarity in their traveling behavior and proximity of residence. To find the crash patterns within the pairs of driver and victim, we employed a probability-based latent class cluster analysis on the income and ethnicity of both driver and victim and random forest algorithm to model the contributing factors to the crash patterns from crash specific information, driver's and victim's socioeconomic profile, road infrastructure, and traffic exposure. Results of the pedestrian and bicyclist crashes in Harris County, Texas, show that lower income and non-White drivers tend to be involved with lower income and non-White victims, while high income and white drivers tend to be involved with higher income and white victims in both pedestrian and bicyclist crashes. The most influential factors in determining this crash patterns include pedestrian/bicyclist exposure, driver's age, victim's age, car used year, AADT, speed limit, road width, and lane width. Crashes of lower income and non-White driver-victim pairs are more likely to happen on the road with higher traffic exposure, speed limit and road width.

Authors	Eric Dumbaugh, Florida Atlantic University Jonathan Stiles, Florida Atlantic University - Boca Raton Campus: Florida Atlantic University Diana Mitsova, Florida Atlantic University - Boca Raton Campus: Florida Atlantic University Dibakar Saha, Florida Department of Transportation
Sponsoring Committee	AME10
Session Number	4072
Session Title	**Current Research in Transportation Equity**
Paper Number	23-03653
Paper Title	**The Most Vulnerable User: Examining the Role of Income, Race, and the Built Environment on Pedestrian Injuries and Deaths**
Abstract	This study examines the incidence of injurious and fatal pedestrian crashes for lower-income and affluent communities in Broward and Palm Beach Counties, Florida, finding notable differences in the environmental risk factors for these populations. In lower-income areas, pedestrian deaths and injuries increase with traffic volumes, multi-lane streets, and restaurants and shopping centers. They decrease with the presence of raised medians, which can serve as a refuge island for crossing pedestrians. These variables all suggest that, at least in lower-income areas, pedestrian death and injury is associated with the difficulty in accessing household-supporting destinations. For affluent areas, the factors associated with increased pedestrian death and injury are those associated with recreation and nightlife—specifically, bars and clubs, hotels, and restaurant. Interestingly, neither traffic volumes nor multilane roads, features that are often the target of Vision Zero-type interventions, were meaningfully related to increased pedestrian death or injury. Perhaps most notably, higher concentrations of black populations were strongly related to increased pedestrian death and injury, even after accounting for differences in income. Considered as a whole, these results suggest that pedestrian crash risk, like much else in U.S. society, is strongly intertwined with broader issues of racial and income inequality. Attempts to address the safety of the transportation system's most vulnerable users, such those encouraged by Vision Zero and Safe Systems efforts, need to move beyond asserting that any pedestrian project constitutes a safety enhancement, and begin to more meaningfully account for social vulnerabilities associated with race and income.

Authors	Cailis Bullard, University of Alabama, Tuscaloosa Emmanuel Adanu, Alabama Transportation Policy Research Center Jun Liu, University of Alabama Steven Jones, The University of Alabama
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-03732
Paper Title	**Crash Severity Analysis of Single-Vehicle Rollover Crashes in Namibia: A Mixed Logit with Heterogeneity in Means and Variances Approach**
Abstract	Road traffic crashes are a leading cause of serious injuries and fatalities globally and also place unnecessary developmental and economic burdens on developing nations as they account for the vast majority of the world's road related deaths. Rollover crashes while quite rare are a particularly dangerous crash type among other various crash types (e.g., ran-off, pedestrian collision, head-on collision, right angle collision, etc.). In the case of Namibia, rollover crashes have reportedly decreased from 843 in 2019 to 756 in 2020 for the entire country while simultaneously increasing in proportion to other crash types from 23% in 2019 to 25% in 2020. This indicates that while other crash types are decreasing from 2019 to 2020, rollover crashes are decreasing at a much slower rate. Reportedly, rollover crashes account for 34% of both road related injuries and fatalities in Namibia for 2020. For comparison, rollover crashes in the United States only accounted for 1.6% of all crash occurrences and made up 7.5% of road fatalities in 2020. When compared to the developed world the issue of rollover crashes severity in Namibia can be clearly seen. This study aimed to investigate and identify the significant factors influencing crash severities and their associated impact magnitudes on single vehicle rollover crash data from 2014 to 2016 in Namibia by employing a mixed logit model with heterogeneity in means and variances to account for unobserved heterogeneity. The findings of the study will be useful in prioritizing countermeasures.

Authors	Sahima Nazneen, HNTB Khaled Ksaibati, University of Wyoming
Sponsoring Committee	ACS40
Session Number	2150
Session Title	**Occupant Protection Posters**
Paper Number	23-03771
Paper Title	**A Comprehensive View of Factors Influencing Child Passenger Safety in Ghana**
Abstract	A high number of road crash-related deaths that occur each year are children between the ages of 0 and 19, and millions of others suffer from serious and life altering injuries. Despite the recent decline in child deaths caused by road traffic crashes in high income countries, low- and middle-income countries have yet to experience a similar trend. Children are among the most vulnerable of road users accounting for 30-40% of all road traffic deaths in LMICs, 50% of which are vehicle occupants. Ghana, a country without child restraint law is no exception to this trend. Previous research suggests that children ages 0-9 are the second most vulnerable age group in Ghana with 54% of the children injured in traffic crashes being killed. Between 2018 and 2020 nearly 6% of the reported road crash fatalities were young children. However, little has been done to identify the associated factors influencing injury severity outcomes for child passengers in Ghana. As a rapidly developing nation, the loss of young lives is a major health and developmental concern. To this end this study aims to analyze the factors contributing to varying injury severity outcomes for child vehicle occupants less than 8 years old involved in road crashes in Ghana from 2014-2020. The findings from this research are expected to emphasize the present issue affecting Ghana and other LMICs and enhance engineering policy and decision making to be used to reduce injury severities for child vehicle occupants in the country and by extension other LMICs.

Authors	Olin Green, University of Connecticut John Ivan, University of Connecticut Monika Filipovska, University of Connecticut Marisa Auguste, University of Connecticut Kai Wang, University of Connecticut
Sponsoring Committee	ACH10
Session Number	4059
Session Title	**Investigating Pedestrian Safety and Accessibility**
Paper Number	23-03804
Paper Title	**Using Logistic Regression to Evaluate Pedestrian-Vehicle Interaction Severity at Side Street Green and Exclusive Phase Signals**
Abstract	This paper uses logistic regression to determine if there is a significant difference in pedestrianvehicle interaction severity at side street green and exclusive phase pedestrian signals, and to evaluate if waiting time and crossing time are useful predictors of pedestrian-vehicle conflicts. To do this, data related to the physical characteristics of each intersection and crossing experience of every pedestrian were gathered at 32 signalized intersections in Connecticut. At each intersection, conflicts between pedestrians and vehicles were classified into four distinct severity levels: undisturbed passage, potential conflict, minor conflict, and serious conflict. After interpreting the results of six different refinements to logistic regression, it was determined that waiting time, crossing time, the number of lanes, AADT, pedestrian compliance, phasing, and the presence of crosswalks were all useful predictors. Based on the results of this analysis, low values of wait time and crossing time are associated with a decrease in odds of a conflict. It was also determined that exclusive phase signals reduce the odds of a conflict by 85%. Future research should investigate variables associated with different land development patterns or demographic information. Along with this, the crossing experience of individuals that do not comply with pedestrian signals or jaywalkers should also be evaluated.

Authors	Richard Dzinyela, Texas A&M University Bahar Dadashova, Texas A&M Transportation Institute Emmanuel Adanu, Alabama Transportation Policy Research Center Okan Gurbuz, Texas A&M Transportation Institute Dominique Lord, Texas A&M University
Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-03880
Paper Title	**A Comprehensive Analysis of the Bicyclist Crash Severity-contributing Factors at Intersection and Mid-block Locations using Random Parameter Models**
Abstract	In the past years, bicyclist crashes, particularly fatal crashes have been increasing. The literature and data exploration indicates that although most of the crashes occur at intersections, however fatal crashes tend to occur at mid-blocks. In this study we use the bicyclist crashes in Philadelphia, PA from 2012 to 2020 to 1) identify crash variables that significantly affect intersection and midblock crashes and 2) identify factors that affect the crash injury severity. We use the binomial and multinomial random parameter logit regression to account for the unobserved heterogeneity in the crash data. The estimation results indicate that the local road crashes are likely to be intersection related. In addition, crashes occurring on local and interstate/state highways are likely to result in major injuries. Driver behavior such as aggressive and distracted driving and bicyclist overtaking are also found to significantly contribute to bicyclist crashes. Additionally, younger bicyclists are likely to be involved in minor/no visible injury whiles older bicyclists are more prone to major injuries. Comparing the estimation results from the two models with results from multinomial logit model shows that accounting for possible unobserved heterogeneity adds important new information and improves overall model fit. The findings from this study provide a deeper, data-driven understanding of how bicycle involved crash outcomes may be affected by vehicle type, driver type, environmental conditions, and roadway infrastructure. These findings will help in developing mitigation measures like separated bike lanes, bicycle safety campaigns, helmet use, and bike/motor detection technologies necessary to reduce bicycle involved crashes.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-03913
Paper Title	**Multilevel Discrete Outcome Modeling for Crash Severity: A Novel Approach for Crash Severity Models**
Abstract	Combining a total crash count model and a crash severity probability model simultaneously to predict crashes by severity is challenging because crash count models are implemented at an aggregate scale, i.e., by sites (segments or intersections), while crash severity probability models are at a disaggregate scale, i.e., by crashes or persons (drivers or occupants). This study develops a multilevel discrete outcome modeling framework to estimate crash counts by severity for California rural four lane divided highways by estimating and combining three models - a univariate count model for total crashes at the site-level predicts total crash counts, an ordered logit discrete outcome crash severity prediction model at the crash-level predicts proportion of crashes by severity, and a proportional regression connection model that predicts proportion of groups of drivers and vehicles to connect the other two models. The combination of all three models provides crash counts by severity at the site-level considering both aggregate and disaggregate factors. The prediction from the multilevel discrete outcome model is compared with predictions made by traditional univariate count models by severity for accuracy and transferability using estimation and validation data. Based on the estimation data, the multilevel discrete outcome model predicts injury and fatal crashes more accurately than the univariate count model. For validation data, the multilevel model has slightly better prediction accuracy for minor and possible injuries. Finally, the calibration factor indicates the multilevel discrete outcome model is more transferable than the univariate count model.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-03994
Paper Title	**Modeling Injury Severity of Left-Turn-Across-Path (LTAP) Motorcycle Crashes at Intersections: A Mixed Logit Method Considering Unobserved Heterogeneity and Temporal Instability**
Abstract	A Left-Turning Across Path (LTAP) motorcycle crash, involving a collision between a motorcycle and a vehicle that turns left across the path of a motorcycle, is the most dangerous type of motorcycle crash in Florida, accounting for over 30 percent of all fatal motorcycle crashes. This study aimed to explore the contributing factors to motorcyclist injury severity in LTAP crashes and examine the temporal instability of contributing factors in LTAP data. To achieve this, historical LTAP crash data were collected in Florida for five years (2015–2019). Based on the data, mixed logit models that consider heterogeneity in the means and variances of random parameters were developed. Likelihood ratio tests showed the temporal instability between any two years and suggested development of models by year and intersection type (signalized and unsignalized). The modeling results identified factors contributing to severe injury in LTAP crashes at signalized intersections, unsignalized intersections, or both, including speed limit, paved shoulder, intersection type, crash type, motorcycle speed, motorcyclist alcohol impairment, rider ejection and helmet use, motorcyclist eye protection, daylight, other vehicle actions, other vehicle driver gender, other vehicle make and year, day of week, and FDOT District. Further study is suggested to investigate temporal instability in LTAP crashes.

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Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04010
Paper Title	**Investigating Safety in Disadvantaged Communities by Integrating Crash and Justice Initiative Data**
Abstract	The United States Department of Transportation's (USDOT) effort to identify disadvantaged communities (DACs) on a census tract level has evoked possibilities of transportation justice and vision zero goal achievement in DAC communities. USDOT has developed six comprehensive indicators to identify DACs based on economy, environment, equity, health, resilience, and transportation. This study will utilize these indicators to explore the association between fatal crashes and disadvantages faced by communities. Five years of fatal crash data are combined with demographic information for 72,769 census tracts of the US. Zero-inflated Negative Binomial (ZINB) model is used for the analysis. The results demonstrate that higher fatal crash rates are associated with census tracts that are disadvantaged health-wise (35.01%), resilience-wise (40.38%), and transportation-wise (48.72%). Furthermore, transportation disadvantaged tracts are associated with substantially higher impaired fatal crashes (60.00% higher). The impaired fatal crashes per 100,000 population in all disadvantaged tracts are 15.15 and 12.22 in non-disadvantaged or privileged tracts. The highest number of pedestrian and bicyclist fatalities are among Hawaiian or other Pacific Islanders. This study can provide information to support policymakers in deciding which disadvantaged community can benefit from resources for transportation improvements.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04036
Paper Title	**Effect of Vehicle-mix on Crash Severity Prediction using Quasi-Induced Exposure data in Multivariate Poisson Log-normal Model**
Abstract	Traffic data collection with classified volume counts of different vehicle types is technically and financially challenging. However recent research efforts show this information to be important in prediction of crashes. This research compares crash severity prediction accuracy of models estimated using vehicle mix information observed or estimated from traffic counts with models using values generated by Quasi-Induced Exposure (QIE) and models not including vehicle mix at all. Multivariate Poisson Lognormal (MVPLN) modeling with full Bayesian estimation is employed because of its ability in considering the correlations among crash severities at a site level. Results confirm the statistically significant and pronounceable effect of truck percentage on prediction of crash severities. Additionally, QIE generated vehicle mix seems to be a viable surrogate for observed vehicle mix in prediction of crashes.

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Sponsoring Committee	ACS20
Session Number	4060
Session Title	**Bicycling and Micromobility Research Omnibus Session**
Paper Number	23-04154
Paper Title	**Typology of e-Scooter and e-Bike Related Crashes**
Abstract	US cities have been adopting micromobility systems to mitigate problems facing the transportation industry. Despite what micromobility systems seem to offer, cities face critical issues in regulating the deployment of the micromobility system since few studies were conducted before their existence. The State of Florida has at least 16 established shared micromobility systems. This study investigates 367 crashes involving e-Scooters or e-Bikes that occurred between 2018 and 2022 in Florida, using crash data from the Signal Four Analytics database. The study analyses the characteristics of the crashes. First, using the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) to assess the crash types based on the motorist and non-motorist maneuver. It then presents the descriptive analysis of the contributing factors such as environmental, roadway, and micromobility user-related factors. Finally, the relationship between crash severity and other explanatory factors was modeled using Ordinal Logistic Regression (OLR). PBCAT results concluded that e-Scooters riders are more vulnerable when crossing the intersection from the right-hand side of the motorist, while for e-Bikes, most crashes occur on the travel/bike lane when the rider is traveling parallel to the vehicle. The descriptive analysis suggested most crashes occurred at intersections, in clear weather conditions with the presence of daylight. Furthermore, only a few riders used safety equipment at the time of the crash. OLR suggested posted speed limit, roundabout intersections, and crossing types of crashes to be the most significant factors affecting the severity of micromobility crashes. Finally, recommendations to mitigate the severity of micromobility crashes were suggested.

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Sponsoring Committee	ACH10
Session Number	4059
Session Title	**Investigating Pedestrian Safety and Accessibility**
Paper Number	23-04198
Paper Title	**Pedestrian Safety: A Review of Data Collection, Analysis, Contributing Factors, and Crash Prevention Methods**
Abstract	The number of pedestrian fatalities and injuries has increased over the past decade. Based on the data provided by the National Highway Traffic Safety Administration (NHSTA), 6,516 pedestrians were killed in traffic crashes in 2020, indicating about one pedestrian death every 81 minutes and one pedestrian injury every 10 minutes. In recognition of the magnitude of this problem, researchers have attempted to investigate the key contributing factors that endanger pedestrian safety and identify the best solutions to combat the growing number of pedestrian-involved crashes. The objective of this study is to conduct a comprehensive review of the state of practice and art in identifying data collection sources, analyzing the crash and incident data, the main factors contributing to pedestrian crashes, and safety countermeasure development to enhance pedestrian safety. The outcome of this study will provide policymakers, engineers, and researchers with a good understanding of pedestrian-involved crashes and emerging safety countermeasures to alleviate the problem.

Authors	Penglin Song, Hong Kong Polytechnic University N.N. Sze, Hong Kong Polytechnic University Jing Guo, University of Tennessee, Knoxville
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04255
Paper Title	**Investigating Differences Between Injury Severity of Single-Vehicle and Multi-Vehicle Crashes at Freeway Ramp Areas**
Abstract	Freeway ramp areas are prone to road crashes because of the merging, diverging, and weaving traffic entering and leaving the freeways. This study evaluates the differences in injury severity and influencing factors between single- and multi-vehicle crashes at freeway ramp areas. Separate injury severity models for single- and multi-vehicle crashes are established based on comprehensive crash data from North Carolina State in 2016-2018. Multinomial logit regression approach is applied to measure the association between crash injury severity, with respect to no injury, minor injury, and severe injury, and influencing factors. To account for the effect of unobserved heterogeneity, random parameters approach with heterogeneity in means and variances is adopted. Results indicate that there are considerable differences in the effects of aberrant driver behavior, vehicle class, and traffic volume on injury severity between single- and multi-vehicle crashes after controlling for unobserved heterogeneity. Findings should shed light on the effective traffic management and control strategies that can mitigate crash and injury risks at freeway ramp areas.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04265
Paper Title	**A Real-time Framework to Predict Crash Likelihood and Cluster Crash Severity**
Abstract	This study proposes a three-stage framework for real-time crash likelihood and severity prediction. Firstly, a real-time crash likelihood prediction model was developed. Secondly, a real-time crash severity clustering model was proposed to cluster the crashes into different severity levels. Thirdly, a severity clustering validation model was developed to assess the performance of the proposed severity clustering model. Extensive data processing techniques were employed to collect real-time features from State Road 408 in Orlando, Florida, and a total of 6,750,072 events (625 crash events and 6,749,447 non-crash events) along with 24 real-time features were used. To develop the crash likelihood prediction model, nine machine learning techniques were attempted, and the convolutional neural network model was found to provide the best result with sensitivity (0.916), false alarm rate (0.111), and area under the ROC curve (0.967). DaviesBouldin Index criteria was used to find the detector location that generated the most accurate traffic information to cluster the crashes into severity levels, and based on this traffic information, K-means clustering was applied to develop the severity clustering model. Finally, a severity clustering validation model was developed after investigating nine machine learning techniques to validate the developed severity clustering model, and the decision tree model provided the best results based on three levels of sensitivity and specificity values. The developed framework has the potential to help traffic management center to warn road users or develop TSM&O strategies in real-time to avoid crashes or minimize the severity and thus, can significantly contribute to improving road safety.

Authors	Subasish Das, Texas State University Valerie Vierkant, Texas A&M University Juan Gonzalez, Texas A&M University
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04325
Paper Title	**A Bayesian Network for Motorcycle Crash Severity Analysis**
Abstract	Due to the lack of protective structural barriers and advanced restraints, motorcyclists are vulnerable road users, comparable to pedestrians and bicyclists. In 2020, motorcycle-involved fatalities occurred 28 times more frequently per vehicle mile traveled than passenger car occupant fatalities. In addition, there were 5,579 motorcycle-related fatalities in the United States in 2020 – the highest number of motorcyclists killed since in 1975. The discovery of patterns and relationships between important contributing elements can aid in the development of strategies for reducing motorcycle-related crashes. In addition to present efforts, additional research must be performed in innovative avenues with increased funding. Bayesian Networks can better discover the relationships between potential speed compliance variables. This study used six years (2014-2019) of motorcycle crash data in Louisiana to determine the conditional probabilities of the influential factors. The findings of this study can be used for decision making and strategy development for motorcycle safety.

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Sponsoring Committee	ACS20
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-04328
Paper Title	**Learning from Moped Crash Data: Safety Factors and Hazardous Scenarios Analysis**
Abstract	Mopeds are light vehicles that provide solutions for short travels, traffic congestion, and environmental pollution issues. However, due to limited physical protection provided by the small vehicle structure, moped riders are more likely to suffer from severe injuries from a crash than vehicle passengers. This study aims to investigate the features and patterns associated with recent moped crashes. This study analyzed the injury severity, and related risk factors to 1,657 moped crashes in Michigan during the recent five years from 2017 to 2021. Two ordered logistic regression models were built to examine the association between crash injury severity levels and 13 variables from three main categories: crash features, rider behaviors/cognitive status, and environmental conditions. The descriptive statistics showed that 79% of moped riders' injuries from crashes were minor or less while the injured riders tend to be younger, male, and not wearing a helmet. According to the model results and odds ratio analysis, the rider injury severity was associated with crash type, riders' mental status (e.g., drinking, careless riding), riders' maneuver behavior (speeding, disregarding traffic control involved), visibility (light condition), and rider age. Head-on crashes and single crashes were two leading crash types resulting in severe/fatal injuries. The results suggested that moped riders should pay more attention to the road, especially when riding at nighttime and should avoid impaired riding. Advanced rider assistance functions, regulations on risky riding behavior (e.g., drinking, speeding, and helmet usage), and additional recommendations on riding age and time are expected to greatly improve moped safety.

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Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04333
Paper Title	**Revisiting the Roles of Speeds in Traffic Crashes: A Geospatial Modeling Study**
Abstract	Speeding or improper speed behaviors are unsafe on road, increasing the risk of crashes as well as the chance of severe injuries in crashes. Extensive research has been conducted to establish the role of speed in traffic safety. However, there are two types of improper speed behaviors: exceeding the posted speed limit (EPSL) and driving too fast for conditions (DTFFC) and most studies do not distinguish them. Crashes that involve these two types of behaviors may exhibit different characteristics of contributing factors and crash injury outcomes. Using a statewide crash database that records the specific improper speed behaviors, this study develops separate models to revisit and compare the correlates of injury severity in crashes involving EPSL and DTFFC, respectively. To capture the geography-related unobserved heterogeneity inherently embedded in traffic crashes, this study adopts a geospatial modeling approach, namely Geographically Weighted Logistic Regression (GWLR), to identify the correlates of injury severity by allowing the model estimates to vary across the space. This paper provides premilitary results with a limited number of variables and more variables will be incorporated in the future. Modeling results show the significant correlates of injury severities are different in two types of crashes (involving EPSL or DTFFC), and the correlates from both models vary substantially across the space. The findings of this study are expected to help agencies identify the high-risk regions for specific speeding behaviorrelated crashes so that transportation planners can provide corresponding countermeasures for different locations.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04469
Paper Title	**Modeling the Continuum of Serious Injuries by Applying a Hazard-Based Duration Model with Heterogeneity-in-Means**
Abstract	Most traffic injury studies have considered serious injury at the aggregate level, denoting severe, hospitalized or incapacitating injuries. As such, the inferences drawn from assuming all serious crashes are at a similar level might not provide in-depth insights into serious injury severities. This study bridges the gap in the literature by introducing a hazard-based duration model to analyze the continuum of serious injury crashes. The proposed model is estimated using police-hospital linked data from Abu Dhabi Traffic Police and the Department of Health for three years (2017–19). With the advantage of utilizing the linked data, this study takes a new perspective by examining serious injury crashes (involving at least one injured vehicle occupant hospitalized) on a continuous spectrum based on length of hospital stay. The results of the likelihood ratio tests showed significant temporal instability among the study sub-periods, suggesting modeling serious injury crashes of a year specific. Three models were then estimated using random parameters hazard-based duration models with heterogeneity in means. Results showed that speeding and heavy vehicle involvement are significantly associated with more serious injury crashes (prolonged length of hospital stay). In contrast, when a female driver is involved, it tends to result in less serious injury crashes (shortened length of hospital stay). Moreover, the heterogeneity in means extracts further insights into factors affecting serious injury crashes. The findings of this study should be useful to police departments and health sectors to better understand risk factors associated with serious injury crashes.

Authors	Subasish Das, Texas State University Juan Gonzalez, Texas A&M University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04476
Paper Title	**Encroachment-related Work zone Crash Injury Analysis using Data-driven Bayesian Network**
Abstract	Work zone safety is one of the critical goals of transportation agencies. Vehicles change travel paths and lanes over a short length of a road section at work zones. Distracted drivers, unable to see advanced warning signals and pavement markings delineating the work zone travel paths, could increase the likelihood of a crash. Recent statistics shows that fatal collisions in work zones have increased by 46 percent in 2019 compared to 2011. The frequency of roadway departures at work zones, higher risks of fatality, and little insights into encroachment types at work zones assert the need for a thorough study. This study aimed to examine vehicle encroachment conditions associated with work zone locations and focused on four years (20162019) of crash data from the Texas Department of Transportation (TxDOT) by applying Bayesian Network (BN) analysis. The findings of this study will be useful for safety engineers to contribute to reducing encroachment-related work zone crashes.

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Sponsoring Committee	AED60
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-04570
Paper Title	**A Pooled Univariate Modeling System to Capture Temporal Instability in the Injury Severity Model**
Abstract	For capturing observed temporal instability in crash data, researchers developed a vast array of statistical models building on the exogenous segmentation approach, which requires analysts to split the data records by different situational attributes under consideration and develop separate univariate models. Splitting the data by situational attributes is likely to result in smaller data samples, which in turn can lead to difficulties in statical inference. Moreover, such an approach does not allow for examination for temporal stability and hence is not parsimonious. In addressing this methodological gap in existing safety literature, in this study, we propose a new pooled univariate modeling system to examine the effects of temporal instability across different situational attributes, which is parsimonious and efficient, providing a unified predictive equation system. Specifically, injury severity data from multiple years are recasted as a pooled data sample in developing a univariate injury severity model, which is estimated by employing random parameter generalized ordered logit formulation. The proposed model is demonstrated by using active traveler (pedestrian and bicyclist) crash data from Queensland, Australia, for the years 2017 through 2020. The analyses are further augmented by elasticity effects in demonstrating the implications of the proposed model.

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Sponsoring Committee	AME10
Session Number	4072
Session Title	**Current Research in Transportation Equity**
Paper Number	23-04631
Paper Title	**An Exploration of the Sources of Inequity in Roadway Safety**
Abstract	While roadway crashes are associated with a communities' demographic and socioeconomic characteristics, the sources of inequity are unknown. This study employs a root cause analysis approach to systematically identify the sources of inequity in roadway safety and their roots. The root cause analysis consists of two steps: (1) understanding the mechanism of roadway crashes and detecting the contributing factors to the occurrence and severity of crashes, and (2) sourcing the inequity in contributing factors to roadway crashes and identifying the roots of disparities. As a result of this analysis, we found nine sources of inequities in roadway crashes: inequity in road user riskier behavior, inequity in traffic law violation, inequality in exposure to road traffic, inequality in transportation infrastructure and design and operation, inequity in access to vehicle safety technology, inequality in access to well-maintained vehicles, inequality in vehicle characteristics, inequity in medical care, and inequity in road emergency response. The sources of inequities are discussed to be stemmed either from systemic social and economic inequities or inequity in transportation engineering and planning. This paper further demonstrates how the findings of this study can be utilized for reactive and proactive interventions through the road safety management process and safety system approach.

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Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04635
Paper Title	**Influence of Adaptive Traffic System on Severity of Intersection Crashes: An Empirical Assessment Using Bayesian Logit Model with Unobserved Heterogeneity**
Abstract	Adaptive Signal Control Technology (ASCT) is an advanced traffic control system that optimizes signal timing based on real-time traffic demand. ASCT can potentially improve the operation and safety of intersections by establishing dynamic coordination among signalized intersections in real-time. This study used a binary Bayesian logit model with random effects, which accounts for unobserved heterogeneity, to explore the impacts of ASCT on the severity of intersection-related crashes in Florida. Two distinct ASCT types (type I and II) were analyzed to assess whether they had similar impacts on crash severity. The analysis revealed that the deployment of ASCT was associated with lower crash severity. Overall, ASCT reduced the likelihood of a fatal plus injury (FI) crash by 14.6%. This reduction was significant at a 90% Bayesian credible interval (BCI). Also, each ASCT type (i.e., types I and II) showed a potential reduction in the likelihood of a FI crash, although the decrease was not significant at a 90% BCI. Other factors outside the presence of ASCT, such as driving under the influence of alcohol, angle crashes, dark lighting conditions, speed limit, and median along a minor road, were associated with a higher risk of a FI crash. Transportation agencies could use the study results to justify the deployment and expansion of ASCT at signalized intersections with high crash severity.

Authors	Jaekook Kim, Oregon State University Salvador Hernandez, Oregon State University
Sponsoring Committee	ACS60
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-04639
Paper Title	**Understanding the Safety Effects Between the Number of Lanes and Commercial Motor Vehicle Crashes: An Exploratory Analysis**
Abstract	Many studies have been conducted to determine the contributing factors to CMV driver crash injury severities. However, the relationship between the number of lanes a particular highway facility has, and the safety of that facility is not fully understood since it may not be considered during the planning process. Fittingly, this study aims to fill the gap in the literature regarding CMV driver injury severity analysis by considering the safety effects of the number of lanes a facility has. To accomplish this, the current study examines the determinants of the injury severity of commercial motor vehicle drivers for different number of lane scenarios and different time periods. A random parameters logit modeling framework with heterogeneity in means and variances was estimated for each subgroup data but categorizing injury levels in two different ways: multinomial levels (severe, minor, and no injury) for 2 and 4 lanes and binary levels (injury and no injury) for 6 lanes. While various contributing factors were identified, the likelihood ratio test results indicated significant differences in model parameters across subgroup models. However, several factors showed relatively stable effects over time. For example, non-Oregonian drivers, older drivers, losing vehicle control, non-collision crashes, crashes beyond shoulder, curves, and grades were factors that increased severe injury outcomes with less temporal variance on 2-lane and/or 4-lane roads. Countermeasures to these factors may improve truck driver safety in the long term.

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Sponsoring Committee	AME40
Session Number	3206
Session Title	**Quantitative Methods for Understanding Travel and Traffic Behavior: Implications for Transport Practitioners in Developing Countries**
Paper Number	23-04738
Paper Title	**Gathering Insights into the Leading Causes of Fatal and Injury Crashes Involving Trucks in Tanzania using Bayesian Network Model**
Abstract	Truck-related crashes are one of the most frequent and severe traffic crashes reported in Tanzania. Trucks pose a serious risk to road users when involved in crashes due to their large size and heavy weight. Understanding factors associated with crash occurrence and injury is essential to reducing truck-related crashes and injury. This study investigated the leading risk factors that influence the injury severity of truck-involved crashes in Dar es Salaam, Tanzania. A Bayesian binary logistic regression model was developed to identify statistically significant factors associated with the injury severity of truck-related crashes. The identified factors were then used to develop a Bayesian network model to investigate factors associated with the injury severity outcome of truck-involved crashes. The analysis was conducted based on seven years (2015-2021) of crash data. The statistically significant factors associated with injury severity were the day of the week, lighting conditions, and crash type. The probabilistic interrelationships between these factors indicated that the factors including nighttime lighting conditions, weekends, and vulnerable road users significantly increase the likelihood of severe crashes. Moreover, crashes that occur on weekends, at nighttime, and involving vulnerable road users have a high probability of being severe. The findings from this research can be used to develop effective countermeasures that reduce truck-involved crash injury severity.

Authors	Weijing Wang, University of California
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04741
Paper Title	**Vision Zero is Not a Failure but a Matter of Action: Policy Intervention Analysis using ARIMA Modelling**
Abstract	In the last year, the US witnessed about 43,000 traffic deaths on roads, making 2021 the deadliest year in traffic safety in the past 16 years. With surging traffic fatalities nationwide, Vision Zero has gained its rapid growth in the US with a goal of zero traffic fatalities and serious injuries. Since Chicago's commitment in 2012, to date, more than 50 localities have adopted Vision Zero. Despite increasing popularities of and dedications to the policy, some Vision Zero communities have seen rising traffic fatalities, including Los Angeles, raising a critical question: Is Vision Zero a failure or hope? To answer this question, the current study uses the Autoregressive Integrated Moving Average (ARIMA) modeling to estimate the policy impact and effectiveness of Vision Zero on traffic fatalities and serious injuries, by differing types of road users. Overall, the results suggest that Vision Zero is not a failure, in which one explanation is the outcomes of policy intervention analysis turn to be sensitive to the chosen time point at which the effects of policy intervention present. Evidence also suggests that the policy impact of Vision Zero on traffic safety differs by road users, in which compared to others, pedestrians have a potential to benefit from the policy implementation to a larger degree. The study concludes that working towards eliminating traffic fatalities and serious injuries, further efforts on concrete methods and strategies in advancing policy implementations and understanding equity impacts of Vison Zero are needed.

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Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04806
Paper Title	**Potential Reduction of Fatal Crashes in South Carolina due to Automated Vehicles**
Abstract	Since 1995, several countries and states have implemented roadway traffic safety projects with the goal of achieving a highway system with no fatal or serious injury crashes. South Carolina's Target Zero plan is multifaceted in that it identifies several preventative measures to reduce fatalities. A common thread of these programs is that they are aspirational, and there is not an expectation that zero fatalities will ever be a reality. While there are many contributors to fatal crashes, by far the biggest contributor is driver error. In South Carolina (SC), the first contributing factor in nearly 85% of fatal crashes is driver related. Thus, to approach a target of zero fatalities will require eliminating drivers from the equation—or at least making drivers error free. This research focuses on how 2019 SC fatal crash data could be impacted hypothetically by different scenarios of autonomous vehicle (AVs) safety applications. A detailed review of contributing factors to over 900 2019 fatal crashes in SC along with a review of site characteristics for each crash was conducted. A deterministic approach was used to calculate the effects of different AV levels on each of the fatal crashes. The approach was based primarily on literature findings regarding the safety effectiveness of vehicle characteristics for each level. The reduction in fatal crashes ranged from 10% to 23% for level 1 to nearly 95% for level 5 AVs. The underlying assumption in terms of AV level is that the entire population of vehicles fall within that AV category.

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Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04894
Paper Title	**An Exploratory Analysis of Two-vehicle Crashes for Distracted Driving with A Mixed Approach: Machine Learning Algorithm with Unobserved Heterogeneity**
Abstract	Two-vehicle crashes, particularly due to distraction and impacting other vehicles, lead to a disproportionately higher number of fatalities and serious injuries over time. The intent of this study is to identify the contributing factors to driver injury severity with the assessment of the machine learning model and quantify those factors affecting injury severity outcomes for two-vehicle crashes in the US. The crash data were extracted from the Crash Report Sampling System (CRSS) from 2016 to 2018. This study applied an XGBoost to identify the top variables based on SHAP value by driver injury levels and mixed logit with heterogeneity in means and variances approach to model driver injury severity. The model results indicate that there is a complex interaction of driver characteristics, such as demographics (male drivers), driver actions (careless driving, driving over the speed limit more than 15 mph, hitting stopped vehicle), a driver without violation destroy, turning violation, drinking, roadway and traffic characteristics (non-interstate highways, undivided and divided roadways with positive barrier, curved roadways, dry surface condition), environmental conditions (rainy weather condition), vehicle characteristics (motorcycle, displacement volume up to 2500 cc, newer vehicle within 5 years from crash), temporal characteristics (afternoon peak: 4 to 6 PM, 3rd quarter of the analysis period (July to September), and analysis year of 2017). The results clearly indicate the importance of driving behavior and roadway design concerning distracted driving behavior that needs to be prioritized for driver training as well as the law enforcement, roadway design, and maintenance agency.

Authors	Junxiang Zhang, Tongji University Bo Yu, Tongji University Yuren Chen, Key Laboratory of Road and Traffic Engineering of the Ministry of Education You Kong, Shanghai Maritime University Jianqiang Gao, Tongji University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04932
Paper Title	**Comparative analysis of influencing factors on crash severity between super multi-lane and traditional multi-lane highways: A hierarchical Bayesian heterogeneity-based approach**
Abstract	With the growth of traffic demand, the number of newly built and renovated super multi-lane highways (i.e., equal to or more than two-way ten-lane) is increasing. Compared with traditional multi-lane highways (i.e., two-way six-lane, or eight-lane), super multi-lane highways have higher design speeds and more vehicle interweaving movements, which may lead to higher traffic risk. However, there is little attention on the factors of crash severity on super multi-lane highways. To fill the research gap, this study aims to explore the differences in factors impacting crash severity between super multi-lane and traditional multi-lane highways. The analysis is based on the crash data of the Guangzhou-Shenzhen highway in China from 2016 to 2019, in which 2455 crashes occurred on ten-lane sections and 13367 on six-lane sections. Considering the effects of spatial unobserved heterogeneity, a hierarchical Bayesian approach was applied. The results showed that the differences of impacting factors of serious crashes between these two kinds of highways were significant. Heavy-vehicle, two-vehicle, and multi-vehicle crashes were more likely to be serious on both super multi-lane and traditional multi-lane highways, but the severity degrees on super multi-lane highways were much higher. In addition, for super multi-lane highways, vehicle-to-facility collisions and rainy weather could lead to high-severity crashes. This study could contribute to the understanding of impacting factors of crash severity on super multi-lane highways and provide help for the future design and safety management of super multi-lane highways.

Authors	M. Ashifur Rahman, Louisiana Transportation Research Center (LTRC) Subasish Das, Texas State University Julius Codjoe, Louisiana Department of Transportation and Development Md Mahmud Hossain, Auburn University Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ACS10
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04962
Paper Title	**Identifying Attribute Associations in Fatal Speeding Crashes with Latent Class Clustering and Association Rule Mining**
Abstract	Speeding has been distinguished as one of the most frequent and persistent contributing factors and is considered to be a critical contributing factor to the degree of injury severity. In the United States, at least a quarter of nationwide annual fatal crashes during the last decade involved speeding. There is still a need for an overarching look at the crashes involving speeding by considering a wider set of crash, roadway, driver, and vehicle characteristics. This paper mitigates the research gap by investigating the collective impacts of variables in homogenous crash clusters by focusing on fatal crashes with FARS data Using crash data of 2015-2019 from the fatality analysis reporting system (FARS) repository, this study applies latent class clustering (LCC) to obtain homogeneous clusters of fatal speeding crashes addressing the unobserved heterogeneity. Assoication rule mining (ARM) has been applied to the homogeneous clusters to find hidden patterns. The finding of association rules – such as motorcycle speeding single vehicle crashes during weekends and in dark-unlighted condition etc. The results of this research and interpretative findings are expected not only to improve the knowledge of speeding-related crash mechanism and but also to provide important insights on countermeasure development.

Authors	Francisca Kasubi, Florida International University MD Sultan Ali, Florida International University Henrick Haule, Florida Atlantic University John Kodi, Florida International University
Sponsoring Committee	ACS20
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-05001
Paper Title	**Analyzing Severity of Crashes Near Entrance Ramps in North Carolina**
Abstract	Freeway entrance ramps have been long considered crash-prone locations. Understanding factors influencing the severity of crashes near entrance ramps can help improve freeway safety. The objective of this study was to evaluate factors influencing the severity of crashes near entrance ramps. The study objective was achieved by analyzing crashes near entrance ramps in North Carolina from 2013 to 2017. The crash data was collected from the Highway Safety Information System (HSIS), and the analysis was done using a hierarchically ordered probit mode available in R studio programming software. The findings indicated that the probability of causing severe crashes decreases as age increases. Moreover, drivers are more conscious when driving at night. For the case of crash types, the results showed that sideswipes crashes were more severe compared to rear-end crashes. In general, the study results and methodology could potentially be used by agencies when devising methods and policies to reduce the severity of crashes near entrance ramps. This study also proposed potential countermeasures to decrease crash severity at freeway entrance ramps.

6 Crash Modification Factors

Anurag Pande
California Polytechnic State University, San Luis Obispo

This year, the subcommittee identified **twelve papers** based on research dealing with crash modification factors (CMF) and did not identify any dealing with crash modification functions. This review only includes CMFs estimated using collision data analysis. For studies using surrogate safety measures, the readers are referred to Section 7. The CMF-related papers/presentations are spread across the following sessions:

- 2098: Safety Effects of Roadway Characteristics and Treatments (Monday, January 09 10:15 AM- 12:00 PM);
- 2043: Recent Advances in Highway Design Research (Monday, January 09 8:00 AM- 9:45 AM);
- 3196: Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others (Tuesday, January 10 3:45 PM-5:30 PM);
- 3215: Safety Models: New, Evolving, and Refreshed (Tuesday, January 10 6:00 PM- 7:30 PM).

Among these, **session 2098** has the most papers related to CMF estimation.

The highlight of the **methodological approach** used in each study was as follows:

- Observational before-after evaluation (23-00224, 23-02971, 23-01580,23-0442);
- Negative Binomial Regression with Fixed Parameters and Random Parameters (23-00643);
- Calibration of SPFs estimated using generalized linear regression modeling (e.g., Negative Binomial regression Models) (23-01672, 23-04898);
- Propensity Scores Matching (22-02398, 23-00965);
- Multivariate adaptive regression splines (MARS) models in comparison with traditional negative binomial (NB) models (23-04250);
- Machine learning approach (23-03827).

For the presentation scheduled for session 2043, P23-21200, the methodology could not be ascertained since no Abstract was provided in the program.

Among these papers, 23-00965 focused on the **safety improvement of vulnerable users** through the evaluation of on-street bicycle facilities. Corridor-level characteristics and treatments on two-lane roads were the focus of 23-00643. Other **specific treatments** evaluated by the studies are as follows:

- Median U-turn or Michigan left turns at signalized intersections (23-01580);
- Median separation layouts on 2+1 roads (23-04898);
- Roadway surface treatments (23-02971);
- Cable median barrier on freeways (23-0442);
- Flashing Yellow Arrow at signalized intersections (23-04250, 23-02254);

- Median openings at unsignalized intersections (23-00224);
- Smart tolling systems on uninterrupted flow highways (23-01057);
- Wildlife crash countermeasures (23-0298).

Among these studies, most were based on data from the US, with 23-00643 (Italy), 23-01672 (South Korea), and 23-04898 (Poland) being the exceptions. The paper 23-03827 was unique in that it focused on a machine-learning approach to mining the CMF clearinghouse resource for application by practitioners.

Below, for each of the forty papers involving crash severity prediction, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Brendan Russo, Northern Arizona University David Smith, City of Henderson, Nevada Samuel Taylor, City of Scottsdale, Arizona
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-00224
Paper Title	**Analyzing the Safety Impacts of Left-In Left-Out Median Opening Treatments at Intersections and Driveways**
Abstract	Over the past few decades the City of Scottsdale, Arizona has installed left-in/left-out (LILO) median opening treatments at approximately sixty intersections/driveways; typically at three-leg intersections or driveways on arterials with medians where the minor leg is stop-controlled. The treatment is relatively unique and consists of a channelizing island with an acceleration length provided for vehicles turning left out of the minor road (these left-turning vehicles then merge with major road traffic). Although anecdotal evidence suggests the treatment has performed well, a data-driven safety evaluation had not been conducted. As such, this study presents the first comprehensive safety evaluation of the LILO median opening treatment, including development of crash modification factors (CMFs). Crash, traffic, and roadway data from 25 LILO treatment sites and 25 control sites were utilized to assess the overall safety impacts of the LILO treatment using a cross-sectional study design, and an Empirical-Bayes before-after analysis was conducted on a subset of treatment sites based on year of installation. Overall, the LILO median opening treatment was shown to be effective in reducing the frequency of angle and left-turn crash types, as well as the frequency of injury crashes. Additionally, the potential safety impacts of LILO specific design features (e.g. signage, acceleration length, etc.) were explored.

Authors	Nicholas Fiorentini, University of Pisa Massimo Losa, University of Pisa: Universita degli Studi di Pisa
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-00643
Paper Title	**Investigating Unobserved Heterogeneity in Factors of Severe Crashes across Italian Two-lane Roads: Fixed and Random Parameters Approach**
Abstract	Developing Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) represent one of the leading approaches for determining how infrastructure-related features impact crash likelihood. In Italy, few works investigated the causes of crash occurrences on secondary road networks, i.e., minor rural, suburban, and urban two-lane roads, connecting the primary road network (freeways and highways) with local roads. Furthermore, few or no studies addressed the issue of unobserved heterogeneity of factors contributing to crash occurrence in Italy. To fill this gap and intending to provide an in-depth analysis of causes of Fatal and Injury (FI) crashes that occur on such networks, this paper proposes the development of SPFs and related CMFs across the whole 905-km secondary road network managed by the Tuscany Region Road Administration (TRRA). Incorporating geometrical, functional, and road context information, a Negative Binomial Regression with Fixed Parameters (FP-NBR) and Random Parameters (RP-NBR) to account for unobserved heterogeneity have been adopted for fitting 5,802 FI crashes that occurred within 2008-2016. Capturing unobserved heterogeneity affecting factors, outcomes show that the RP-NBR markedly outperforms the FP-NBR in terms of predictive performance. Conversely, the latter shows a higher level of interpretation; elasticities and CMFs indicate that traffic flow, carriageway width, driveway density (especially in urban areas), the density of intersections, and road area type are the most influential ones, whereas longitudinal gradient and road alignment have a weaker effect on FI occurrences. These SPFs and related CMFs can improve planning activity, as well as monitoring and maintenance duties of road authorities.

Authors	Jonathan Kay, Michigan State University Timothy Gates, Michigan State University Peter Savolainen, Michigan State University Md Shakir Mahmud, VHB
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-01580
Paper Title	**Safety Performance of Signalized Median U-Turn Intersections**
Abstract	Alternative intersection designs can offer safety and operational benefits with potentially lower costs than conventional intersections when implemented in the proper setting. The Federal Highway Administration has previously identified a subset of alternative designs called reduced left-turn conflict intersections as a proven safety countermeasure. Median U-turn intersections (also known as “Michigan lefts”) are one such design that accommodates all left-turn movements via directional Uturn crossovers within the median. Prior work has consistently shown that median U-turn intersections can provide superior safety performance when used in the appropriate conditions. This study evaluated historical traffic crashes and volume data at 167 signalized intersections throughout Michigan. This included the collection of data for 82 median U-turn sites and 85 reference group sites to estimate safety performance functions and crash modification factors for conversion of conventional intersections to signalized MUTs. Several design features of signalized MUT intersections were identified as having a significant impact on safety performance, including the distance to crossovers from the main intersection, the length of weaving areas, the number of signalized crossovers, and the number of storage lanes. Crash modification factors (CMFs) of 0.656 for fatal and injury crashes and 0.684 for property damage only crashes were developed for the conversion of conventional signalized intersections with undivided approaches to a MUT design. While CMFs specific to converting a conventional signalized intersection with a divided major approach suggest increases in both fatal and injury crashes (1.423) and property damage only crashes (1.668), considerable reductions were observed in potentially severe crash types.

Authors	Seung-oh Son, Hanyang University Kyeongju Kwon, Hanyang University, Ansan Juneyoung Park, Hanyang University Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-01672
Paper Title	**Evaluating the Safety Benefits of a Smart Tolling System on Freeways Applying Improved Calibration Method**
Abstract	This study proposed the crash modification factor (CMF) estimation technique using the calibration method to analyze the safety improvement effect of installing the open road tolling (ORT). Although the OPT system in South Korea has recently been introduced in many highway tollgate sections, it is impossible to collect statistically significant crash data samples due to a short operating period as an initial stage of introduction. Therefore, in this study, CMF was estimated by applying the calibration method to the research results conducted in Highway Safety Manual (HSM) and Florida. The calibration method proposed by HSM was used as the basic method, and a new calibration method was developed and applied based on the fact that the relationship between the observed and predicted crashes was not a simple linear relationship. The CMF of ORT installation was estimated by applying the calibration method, and the safety improvement effect was 43% to 51%. In addition, among the proposed calibration functions, the function using the quadratic model was found to be the best in terms of prediction accuracy. This study is meaningful in that CMF was estimated using the calibration method in situations where the sample size was insufficient. In addition, it has a research contribution in that it utilizes new functions to predict nonlinear relationships that are difficult to calibrate with simple linear relationships in existing calibration methods.

Authors	Mariusz Kiec, Cracow University of Technology Wojciech Kustra, Gdansk University of Technology: Politechnika Gdanska Salvatore Cafiso, University of Catania Piotr Szagala, Warsaw University of Technology: Politechnika Warszawska Alessandro Calvi, Roma Tre University Carmelo D'Agostino, Lund University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-04898
Paper Title	**Investigating the Safety Effects of Median Separation Layout on 2+1 Roads**
Abstract	Evaluations of 2+1 roads focus mainly on the comparison between two-lane rural roads and three-lane configurations, indicating all the safety benefits of the latter. In Poland, several solutions are currently adopted for separating traffic directions, which include only horizontal marking, horizontal marking with additional measures to improve safety (low or high safety devices), and physical separation using cable barriers. However, the literature lacks studies about the impact of all the above-mentioned median separations on safety. When the target of the investigation is the safety performance of 2+1 roads, their contribution cannot be ignored. Based on this assumption, the aim of the present research work is to investigate the safety performance of 2+1 roads, considering various solutions for separating traffic directions, considering the accident' costs. The methodological approach includes the statistical inference by means of regression models quantifying the predicted number of crashes considering exposure and other variables. The quantification is carried out by calibrating the Safety Performance Functions (SPFs) for total crashes, based on the traffic flows, inventory and crash data. To develop the SPF model the generalized linear regression modeling (GLM) approach was used by calibrating the model on homogeneous segments. Crash Modification Factors (CMFs) for 2+1 roads were estimated to evaluate the influence on the safety of the various solutions of separating. The lowest cost of crashes is expected for cable barrier separation, although the greatest number of crashes but mainly non-injured is observed.

Authors	Irfan Ahmed, HDR Mohamed Ahmed, University of Cincinnati
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02398
Paper Title	**Evaluating Safety Effectiveness of Wildlife-Vehicle Crash Countermeasures using Cross-Sectional Analysis and Propensity Scores-Potential Outcomes Framework**
Abstract	Wildlife-vehicle crashes (WVC) pose a significant threat to not only wildlife populations but also highway safety. The most expensive WVC countermeasures include crossing structures with fencing, while the least expensive countermeasure is the wildlife warning signs. This study is aimed at estimating the crash modification factors (CMFs) for these two countermeasures using cross-sectional analysis and propensity scores-potential outcomes approach. Propensity-scores matching approach is a viable method for identification and selection of a suitable reference group. Two types of WVC data are used in this study: carcass removal data and traditional crash data. A random-intercept Bayesian approach was utilized to incorporate the contributing factors representing traffic volume, roadway geometry, weather conditions, and unobserved heterogeneity due to between-site variance. The No-U-Turn Hamiltonian Monte Carlo sampling technique was employed due to its high efficiency in handling complex models.

Authors	Matthew Liu, Georgia Institute of Technology (Georgia Tech) Ronald Knezevich, Georgia Department of Transportation Jiashu Li, Georgia Institute of Technology (Georgia Tech) Yi-Chang Tsai, Georgia Institute of Technology (Georgia Tech)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02971
Paper Title	**Crash Reduction Analysis of Friction Improvement Surface Treatments in Georgia**
Abstract	Crashes on curves represent 25 % of all roadway fatalities the vast majority of these fatalities are roadway departures. An effective treatment to mitigate roadway departures are friction improvement surface treatments (FISTs). The Georgia Department of Transportation (GDOT) has implemented friction improvements on more than 400 curves. Before this study, there were no crash modification factors (CMFs) for these friction improvements in Georgia. Thus, the objective of this study was to analyze the crash reduction effectiveness of three FISTs in Georgia. These materials include phonolite, lightweight aggregate (LWA), and high friction surface treatment (HFST, or calcined bauxite). This objective was achieved by using naïve Bayes and empirical Bayes methods to develop CMFs. The calculated CMFs show that HFST significantly reduces curve crashes with an overall CMF of 0.672. HFST is the only material implemented where the calculated CMFs provided significant evidence for crash reduction. Crash types that were significantly reduced include single vehicle, those labeled as negotiating a curve, and wet road. The CMF was then modeled as a function of the roadway environment. It was found that significant curve site characteristics that led to a lower (i.e., more effective) CMF were 1) prior crash frequency, 2) absence of an intersection, and 3) lower traffic volumes. These findings are used to display CMFs for different site characteristics and can be used to strategize implementation of HFST on curves in the future. It is recommended to perform life cycle cost-integrated crash reduction benefit cost analyses.

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Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)

Session Number 2098

Session Title **Safety Effects of Roadway Characteristics and Treatments**

Paper Number 23-04442

Paper Title **Development of Crash Modification Factors for Cable Median Barrier Using Improved Prediction Model**

Abstract Freeway cross-median crash is regarded as one of the most severe hazards since it usually results in fatalities and serious injuries. To prevent such crashes, cable median barriers (CMB) have been commonly installed on the median of rural freeways. Because of the reduced clear zone, it is possible less severe type of crashes could increase with CMB. The cost of CMB installation, repair and maintenance could be expensive compared to the cost of other effective crash countermeasures, such as rumble strips. To accurately evaluate the safety effectiveness of CMB, this study conducted a before and after crash analysis using the improved prediction model with the crash data from the Louisiana 23 freeway segments, total 231 miles. To identify the targeted crashes, a unique flowchart was developed to filter out the median-related and cross-median crashes from the total number of crashes three years before and after the CMB installation. The results show that CMB is highly effective in reducing fatal and severe injury crashes, particularly for the cross-median crashes. The cross-median's fatal and severe injury crashes declined by 100%, and the total cross-median crashes by 68%. The estimated impressive crash modification factors (CMF) for the targeted crashes and their corresponding standard deviation indicate the assurance of the crash reductions. Although the PDO crashes increased significantly with the CMB, the trade-off between eliminating fatalities and increasing PDO crashes is acceptable in the monetary values as well as meeting the safety objective in reducing crash severity.

Authors Xi Zhang, The University of Arizona
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Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)

Session Number 2098

Session Title **Safety Effects of Roadway Characteristics and Treatments**

Paper Number 23-04250

Paper Title **Safety Performance Evaluation of Flashing Yellow Arrow: Time-of-Day vs 24-hour Operations**

Abstract The flashing yellow arrow (FYA), as the permissive left-turn indication, has been widely implemented to mitigate driving confusion caused by the permissive steady green indication. The selection of an appropriate FYA operation type, however, remains an open-ended question as few studies have evaluated the safety effectiveness of FYA under different FYA operation types, i.e., 24-hour, time-of-day (TOD), and switching from 24-hour to TOD. Moreover, since FYA has been typically used at intersections with a single left-turn lane, its safety effectiveness at intersections with dual left-turn lanes has not been well investigated. To bridge these gaps, this paper focuses on evaluating the safety effectiveness of FYA at intersections with varying numbers of left-turn lanes under different operation types and examining whether the FYA operation type switch affects safety performance. Empirical Bayes (EB) before-after studies are conducted for 24-hour, TOD, and switching from 24-hour to TOD FYA operation types using multivariate adaptive regression splines (MARS) models in comparison with traditional negative binomial (NB) models. Safety performance functions (SPFs) are developed for different combinations of crash types and a different number of left-turn lanes. Results show that for intersections with either a single left-turn lane or dual left-turn lanes, 24-hour and TOD FYA operation types reduce crashes by 8.76% to 50%. However, intersections with dual left-turn lanes experience a 31.2% increase in total crashes when switching from 24-hour to TOD FYA operation type, while intersections with a single left-turn lane see a 60% decrease in rear-end crashes.

Authors	Pranesh Biswas, University of South Alabama Min-Wook Kang, University of South Alabama Moynur Rahman, City of Mobile
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02254
Paper Title	**Safety Evaluation of Offset Left-Turn Lanes and FYA Signals at Signalized Intersections on Multi-lane Divided Highways in Alabama**
Abstract	The present study conducted an Empirical Bayes (EB) before-after analysis to investigate the combined effects of offset left-turn lanes and Flashing Yellow Arrow (FYA) signals implemented at signalized intersections on multi-lane, divided highways in Alabama. A total of thirty-five signalized intersections were selected for the EB safety analysis. Among them, thirty intersections were classified as a reference group and five were classified as a treatment group. The reference group includes intersections which have not undergone any left-turn treatments from the period of 2010 to 2020, while the treatment group includes those improved with offset left-turn lanes and FYA signals implementation concurrently during years in that period. Safety Performance Functions were developed with data collected at reference group intersections to predict crashes at such intersections under a no treatment scenario. A study focus was then given to understanding the change in crash frequency before and after the combined treatments for the treatment group intersections, using the EB method. Results show that the combined left-turn treatments could reduce total and left-turn crashes by 30% (CMF = 0.70) and 43% (CMF = 0.57), respectively. It is important to note that such huge crash reduction effects are due to the combined effect of both offset left-turn lanes and the FYA signals implementation, not because of a single treatment.

Authors	Yanlin Qi, University of California, Davis Jia Li, Washington State University Michael Zhang, University of California, Davis
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-03827
Paper Title	**Predicting Crash Modification Factor (CMF) Cost-effectively: A Machine Learning-based Framework**
Abstract	Crash modification factor (CMF) is an effectiveness measure of safety countermeasures. It is widely used by state agencies to evaluate and prioritize various safety improvement projects. The Federal Highway Administration (FHWA) CMF Clearinghouse provides CMFs for a broad range of countermeasures, but still, the existing CMFs often cannot meet the needs for characterizing the safety impacts of countermeasures in new scenarios. Developing CMFs, meanwhile, is costly, time-consuming, and requires extensive data collection. A more cost-effective way to provide preliminary CMF estimations is needed. To address this need, this study develops a low-cost and easily extendable data-driven framework for CMF predictions. This framework performs data mining on existing CMF records in the FHWA CMF Clearinghouse. To tackle the heterogeneity of data, we introduce interdisciplinary techniques to maintain model compatibility. We also integrate multiple machine-learning models to learn the complex hidden relationships between different safety countermeasure scenarios. Finally, we train the proposed framework against the CMF Clearinghouse data and perform comprehensive evaluations. The results show that the proposed framework is capable of providing CMF predictions for new countermeasure scenarios with reasonable accuracy, with overall MAEs less than 0.2. We also discuss an enhanced approach that leverages structured information in certain CMF descriptions, which can boost the CMF prediction accuracy, showing MAE less than 0.1 in a case study.

Authors	Bahar Dadashova, Texas A&M Transportation Institute Joan Hudson, Texas A&M Transportation Institute Boya Dai, The Goodman Corporation Robert Benz, Texas A&M Transportation Institute Xiao Li, Texas A&M Transportation Institute Ipek Nese Sener, Texas A&M Transportation Institute Karen Dixon, Texas A&M Transportation Institute Shawn Turner, Texas A&M Transportation Institute Soham Sarda, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3196
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-00965
Paper Title	**Developing Crash Modification Factors for On-Street Bicycle Facilities using Propensity Score Matching**
Abstract	Bicycle crashes, as well as fatal and suspected serious injury crashes involving bicyclists, have been on the rise. There have been 26,582 crashes involving bicyclists from 2010 to 2020 in Texas. These crashes have resulted in 3,989 fatalities and suspected serious injuries (KA), and 21,278 non-incapacitating and possible injuries (BC). On-street bikeway treatments are used as some of safety countermeasures to improve the bicyclist safety. Despite the added benefits, however, proving their safety effectiveness has been challenging due to the limited data. In this paper, the research team developed crash modification factors (CMFs) for bikeway facilities implemented on Texas roadways to assess their safety and economic effectiveness. To accomplish this goal, the research team has developed a comprehensive database using various data collection methods such as survey, crowdsourced and field data. Using the propensity score matching method the research team demonstrate that on-stret bikeway facilities are indeed safer than having no treatments on travel lanes that accommodate the bicyclists. Namely, the conventional bicycle lanes, buffered bicycle lane and separated bicycle lanes are found to significantly improve the bicyclist safety and can contribute to 41-65 percent reduction on two and four-lane urban street segments. These findings can help the transportation and planning agencies to make informed decisions when installing such facilities in urban streets.

Authors	Humayra Kabir Priyanka, Auburn University
Sponsoring Committee	Standing Committee on Performance Effects of Geometric Design (AKD10) Young Members Coordinating Council (A0010C)
Session Number	2043
Session Title	**Recent Advances in Highway Design Research**
Paper Number	P23-21200
Paper Title	**Analyzing the Safety Impacts of Left-In Left-Out Median Opening Treatments at Intersections/Driveways**
Abstract	No Abstract Provided.

Authors	Amirarsalan Mehrara Molan, University of Mississippi Anurag Pande, California Polytechnic State University, San Luis Obispo Stuart Harvey
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01057
Paper Title	**Before-After Safety Evaluation of Coordinated Ramp Metering System using Empirical Bayes Approach: A Case Study on I-80 in California**
Abstract	Coordinated Ramp Metering (CRM) systems are implemented on freeways primarily to improve operational conditions. However, smoother traffic flow resulting from CRM may also have significant safety benefits. The main objective of this research is to evaluate the safety performance of CRM systems on I-80 corridor in California using an empirical Bayes (EB) before-after approach. The authors collected geometric features, traffic volume, and historical crash data from I-80 in the San Francisco Bay area (Caltrans District 4). Then, the Enhanced Interchange Safety Analysis Tool (ISATe; developed as part of a National Cooperative Highway Research Program project) was utilized to predict the counterfactual, i.e., the number of crashes if no CRM system was implemented on the corridor. Based on the results, CRM implementation has led to a decrease in the number of fatal and injury crashes on I-80. Spatial analysis of the results is used to gain further understanding of the CRM safety performance. The differences in the resulting safety performances are contextualized based on the differences in settings where the systems are implemented. As expected, CRM systems are more effective for segments in the vicinity of ramps. Safety Performance Functions (SPFs) for shorter durations (e.g., for peak hour), the subject of an ongoing NCHRP project, will help in more precisely estimating the safety impact of CRMs.

7 Surrogate Measures of Safety

Andrew Tarko, Vamsi Krishna Bandaru, and Mario Romero
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This year, **forty-nine papers** that use surrogate measures of safety (SMoS) were identified. In these studies, the surrogate measures are used either as the primary approach to safety analysis or as a complement to the traditional crash-based approach.

Broadly, the papers can be classified in to the following topics: **intersections**, **non-motorized users**, **applications of SMoS** (implementing SMoS or proposing frameworks), **connected and autonomous vehicles** (CAV) and **real time safety monitoring** and/or **safety simulation.** Fifteen papers analyze safety at **intersections** (23-01175, 23-01496, 23-01748, 23-01893, 23-02365, 23-02612, 23-02622, 23-02767, 23-03132, 23-03755, 23-03777, 23-04347, 23-04785, 23-04799, 23-04906). **Pedestrians and non-motorized** users were investigated in twelve papers (23-00920, 23-01496, 23-01748, 23-02037, 23-02298, 23-02763, 23-02763, 23-02767, 23-04188, 23-04347, 23-04778, 23-04876). Various **SMoS applications** were presented in twenty papers (23-00758, 23-00920, 23-01496, 23-02298, 23-02365, 23-02511, 23-02622, 23-02763, 23-02799, 23-03069, 23-03076, 23-03598, 23-04347, 23-04690, 23-04737, 23-04773, 23-04799, 23-04838, 23-04876, 23-04906). **Real-time safety analysis** is highlighted in twelve papers (23-00264, 23-00487, 23-00758, 23-01107, 23-01496, 23-01581, 23-01695, 23-03069, 23-03076, 23-03255, 23-03598, 23-04876). Finally, **Connected and autonomous vehicles technologies** applications are discussed in six papers (23-00630, 23-02298, 23-03076, 23-03255, 23-03689, 23-04369)

Concerning surrogate measures of safety we found that **traffic conflicts** are used in twenty nine papers (23-00264, 23-00280, 23-00487, 23-00630, 23-00758, 23-01107, 23-01175, 23-01456, 23-01748, 23-01893, 23-02365, 23-02504, 23-02511, 23-03069, 23-03132, 23-03255, 23-03598, 23-03755, 23-03777, 23-04347, 23-04369, 23-04690, 23-04737, 23-04773, 23-04778, 23-04785, 23-04799, 23-04838, 23-04876). In terms of traffic conflict indicators, the **time-to-collision (TTC) and its variants** such as modified time to collision (MTTC), generalized time to collision (GTTC) are used in fourteen papers (23-00280, 23-00512, 23-00630, 23-00920, 23-01175, 23-01581, 23-01893, 23-02037, 23-02763, 23-04001, 23-04369, 23-04785, 23-04838, 23-04876) while the **post-encroachment time (PET)** is applied in eleven papers (23-01581, 23-02037, 23-02612, 23-02622, 23-02767, 23-02799, 23-03755, 23-04347, 23-04369, 23-04799, 23-04906). Indicators related to **deceleration** such as deceleration rate, deceleration rate to avoid crash (DRAC) were used in six papers (DRAC, 23-00920, 23-01175, 23-04001, 23-04369, 23-04785, 23-04838). Alternatively, **speed charachteristics** were used in five papers (23-00512, 23-02365, 23-02767, 23-03755, 23-04785). Lastly, **time spent in conflict** (TSC) was used as a conflict measure in two papers (23-03069, 23-03598). Other nearness measures such as exposure to risk index (ERI), lane-change risk assessment index (LCARI), crash index (CI) etc were used in eight papers (23-00512, 23-00920, 23-02072, 23-02365, 23-03076, 23-04347, 23-04369, 23-04906).

In terms of input data, user **trajectories** and data derived from **video** were the most common sources of data. vehicle **trajectories** was used thirteen papers (23-00630, 23-00758, 23-01456, 23-01893, 23-02504, 23-03069, 23-03777, 23-04001, 23-04369, 23-04690, 23-04773, 23-04785, 23-04838) and data

extracted from **video** was used in thirteen papers as well (23-00280, 23-00487, 23-01496, 23-02511, 23-02612, 23-02763, 23-02767, 23-03133, 23-03755, 23-04690, 23-04737, 23-04876, 23-04906). **Naturalistic driving data** was in the input used in two papers (23-02072, 23-04188). **Simulated data** was used in five papers (23-00630, 23-00920, 23-01695, 23-02298, 23-03255, 23-04369). **GPS and smartphones data** is used in one paper (23-03689). Finaly, there were two papers that performed a review or meta analysis. One paper reviewed the application of CV techniques in traffic safety modeling using surrogate measures of safety (23-03133). The other paper evaluated eight different conflict indicators for CAVs in car following at signalized intersections (23-04369).

Some authors target specific maneuvers and driving behavior using surrogate measures of safety such as **car-following**, **turning** and **lane changing** maneuvers**. Car following** scenarios which include **rear end** conflicts were analysed in eight papers (23-00280, 23-01175, 23-01658, 23-02365, 23-02504, 23-02511, 23-03777, 23-04785). **Turning** manuevers were investigated in three papers (23-01748, 23-04347, 23-04906). Lane change was investigated in one paper (23-00512).

Regarding data analysis, **statistical regression models** are used in twenty two papers (23-00630, 23-01107, 23-01496, 23-01581, 23-01658, 23-01748, 23-02037, 23-02365, 23-02504, 23-02511, 23-02612, 23-02622, 23-02763, 23-02767, 23-02799, 23-03132, 23-03755, 23-04001, 23-04188, 23-04347, 23-04799, 23-04906) whereas **machine learning and deep learning** methods were used in sixteen papers (23-00264, 23-00280, 23-00758, 23-01107, 23-01456, 23-01581, 23-01893, 23-02504, 23-03069, 23-03598, 23-03755, 23-03777, 23-04690, 23-04773, 23-04785, 23-04876).

To conclude, it is relevant to highlight that the **crash risk** was predicted in seven papers (23-00512, 23-01456, 23-01496, 23-01658, 23-02622, 23-03755, 23-04001).

The papers forty nine papers dealing with surrogate measures of safety ordered by their paper number are listed below.

Authors	Handong Yao, University of South Florida Qianwen Li, University of South Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-00264
Paper Title	**Physics-informed multi-step real-time conflict-based vehicle safety prediction**
Abstract	Real-time vehicle safety prediction is critical in roadway safety management as drivers or vehicles can be altered beforehand to take corresponding evasive actions and avoid possible collisions. This study proposes a physics-informed multi-step real-time conflict-based vehicle safety prediction model to enhance roadway safety. Physics insights (i.e., traffic shockwave properties) are combined with data-driven features extracted from deep-learning techniques to improve the prediction accuracy. A time series of future vehicle safety indicators are predicted such that vehicles/drivers have enough time to take precautions. The safety indicator at each time stamp is a continuous value that the sign reflects the presence of conflict risks, and the absolute value indicates the conflict risk level to advise different magnitudes of evasive actions. A customized loss function is developed for the proposed prediction model to give more attention to risky events, which are the focus of safety management. The prediction superiority of the proposed model is proven through numerical experiments by comparing it with two benchmarks constructed based on the literature. Further, sensitivity analysis on key model parameters is carried out to advise parameter selections in developing real-world conflict-based vehicle safety prediction applications.

Authors	Federico Orsini, Università degli studi di Padova Massimiliano Gastaldi, University of Padova Riccardo Rossi, University of Padova
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-00280
Paper Title	**Conflict-based Real-time Road Safety Analysis: Sensitivity to Data Collection Duration and its Implications on Model Resilience**
Abstract	Conflict-based approaches to real-time road safety analysis can provide several benefits over traditional crash-based models. In particular, as traffic conflicts are much more frequent than crashes, models can be trained with significantly shorter data collection periods. As the existing literature never investigated the sensibility of real-time conflict prediction models (RTConfPM) to data collection duration, here we aim to fill this gap and discuss the implications in terms of model resilience. A real-world highway case study was analyzed. Methodologically, various traffic variables aggregated into 5-minute intervals were selected as predictors; synthetic minority oversampling technique (SMOTE) was applied to deal with the unbalanced classification issue; support vector machine (SVM) was chosen as classifier; recall, specificity, and AUC were used to evaluate performance. The dichotomous response variable separated safe and unsafe intervals into two classes; the latter were defined considering a minimum number of rear-end conflicts within the interval, which were identified using a surrogate measure of safety (time-to-collision). Several RTConfPMs were trained and tested, considering different data collection durations and different criteria to define the unsafe situation class. The results show that the models were able to provide reliable predictions with just 3-5 days of data, and that the improvement in performance with collection periods longer than 10-15 days was negligible. These findings can be generalized by considering the number of unsafe situations corresponding to the data collection period of each tested model; they highlight the relevance of RTConfPM as a more flexible and resilient alternative to the crash-based approach.

Authors	Kingsley Adjenughwure, Netherlands Organization for Applied Scientific Research: TNO Gerdien Klunder, TNO Jeroen Hogema, TNO Richard Horst, TNO
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-00487
Paper Title	**Estimating the Collision Probability of a Real Traffic Conflict via Monte-Carlo Based Microsimulation: A Proof of Concept Study**
Abstract	During driving in real traffic, often conflict situations arise which did not lead to an accident, however, they offer a good indication of traffic (un)safety. There are many methods and indicators for classifying whether a current driving situation can be considered as a conflict or not (e.g. TTC, PET or other conflict indicators). However, not many approaches are there to predict how such conflicts will evolve once they have been identified and what the collision probability would be given the conditions of the conflict. Current available methods make strong assumptions about driver behavior during the conflict, usually do not consider all participants involved in the conflict (only two vehicles) and have limited applicability to various types of real conflicts. In this paper, a Monte-Carlo-based microsimulation approach is proposed to estimate the probability of collision for a conflict of any type. Unlike previous approaches, the proposed method can be used to simulate any type of conflict with an arbitrary initial conflict condition and an arbitrary number of vehicles in conflict. The method was developed based on real-world video data of a complex signalized intersection in Delft, from which conflicts were identified with the DOCTOR method. As proof of concept, the proposed method is applied to a real conflict involving four vehicles which was extracted from these video data. The results show that our approach is capable of simulating real conflicts of various types with multiple participants and predicting their probability of collision.

Authors	Jinbao Zhang, Central South University Jaeyoung Lee, Central South University Mohamed Abdel-Aty, University of Central Florida Ou Zheng, University of Central Florida Guiming Xiao, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-00512
Paper Title	**Enhanced Index of Risk Assessment of Lane-Change on Expressway Weaving Segments**
Abstract	Vehicles frequently change lanes at weaving segments, and there is a high probability of collision. To assess the risk of lane-change, this study proposes a novel lane-change risk assessment index (LCRAI), which takes both exposure time and conflict severity into consideration. First, the generalized time-tocollision (GTTC) and exposure-to-risk index (ERI) are proposed to evaluate conflicts during lane-change, and then a spatiotemporal overlap analysis is applied to exclude the cases when two vehicles arrive at the conflict area at different time. Second, the change of velocity after a crash occurrence is calculated and used to evaluate the severity risk (SRI). Finally, ERI and SRI are combined to compute the LCRAI. A case study of a weaving segment is conducted, and the weaving segment is divided into four sections to compare their risks. The LCRAI show that the middle section is the most dangerous while the last 100 m section is the safest on the weaving segment.

Authors	Maria Oikonomou, National Technical University of Athens (NTUA) Marios Sekadakis, National Technical University of Athens (NTUA) Christos Katrakazas, National Technical University of Athens (NTUA) Professor George Yannis, National Technical University of Athens (NTUA)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	23-00630
Paper Title	**Safety impacts of autonomous shuttle bus with different operational speeds towards increasing market penetration rate of connected and automated vehicles**
Abstract	The current study aims at evaluating the impacts of different operational speeds of an autonomous shuttle bus service on road safety by increasing Connected and Automated Vehicles (CAV) Market Penetration Rate (MPR) and combining network characteristics. A microscopic simulation analysis was performed in order to quantify the impact of road safety of an automated shuttle bus service within traffic. In the traffic network of Villaverde, Madrid, several scenarios were simulated using the Aimsun Next software considering the various CAV MPRs (0-100%), and the different operational speeds of the service, namely 15, 30, and 45 km/h. From the microscopic simulation, the vehicle trajectories were extracted and analyzed using the Surrogate Safety Assessment Model (SSAM) software that identified conflicts. Statistical analysis was then performed using negative binomial regression and specifically the dependent variable was the frequency of conflicts that the shuttle bus service was involved in. The analysis revealed that the conflict frequency is lower when the shuttle bus operates at 45 or 30 km/h compared to 15 km/h, with the 45 km/h speed showing the largest reduction due to the shuttle bus adapting more easily to the average traffic speed and is more synchronized with traffic flow. Furthermore, greater CAV MPR results in steadily decreased conflict frequency probably due to the automated shuttle's adaptability and collaboration with automated and connected traffic vehicles. The current study establishes a solid relationship for the conflict frequency of AV shuttles enabling stakeholders to optimize road safety towards a future of automated traffic.

Authors	Yuping Hu, Central South University Ye Li, Central South University Helai Huang, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-00758
Paper Title	**Spatio-temporal Evolution Analysis of Traffic Conflict Risk Based on Trajectory Data**
Abstract	Traditional spatio-temporal researches of crash risk have been conducted to explore its evolution mechanism from an aggregated perspective. Since real-time risk estimation approach can promote the proactive safety management, more microscopic aspects have attracted researchers' attention. Considering the limitations of crash-based studies, it is practical to utilize traffic conflict technique and investigate risk evolution trend within small-scale area. This study attempts to analyze the dynamic change of spatio-temporal conflict risk and its potential correlationship with real-time traffic characteristics. The spatio-temporal sequence data of gridded units can be obtained by associating the vehicle trajectories with cross-sectional traffic data. Different from most previous studies, both conflict frequency and severity are together considered in this study. To comprehensively measure the systematic risk, the issue is simplified by applying fuzzy logic, and the whole risk indicator (WRI) is proposed for evaluation. The trajectories on U.S. Highway101 from NGSIM dataset are utilized, and a two-step analysis framework is proposed to explore the risk evolution trend. The spatial Markov method and classic panel data modeling approaches are employed to conduct the quantitative analysis. Results show that different spatial lag types may produce different influences on risk evolution trend, and the short-term risk change is also affected by dynamic traffic characteristics. The proposed framework contributes to a more systematic understanding of conflict risk and assess the real-time road safety more effectively.

Authors	Gagan Gupta, Michigan State University Vishal Mahajan, Technische Universitat Munchen Indrajit Ghosh, Indian Institute of Technology Roorkee Constantinos Antoniou, Technische Universitat Munchen
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-00920
Paper Title	**Evaluating the Safety Effectiveness of Textured Pavement and Speed Hump at Uncontrolled Midblock Crosswalk in Mixed and Heterogeneous Traffic Conditions**
Abstract	Pedestrian safety in an uncontrolled mid-block section is always a point of concern for road safety experts. Over-speeding of vehicles and the low yielding rate of drivers increase the risk for pedestrians in such settings. Traffic calming measures are suggested to reduce vehicles' speed and increase their yielding. This paper evaluated the effectiveness of two traffic calming devices, speed hump and textured pavement, to reduce vehicle speed and increase the safety of pedestrians. A calibrated and validated micro-simulation model was developed using Simulation of Urban MObility (SUMO) to simulate the field conditions. Pedestrian safety is compared in different scenarios with the help of time-to-collision (TTC), modified time-to-collision (MTTC), deceleration rate to avoid the collision (DRAC), and crash index (CI) as surrogate safety measures. Compared to the baseline, textured pavement reduced the speed of vehicles by 51% and increased their time loss by 70%, while for the speed hump, the speed reduction was 44%, and the increase in time loss of vehicles was 47%. In the case of textured pavement, the percent share of events when the value of TTC and DRAC exceeds the threshold value reduces to half, while for speed hump, the percent share reduces by one-third only. The results show that the textured pavement is more effective in reducing pedestrians' speed and increasing pedestrians' safety than the speed hump. These insights could be used as guidance when designing locations with restricted vehicle speeds.

Authors	Xintong Yan, Southeast University Jie He, Southeast University Changwen Zhan, Southeast University School of Transportation Ziyang Liu, Southeast University Changjian Zhang, Southeast University Chenwei Wang, Southeast University Yuntao Ye, Southeast University School of Transportation
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-01107
Paper Title	**Predicting Real-time Crash Risks Based on Traffic Conflicts: Accommodating the Influence of Temporal Shifts**
Abstract	Conventional conflict-based studies contributed to the knowledge by extending the traditional crash-based risk prediction to conflict-based, whereas they seemed to overlook the influence of the temporal instability. Consequently, this paper aims to investigate the temporal shifts of the determinants influencing different traffic conflict severities. Using the conflict observations with crash potential, the current study further determines four conflict severity outcomes to interpret the causality and predict conflicts at a disaggregated level. Random parameters logit models with heterogeneity in the means and variances are estimated to investigate the influence of contributors determining peak crash-prone conflicts and non-peak crash-prone conflicts at different severity levels. Temporal instability between the peak and non-peak periods is captured through two groups of likelihood ratio tests. This paper also compares out-of-sample and within-sample prediction to understand the impact of temporal shifts on predicting the conflict severities for peak and non-peak periods. Additionally, three tree-based data-driven methods are applied including XGBoost, LightGBM and CatBoost to predict the real-time conflicts with crash potential with two data resampling techniques. SHAP is also utilized to interpret the feature importance. The results present that the temporal instability may result in contrary effects of some variables conflict severities such as choosing the deceleration lane as the initial lane and maximum acceleration of the following vehicle. The combination of CatBoost and SMOTE outperforms other approaches. This study provides some insights into the temporal shifts in predicting real-time crash risks based on traffic conflicts, and it also outlines some directions for future research.

Authors	Shahana A, Indian Institute of Technology, Bombay Vedagiri Perumal, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-01175
Paper Title	**Safety Modeling for Signalized Intersection at Approach-level Using Mixed Traffic Trajectory Data**
Abstract	The majority of accidents observed at signalized intersections comprise rear-end collisions resulting from a diversity of vehicle interactions happening during signal change. This study aims to develop conflict-based safety performance functions (SPFs) to predict the number of rear-end conflicts at the signal cycle level in mixed traffic conditions with poor lane discipline. More than 9000 vehicle trajectory data was extracted from traffic video data collected from four signalized intersections in various cities in India. Interacting leader-follower pairs were identified using a methodology suitable for mixed traffic conditions i.e., by considering the width and the lateral gap between vehicles. Time to Collision (TTC) was used to identify the rear-end conflicts. The variation in TTC value with respect to the deceleration rate of vehicles showed that the lower TTC values are obtained for motorized two-wheelers and motorized three-wheelers indicating that smaller vehicle types contribute to more critical vehicle interactions. The SPFs are developed at varying TTC thresholds suitable for mixed traffic conditions which help to address different conflict severity levels. The results show that higher conflict occurrence is expected during signal cycles with more traffic volume, vehicle arrival speed, delay, and lower platoon ratio. Several goodness-of-fit measures used show that the SPFs developed in this study can provide a better prediction of rear-end conflicts at signalized intersections. These results can be most beneficially used for optimizing safety at signalized intersections in mixed traffic conditions.

Authors	Ye Li, Central South University Chang Ge, Central South University Lu Xing, School of Traffic and Transportation Engineering, Changsha University of Science and Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-01456
Paper Title	**Conflict Prediction of Merge Process on Roundabouts Based on CNN-LSTM Model with Attention Mechanism**
Abstract	ABSTRACT Conflict risk prediction is expected to play an essential role in traffic accident prevention. However, few related research studies have focused on roundabouts, especially the merger process. Therefore, a detailed analysis was carried out to fill this research gap. Based on microtrajectory data, this study analyzed roundabout merge conflicts from two-dimensional views in normal and tangential directions. A conflict prediction model of CNN-LSTM integrated with a convolutional block attention module (CBAM) attention mechanism is proposed, which can learn multiple features involving distance, speed, acceleration, and angle from merged vehicle groups. Besides, three commonly used models of CNN, LSTM, and CNN-LSTM are used as benchmarks to compare with the proposed model. The results show that the CNN-LSTM embedded with CBAM has excellent prediction performance with an accuracy of 96.48%, which is much higher than benchmark models. This indicates that the attention mechanism effectively captured important features when applied to conflict prediction. In addition, an interesting finding is the performance difference between CNN and LSTM for conflict prediction and crash prediction. In the study, CNN contributes significantly to merging conflict prediction while LSTM plays a less role. However, two models performed oppositely in previous crash prediction studies. The finding provides a meaningful research point for conflict prediction and collision prediction based on deep learning methods. Moreover, the study provides a practical reference for reducing conflicts and improving the traffic safety of roundabouts. Keywords: Conflict Prediction, Roundabout, Attention Mechanism, Deep Learning

Authors	Yasir Ali, Queensland University of Technology Shimul (Md. Mazharul) Haque, Queensland University of Technology
Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-01496
Paper Title	**Estimating real-time vehicle-pedestrian crash risk for signalised intersections: A Bayesian non-stationarity extreme value model**
Abstract	This study proposes a novel real-time vehicle-pedestrian crash risk modelling framework for signalised intersections. At the core of this framework, a Bayesian Generalised Extreme Value modelling approach is employed to estimate crash risk in real-time from traffic conflicts captured by post encroachment time. A Block Maxima sampling approach, corresponding to a Generalised Extreme Value distribution, is used to identify pedestrian conflicts at the traffic signal cycle level. Several signal level covariates are used to capture the non-stationarity of traffic extremes in the extreme value model. The unobserved heterogeneity associated with crash risk of different cycles is also addressed within the Bayesian framework. The proposed framework is operationalised using a total of 144 hours of traffic movement video data from three signalised intersections in Queensland, Australia. To obtain signal cycle-level covariates, an automated covariate extraction algorithm is proposed that fuses three data sources (i.e., trajectory database from the video feed, traffic conflict database, and signal timing database) to obtain different covariates used to explain time-varying crash risk across different cycles. Results show that the developed model provides a good estimate of historical crash records at the study sites. In addition, the proposed model provides real-time crash estimates at the signal cycle level and is capable of differentiating safe and risky signal cycles. The real-time crash risk model also helps understand the differential crash risk of pedestrians across different periods. This study demonstrates the efficacy of the proposed real-time framework in estimating the vehicle-pedestrian crash risk at signalised intersections

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Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	2099
Session Title	**Truck and Bus Safety Research**
Paper Number	23-01581
Paper Title	**Traffic Conflict Extreme Value Model for Truck Risk Identification and Collision Prediction on Two-Lane Rural Highways**
Abstract	Collision risk identification and prediction is an effective means to prevent truck accidents. However, most of the existing studies focus only on highways, not on two-lane rural highways. To predict truck collision probabilities and identify high-risk scenes on two-lane rural highways, this study first calculated TTC and PET using high-precision trajectory data and combined them with Extreme Value Theory (EVT) to predict the truck collision probability. Subsequently, a traffic feature parameter system was constructed with the Driving Behavior Risk Tendency (D BR) parameter. Furthermore, LightGBM was used to identify critical feature parameters that affect truck collision risk. Eventually, EVT based on TTC and PET incorporated LightGBM to identify high-risk truck driving scenes. The experiments showed that the results of Univariate EVT (UEVT) are obviously biased, whereas Bivariate EVT (BEVT) integrates the applicability of TTC and PET for different driving trajectories of trucks, resulting in significantly better prediction performances than UTCEV. Additionally, D BR is found to have the greatest impact on truck collisions, with importance of 22.466%, especially when D BR ＜43 points, indicating highly risky driving behavior. This study extends a single variable safety evaluation method on trucks to a bivariate that will help design real-time dynamic early warning systems.

Authors	Tianyu Dong, Nanyang Technological University Jiazu Zhou, Singapore-ETH Centre for Global Environmental Sustainability Feng Zhu, Nanyang Technological University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-01658
Paper Title	**An Analytical Investigation of Traffic Safety and Stability Based on Car-following Model**
Abstract	Road traffic safety has long been a focal issue in the field of transportation research. The theoretical analysis of road traffic safety is still limited. In addition, the previous literature regards traffic string stability as an indicator of traffic safety. However, the detailed relationship between traffic safety and stability is still unclear, and there is a lack of relevant research. This study aims to analytically derive the traffic safety criterion based on a generic car-following (CF) model, and compare the traffic stability criterion and traffic safety criterion. In particular, both the real collision and the potential collision risk which is often quantified by surrogate safety measures (SSM), are adopted to assess traffic safety performance. The results of theoretical analysis are validated by simulations. Moreover, this work also obtains a specific and explicit relationship by comparing the traffic stability and safety criterion. The results show that regarding the infinite-size fleet, traffic string stability criterion is equivalent to non-crash criterion. While string stability is a sufficient but unnecessary condition for the non-crash criterion of a fleet with a finite number of vehicles. This study also demonstrates that string stability is a necessary but insufficient condition for traffic safety when SSMs are adopted as the traffic safety indicator. The findings of this research have the potential to not only improve the theoretical traffic safety analysis, but also provide guidance for automated vehicle design and safety assessment of human driving behaviors.

Authors	Narayana Raju, Delft University of Technology Aries van Beinum, Witteveen en Bos Haneen Farah, Delft University of Technology
Sponsoring Committee	Standing Committee on Traffic Simulation (ACP80)
Session Number	3214
Session Title	**Simulation 2023, Part 2 (Part 1, Session 2205; Part 3, Session 4062)**
Paper Number	23-01695
Paper Title	**Influence of Behavioural Model Formulation on Surrogate Safety Measures in Traffic Microsimulation**
Abstract	Traffic microsimulation is a commonly used tool in traffic engineering. Given its flexibility and costefficiency, it is increasingly used for evaluating traffic safety. In real life traffic, unsafety is in many cases due to human error in driving behaviour. In traffic microsimulations however, driving behaviour is highly dependent on the formulated driving behavioural models and the level of their realism. Most of these behavioural models were developed ignoring the inconsistencies and error proneness of human behaviour. A quantitative evaluation of the differences in the safety level between real life and simulated traffic, considering the mathematical formulation of different driver behavioural models, is lacking in the literature. The main aim of this study is to investigate the influence of different behavioural models' formulations on the correlation between simulated and empirical surrogate safety measures' outcomes. For this purpose, high-quality empirical trajectory data were used to calibrate and validate different driver behavioural models. SUMO (Simulation of Urban MObility), an open-source traffic microsimulation software, was used as a platform for calibrating, validating, and testing four distinct combinations of car following and lane changing models. The results show that, regardless of the behavioural model formulations used, the number of simulated traffic conflicts is overestimated. This is most likely due to a higher frequency of lane changes and an unrealistic distribution of traffic over the different lanes in microscopic traffic simulation. The severity of the simulated conflicts was shown to be reasonably accurate at an aggregate level but not significantly comparable at a microscopic level.

Authors	Robert Mansell, Ryerson University Bhagwant Persaud, Toronto Metropolitan University Craig Milligan, MicroTraffic Inc. Amanda Pushka, MicroTraffic Inc
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-01748
Paper Title	**Investigating Factors that Affect Conflicts Between Bicyclists and Right Turning Vehicles at Signalized Intersections**
Abstract	Due to the recognition of active transportation as a beneficial alternative to more traditional modes of transportation, there is increasing interest in designing infrastructure systems to promote the safe use of forms of active transportation such as bicycling. Collision data, which are typically used in road safety studies, may be incomplete and the use of such data is reactive as it requires collisions to have already taken place. Additionally, collisions involving bicyclists and vehicles are less common than those between vehicles. As a result, alternative approaches of evaluating the safety effect of various infrastructure attributes, such as the use of surrogate safety measures, specifically traffic conflicts, could be considered. Most collisions between bicyclists and vehicles occur at intersections and of these, collisions between right turning vehicles and bicyclists form the majority. The main objective of this study was to use cross-sectional regression models to investigate various intersection characteristics, including geometry, signal phasing, and bicycle infrastructure, with a view to determining which attributes are associated with a significant effect on right turning conflicts and how this may change with different conflict severity levels. Various intersection attributes were found to be associated with the frequency of right turning conflicts such as exposure levels, the lateral offset of the bicycle facility and the grade of the approach to the intersection. The significance levels of the associated effects of certain attributes were observed to change with the severity level of the conflicts, with effects becoming either more or less significant with increased severity levels.

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Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications
Session Number	4080
Session Title	**Artificial Intelligence Applications in Transportation Planning**
Paper Number	23-01893
Paper Title	**Trajectory Prediction for Vehicle Conflict Identification at Intersections Using Sequence-to-Sequence Recurrent Neural Networks**
Abstract	Surrogate safety measures in the form of conflict indicators are indispensable components of the proactive traffic safety toolbox. Conflict indicators can be classified into past-trajectory-based conflicts and predicted-trajectory-based conflicts. While the calculation of the former class of conflicts is deterministic and unambiguous, the latter category is computed using predicted vehicle trajectories and is thus more stochastic. Consequently, the accuracy of prediction-based conflicts is contingent on the accuracy of the utilized trajectory prediction algorithm. Trajectory prediction can be a challenging task, particularly at intersections where vehicle maneuvers are diverse. Furthermore, due to limitations relating to the road user trajectory extraction pipelines, accurate geometric representation of vehicles during conflict analysis is a challenging task. Misrepresented geometries distort the real distances between vehicles under observation. In this research, a prediction-based conflict identification methodology was proposed. A sequence-to-sequence Recurrent Neural Network was developed to sequentially predict future vehicle trajectories for up to 3 seconds ahead with 0.5 second intervals. Furthermore, the proposed network was trained using the CitySim Dataset to forecast both future vehicle positions and headings to facilitate the prediction of future bounding boxes, thus maintaining accurate vehicle geometric representations. It was experimentally determined that the proposed method outperformed frequently used trajectory prediction models for conflict analysis at intersections. A comparison between Time-toCollision (TTC) conflict identification using vehicle bounding boxes versus the commonly used vehicle center points for geometric representation was conducted. Compared to the bounding box method, the center point approach often failed to identify TTC conflicts or underestimated their severity.

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Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-02037
Paper Title	**Investigating Pedestrian Safety Surrogate Measures at Midblock RRFB and PHB Crossings using Roadside Camera Data**
Abstract	This study aims to evaluate and compare Surrogate Safety Measures (SSMs) at five selected midblock Rectangular Rapid Flashing Beacons (RRFB) sites and two selected midblock Pedestrian Hybrid Beacons (PHB) sites in Florida using video data collected over the study period of July to November 2021. Computer Vision processing and data processing resulted in four SSMs, namely spatial gap, temporal gap, time to collision (TTC) and Post Encroachment Time (PET). Initial Mann-Whitney U tests revealed significant differences in SSM values across different treatment types and time periods. Afterwards, a multivariate linear regression model considering temporal gap, TTC and PET, and a linear regression considering only the spatial gap revealed significant differences across RRFB and PHB sites. After considering various traffic and operational parameters, data was aggregated for each pedestrian-vehicle interaction on each lane to create a total of 395 observations. The target variables included average spatial gap, temporal gap, TTC and PET for each interaction on each lane. The model involving the temporal SSMs performed better than the one involving spatial SSM. PHB presence, weekday, signal activation, lane count, pedestrian speed, vehicle speed, land use mix and pedestrian starting position have been found to be significant determinants of SSMs. Results suggest that temporal SSMs increase at PHB sites compared to RRFB sites, which increase traffic safety at PHB sites. However, spatial gap decreased at PHB sites, which suggests that pedestrians tended to start crossing RRFB sites when they perceived vehicles to be further away than at PHB sites.

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Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-02072
Paper Title	**A New Surrogate for Safety Evaluation based on Microscopic Driving Model**
Abstract	Emerging large-scale high-frequency, high-resolution driving data reflects driving dynamics and provides valuable information to evaluate driving risk. Microscopic driving models are one of the fundamental tools for analyzing driving kinematic data and understanding temporal patterns within instantaneous driving decisions. However, characterized by severe jerky behaviors, traffic crashes fall outside the comfort zone of widely accepted driving models. To fill this gap, this work proposes a jump-based stochastic driving model. We introduce a novel jump process to mimic crash-related aggressive driving behaviors, such as hard brakings. A new safety surrogate, Total Volatility (TV), is derived based on this model, which considers all levels of unsafe driving volatility. We thoroughly investigate TV's theoretical property and builds its connection with some of the other common safety surrogates. Compared with other safety surrogates, this new surrogate has better predictive performance and solid theoretical foundations. In the real-world data applications, we apply the proposed stochastic model and associated Total Volatility to the Second Strategic Highway Research Plan (SHRP2) Naturalistic Driving Study data with 250 severe crashes, 579 minor crashes 6988 near-crash segments, and nearly 0.3 million routine safe driving segments. The proposed surrogate performs better than state-of-the-art counterparts in various evaluation metrics based on ordinal logistic regressions.

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Sponsoring Committee	Standing Committee on Traffic Simulation (ACP80)
Session Number	3214
Session Title	**Simulation 2023, Part 2 (Part 1, Session 2205; Part 3, Session 4062)**
Paper Number	23-02298
Paper Title	**Collision Avoidance Thresholds of Autonomous Vehicles at Conflicts with Cyclists at Unsignalized Crossings – A Co-Simulation Study**
Abstract	This research evaluates the interactions and conflicts among bicyclists and autonomous vehicles (AV) at unsignalized crossings in an urban traffic network using the co-simulation. The co-simulation incorporates the autonomous vehicle simulator CARLA and microscopic simulation platform SUMO. Conflict scenarios for the cyclists crossing the conflicting zones are studied to reveal the conflict levels with different designs of AV gap acceptance and waiting time thresholds. Performance indicators of the conflicts, such as the number of collisions, collision impulse, lost time of the ego autonomous vehicle and other impacted vehicles, were collected from the simulations. The results clearly show that AV gap acceptance and waiting time thresholds have significant impact on the conflicts performance indicators. Designs with fewer collisions tend to have higher lost times in most of the scenarios. Such findings indicate these two types of performance indicators are somewhat conflicting, and a proper tradeoff between these two is necessary in the AV designs.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-02365
Paper Title	**Safety Assessment for Rear-End Conflicts in Weak Lane Disciplined Traffic due to Dilemma Zone at Signalized Intersections**
Abstract	At the end of the green phase and during the amber phase of the signalized intersection, the traffic stream attains the highest speed. Traffic collisions of high severity occur when the speed of the vehicles is high. During the amber phase, the vehicles often face the dilemma in deciding to stop or go at the intersection. This creates rear-end conflict between the leader-follower vehicles near the stop-line during the amber phase. The probability of rear-end conflicts due to the dilemma is increased even more in weak lane disciplined heterogeneous traffic conditions observed in India. The present study aims to assess rear-end collisions during the dilemma period by analyzing the arriving vehicular trajectories during the amber phase at the intersections. A methodology for assessing the variation of safety aspects regarding rear-end conflicts due to the dilemma in decision-making during the amber phase is presented. The spatial variation and critical locations of the rear-end conflicts due to the dilemma are studied. The distance between the stop line and 40m (upstream of the stop line) is the most critical for weak lane disciplined traffic conditions. A binary logistic regression model is developed to estimate the probability of a rear-end conflict for an individual vehicle using multiple traffic parameters. Using the developed model, a speed restriction (limit) strategy is developed to mitigate the likelihood of rear-end conflicts. Another measure of providing a driver's decision-assistance system for enhancing proactive safety during the amber phase is also explored with positive results.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-02504
Paper Title	**Expressway Rear-end Conflict Pattern Classification and Modeling**
Abstract	The study of expressway rear-end conflicts is of great significance to analyze driving behaviors and improve traffic safety. However, research on the classification and modeling of conflict patterns is still lacking. This study aimed to explore conflict patterns and their relationship with influencing factors. The conflict data used in this study was extracted from a trajectory dataset collected from 7:40 to 10:40 a.m. on a section of the Shanghai Inner Ring. An improved K-Means algorithm, which can automatically obtain the optimal number of clusters, was used to classify the conflict events into six conflict patterns. The conflict patterns were interpreted from five aspects, including risk level, speed of risk-changing, risk-avoidance response, risk-avoidance attitude, and risk-avoidance action. Furthermore, a multivariate Poisson-lognormal (MVPLN) model considering spatial-temporal correlation was applied. The relationship between the independent variables and the number of each conflict pattern within the spatial-temporal unit was obtained. The Root Mean Square Error (RMSE) of MVPLN model was 0.81. Compared to univariate Poisson model, univariate negative binomial model, and univariate Poisson-lognormal model, MVPLN model improved 73.8%, 81.3%, and 29.6% in accuracy respectively. The results of this study can classify expressway rear-end conflict patterns and obtain the number of each conflict pattern with roadside traffic data. It helps to provide personalized driver assistance and targeted traffic control strategies.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02511
Paper Title	**Safety Evaluation of High Friction Surface Treatment at Signalized Intersections in British Columbia: Automated Video-based Traffic Conflict Analysis**
Abstract	High Friction Surface Treatment (HFST) is a pavement treatment intended to reduce crashes at locations with friction-demand issues. The increased pavement friction reduces tire skidding during speed/direction changes and helps motorists maintain better control in dry and wet driving conditions. Typical crash types targeted by HFST are road-departure at horizontal curves or rear end at off-ramps and intersection approaches. This study aims to quantify the safety effectiveness of HFST at signalized intersection approaches using automated video-based traffic conflict analysis. The frequency and severity of rear-end conflicts were extracted from 147 hours of video data collected at two signalized intersections in British Columbia, Canada, where the HFST has been implemented by the Ministry of Transportation and Infrastructure. The video data were collected before and after the HFST implementation and classified into a treatment group and a comparison group. While accounting for traffic volumes, the safety effectiveness evaluation included two methods: before-after evaluation and cross-sectional evaluation. The results indicated that the HFST led to a significant decrease in rear-end vehicle-vehicle conflicts. Specifically, the before-after evaluation and the cross-sectional evaluation showed a reduction of 38.7% and 36.5% in rear-end conflicts, respectively.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02612
Paper Title	**Investigating and Modeling the Influence of PET-Types on Crossing Conflicts at Urban Unsignalized Intersections in India**
Abstract	Un-signalized intersections in India witnessed the maximum number of crashes and fatalities in 2019. The nature of the crash investigation in India is reactive. Further, the crash records are unscientific, and critical details are missing. Therefore, a proactive approach using surrogate safety measures is more promising and prudent in analyzing traffic safety. The present study investigates and models crossing conflicts at unsignalized intersections under mixed traffic conditions. Traffic video data for fourteen un-signalized intersections (eight un-signalized three-legged intersections and six un-signalized four-legged intersections) were collected. The crossing conflicts were identified and characterized based on the values of post encroachment time (PET). The observation revealed the existence of both positive and negative PET values. The physical interpretation of positive and negative PET values of risk and crash risk is investigated and discussed. The results revealed that crossing conflicts with negative PET values are riskier and more unsafe than crossing conflicts with positive PET values. Therefore, the crossing conflicts with positive and negative PETs were modeled separately. The positive and negative PET-based critical crossing conflicts are modeled as a function of traffic flow and intersection geometry-related characteristics using truncated negative binomial regression under a full Bayesian modeling framework as an essential practical outcome. The modeling results revealed that the volume and traffic composition of the offending and conflicting stream and intersection geometry significantly influence the number of positive and negative PET-based critical crossing conflicts.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02622
Paper Title	**Before-After Safety Evaluation of Geometric Improvements at Un-Signalized Intersections using Traffic Conflicts**
Abstract	The use of traffic conflicts for before-after evaluation is widely recognized and appreciated because of the problems associated with the historical crash records. The present study presents a traffic conflict-based before-after safety evaluation of intersection geometry improvement schemes at un-Signalized intersections. Traffic video data for two un-signalized intersections were collected under fair weather conditions during the before and after periods. The crossing conflicts are identified using PostEncroachment Time (PET). The safety benefit of the intersection geometry improvement scheme is evaluated by adopting the Extreme Value Theory (EVT) based safety assessment framework. The safety benefits were quantified by computing the changes in (a) crash risk and the number of theoretical crashes and (b) the Probability of Critical Crossing Conflicts (PCCC). Compared to the before condition, a reduction of 33.43% to 57% in crash risk for the after the condition was noted. Therefore, the geometric improvements had improved the safety at un-signalized intersections. The study proposed a framework for evaluating the safety benefits of geometric improvement schemes using a before-after perspective. Traffic conflicts can be used to evaluate the safety benefits of geometric improvements in the absence of a historical crash database.

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Sponsoring Committee	Standing Committee on Pedestrians (ACH10) Subcommittee on Pedestrian and Autonomous Vehicle Interactions (ACH10(2))
Session Number	4058
Session Title	**Automation, Technology, and Pedestrian Interactions**
Paper Number	23-02763
Paper Title	**A Multi-Conflict-Type Evaluation of Leading Pedestrian Intervals Using an Enhanced Non-Stationary Extreme Value Analysis**
Abstract	Pedestrian safety is a significant concern and engineering challenge. Targeted safety treatments are particularly needed at urban intersections where pedestrians regularly conflict with turning vehicles. Leading Pedestrian Intervals (LPIs) are an innovative, low-cost treatment where the pedestrian and vehicle usage of the potential conflict area (a crosswalk) is staggered in time to give the pedestrians a head start of a few seconds. There is mixed evidence on the effectiveness of LPI treatment on pedestrian safety and no studies of its effects on vehicular conflicts. This study uses an enhanced Extreme Value analysis model to investigate the before-after effects of LPI treatments on vehicle-pedestrian and vehicle-vehicle conflicts. Total 504 hours of before-after traffic videos were collected from three intersections in Bellevue, Washington. The recorded movements were analyzed using Microsoft's Edge Video Service and AMAG's SMART Safety platform to analyze road user trajectories and extract traffic conflicts with minimum Time-to-Collision < 3 s. A Bayesian quantile regression analysis was conducted to estimate the conflict thresholds corresponding to a high (95th) quantile, which were used to estimate a Bayesian hierarchical extreme value model using treatment (treated/control), period (before/after), and conflict type as covariates. Odds ratios were estimated for both conflict types using untreated crossing as a control group. Results show that the LPI treatment reduces the crash risk of pedestrians as measured by the reduction in extreme vehicle-pedestrian conflicts by about 42%. The LPI treatment has also been found not to negatively affect rear-end conflicts along the approaches with treated pedestrian crossings.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3062
Session Title	**Paper Awards: Transportation Safety Management Systems**
Paper Number	23-02767
Paper Title	**Do Traffic Countermeasures Improve the Safety of Vulnerable Road Users at Signalized Intersections? A Combination of Case-control and Cross-sectional Studies Using Video-based Trajectory Data and Surrogate Measures of Safety**
Abstract	Driven by the vision to eliminate road fatalities, Vision Zero initiatives have been widely adopted by many cities around the world, with significant investments of resources in various safety programs and countermeasures. However, there is still a lack of reliable quantitative evidence on the effectiveness of those countermeasures and their relation to various external factors. This research attempts to address this challenge with a combination of case-control and cross-sectional studies, aiming at quantifying the safety effects of three commonly applied Vision Zero countermeasures, namely, Leading Pedestrian Interval (LPI), No Right Turn On Red (NRTOR), and installation of a dedicated Bicycle Lane (BL). A case study was conducted using video trajectory data from ten signalized intersections in the City of Toronto. The traffic interactions between vehicles and vulnerable road users (VRUs) were extracted using a video data processing platform and two surrogate measures of safety, including post-encroachment time (PET) and conflict speed, were obtained and then used to classify the conflict severity into different levels. A comparative analysis using mixed-effects negative binomial regression was conducted to quantify the impacts of different treatments on the frequency of traffic conflicts under specific road weather and traffic conditions. The results show that these three types of traffic countermeasures can effectively reduce the frequency of high-risk and moderate-risk traffic conflicts, moderated by various, traffic exposure, weather and environmental conditions, and accessible pedestrian signals (APS). These findings could help road safety engineers and decision makers make better informed decisions on their road safety initiatives and projects.

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Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications
Session Number	4080
Session Title	**Artificial Intelligence Applications in Transportation Planning**
Paper Number	23-02799
Paper Title	**Modelling the Relationship Between Post Enchroachment Time and Signal Timings Using UAV Video data**
Abstract	Intersection safety often relies on the correct modelling of signal phasing and timing parameters. A slight increase in yellow time or red time can have significant impact on the rear end crashes or conflicts. This paper aims to identify the relationship between surrogate safety measures and signal phasing. Unmanned Aerial Vehicle (UAV) video data has been used to study an intersection. Post Encroachment Time (PET) between vehicles was calculated from the video data as well as speed, heading and relevant signal timing parameters such as all red time, red clearance time, yellow time, etc. Random Parameter Ordered Logit Model was used to model the relationship between PET and these signal timing parameters. Overall, the results showed that yellow time and red clearance time is positively related to PETs. The model was also able to idendity certain signal phases that could be a potential safety hazard and would need to be retimed by considering the PETs. The odds ratios from the models also indicates that increasing the yellow and red clearance times by one second can improve the PET levels by 16% and 3% respectively.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-03069
Paper Title	**Comprehensive Traffic Conflict Assessment Framework Using Macroscopic Traffic Flow Variables: A Novel Method for Trajectory-Based Proactive Safety Assessment**
Abstract	Traffic dynamics at different traffic facilities and vehicle operations such as lane change, lateral shift, overtaking, and merging involve interaction with multiple vehicles in two dimensions (2-D) and, therefore, could result in a spectrum of traffic conflicts like rear-end and sideswipe conflicts. Consequently, it is imperative to account for the 2-D vehicle-to-vehicle interactions for analyzing traffic conflicts. The present study develops a comprehensive traffic conflict assessment framework using macroscopic traffic state variables. To this end, vehicular trajectories extracted for a midblock section of a ten-lane divided Western Urban Expressway in India are used. A macroscopic indicator termed "time spent in conflict (TSC)" is adopted to evaluate traffic conflicts. A two-dimensional framework based on the influence zone of the subject vehicle is proposed and employed to evaluate TSCs . The TSCs are modeled as a function of macroscopic traffic flow variables, namely, traffic density, speed, the standard deviation in speed, and traffic composition, using data-driven machine learning models. Three machine learning models, namely, random forest (RF), support vector machine (SVM), and eXtreme gradient boosting (XGB), were used to model TSCs. Results revealed that intermediately congested traffic flow conditions are critical for traffic safety. Among different machine learning models, the random forest (RF) model was observed as the best-fitted model to predict TSC based on macroscopic traffic variables. The developed machine learning model facilitates the monitoring of traffic safety in real-time.

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Sponsoring Committee	Standing Committee on Pedestrians (ACH10) Subcommittee on Pedestrian and Autonomous Vehicle Interactions (ACH10(2))
Session Number	4058
Session Title	**Automation, Technology, and Pedestrian Interactions**
Paper Number	23-03076
Paper Title	**Risk Situation Prediction for Autonomous Vehicles by Analyzing Temporal-spatial Urgency of Pedestrian-Vehicle Collision**
Abstract	Assess the risk of a collision with pedestrians ahead accurately is crucial for route planning and driving decision making of autonomous vehicle (AV) systems. For complicated AV driving scenarios involving multi-pedestrian, this paper proposes a novel general framework for pedestrian-vehicle collision risk situation prediction. Based on the prediction results of multimodal trajectories, the bounding box detection technology is applied to calculate the overlapping between the predicted pedestrian trajectories and the AV's planned path. It can derermine whether a pedestrian's trajectory is likely to lead to a collision. Pedestrian's multimodal trajectories are divided into two categories: potential collision trajectories (PCT) and temporary safe trajectories (TST). Then, a temporal-spatial urgency quantification model is established by using extreme value theory and catastrophe theory based on the conflict parameters in temporal and spatial dimension. These conflict parameters are calculated from PCT and TST. Finally, the risk degree and the safety distance between pedestrian and AV can be generated by the proposed model. By combining the risk degree and the safety distance of all the pedestrians, the entire risk situation at that moment is constructed. Pedestrian-vehicle interaction data which extracted from driving dataset acquisited by our team are used for model verification. In general, the proposed model can identify the hazard from 0.5-1s in advance, and judge the disappearance of danger more accurately, which is better than the traditional TTC model.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-03132
Paper Title	**Intersection Crash Expansion Factors Based on Probability Models Applicable to Traffic Conflicts**
Abstract	Traffic conflicts are the most promising surrogate measures of safety. Traffic conflicts collected in relatively short periods can be converted to the corresponding number of crashes in expected these periods. This paper attempts to develop a method of expanding a short-term crash frequency into the corresponding annual value – a safety estimate widely used in existing safety management systems. This conversion step is not sufficiently addressed in the past research. Thus, an important task of estimating the annual expected crash frequency based on a short-term estimate remains unanswered. Addressing this need is the research objectives and contribution of this study. Advanced statistical methods are successfully used to develop models to estimate the expected crash frequencies in annual and even short periods. The ratio of such two estimates can be seen as a crash frequency expansion factor. This study presents the modeling effort aimed at providing crash expansion factors applicable to different types of crashes at signalized and unsignalized intersections. Traditional and emerging data, such as traffic volumes, speeds, road characteristics, weather, and other features were collected and assembled at randomly selected 194 intersections. Then, the assembled data were used to estimate logistic models of hourly crash probability. The models were utilized to calculate the expansion factors for a selected existing intersection to illustrate the method and its results.

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Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications
Session Number	4080
Session Title	**Artificial Intelligence Applications in Transportation Planning**
Paper Number	23-03133
Paper Title	**A Review of the Applications of Computer Vision Technology in Surrogate-Safety-Measures-Based Traffic Safety Analysis**
Abstract	The application of Computer Vision (CV) techniques massively stimulates microscopic traffic safety analysis from the perspective of traffic conflicts and near misses, which is usually measured using Surrogate Safety Measures (SSM). However, as the vehicle trajectory extraction and traffic safety modeling are two separate research domains and few research have focused on bridging the gap between them systematically, it is necessary to provide transportation researchers and practitioners with guidance in video processing and traffic safety analysis. With this aim in mind, this paper focuses on reviewing the application of CV techniques in traffic safety modeling using SSM and suggesting the best way to improve. First, the CV models that are used for vehicle trajectory extraction from early approaches to the state-of-the-art analysis are introduced with explanation of how they work on two main video sources CCTV and UAV videos. Second, a detailed review of SSM that can be applied to vehicle trajectory data is conducted. Then, the application of SSM in conflict measurement and various traffic safety analysis purposes are summarized. Last, practical issues that we may encounter from video processing to safety analysis are discussed, and the available or potential solutions corresponding to these issues are presented. This review is expected to assist transportation researchers and engineers with the selection of suitable CV techniques for different video sources, and the usage of SSM for various traffic safety research objectives.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	23-03255
Paper Title	**Exploring Freeways Interchanges Performances under Connected and Automated Vehicles Environment. An Application for North-American and Italian Road Network.**
Abstract	The implementation and deployment of CAVs on motorways is challenging. One of the main concerns is the mixed traffic situation where CAVs and manual vehicles share the road and the effects of these interactions on traffic performance and traffic safety. While there is literature to provide evidence that human drivers adapt their behaviours when interacting with CAVs, the causes for the change of behaviour and the extent of the risk involved is not yet well understood. Such issues are highlighted at freeway junctions, characterized by significant speed variations, especially during maintenance interventions. Our study examines the interactions between CAVs and manuanal vehicles (MVs) through microsimulation analysis and a traffic conflict identification process using surrogate safety assessment measures (SSAM) software. We focus on traffic safety and network performance and the advantages and disadvantages of various geometric configurations of interchanges in Italy and the USA. Chosen samples for this study were selected considering junctions belonging to ring-roads located in heterogeneous urban context, but associable both to Italy and USA roadway design standards. The simulation tools also provide an estimation of the effects of rehabilitation interventions on traffic safety within this context. The findings suggest that implementation of auxiliary lanes on arterial roads facilitates the reduction of risk, mainly for CAVs and the potential for rear-end collisions. The study also points toward the further development of tools for suitability analyses of various urban morphologies and geometrical configurations to minimize the potential for conflicts in a mixed environment with manual vehicles.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-03598
Paper Title	**Novel Traffic Conflict-Based Framework for Real-Time Traffic Safety Evaluation Under Heterogeneous and Weak-Lane Discipline Traffic**
Abstract	The present study proposed a real-time traffic safety evaluation framework using macroscopic flow variables. To this end, open access extended vehicle trajectories are employed. Rear-end traffic conflicts and macroscopic traffic flow variables are derived from the trajectory data and are integrated for real-time safety evaluation. The proportion of Stopping distance (PSD) accounts for all types of interactions (both safe and unsafe) in the traffic stream; hence, the same was adopted to analyze the rear-end traffic conflicts. A macroscopic indicator termed "time spent in conflict (TSC)" is derived to evaluate the rear-end traffic conflicts. Machine learning models, namely, Random Forest (RF), Support Vector Machines (SVM), and eXtreme Gradient Boosting (XGB), are employed to predict TSCs using macroscopic traffic flow variables. The results revealed that the TSC computed based on PSD exhibit a reliable and explainable relationship with the macroscopic traffic flow variables. TSC computed based on PSD revealed that intermediately congested traffic flow conditions are critical in traffic safety and can be attributed to complex traffic phenomena such as traffic hysteresis, traffic oscillations, and increased speed variance. Moreover, a stable relation between traffic safety and traffic flow was suggested for varying threshold values. Among different machine learning models, the RF model was observed as the best-fitted model to predict TSC based on macroscopic traffic variables. The developed machine learning model facilitates the monitoring of traffic safety in real-time.

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Sponsoring Committee	Standing Committee on Urban Transportation Data and Information Systems (AED20) Subcommittee on Urban Big Data (AED20(2))
Session Number	3200
Session Title	**Innovations in Big Urban Data Applications**
Paper Number	23-03689
Paper Title	**Understanding the Impact of Vehicle Dynamics and Roadway Attributes on Surrogate Safety Measures Using Connected Vehicle Data**
Abstract	Traditional safety research mostly relies on crash data to analyze the precedents to a crash. Alternatively, surrogate safety measures have the potential to proactively evaluate safety events. The era of connected vehicles and smart sensing has brought about tremendous innovations in safety research. GPS data from such vehicles form a useful case of big data analytics where surrogate safety measures have largely been unexplored. In this paper, we propose time to collision estimation from connected vehicle GPS data. The vehicle dynamics such as speed, acceleration, yaw rate, etc are then coupled with geometric and nongeometric roadway attributes to understand the contributing factors for a traffic conflict. The dataset contains 2,568,421 GPS points from 14,753 unique journeys. 1:4 ratio of conflict to non-conflict events was used to select 15258 samples. Binary logit model was used to investigate the relationship of these variables with conflicts. Model results showed that out of 28 independent variables, 6 independent variables and 7 interaction variables were found significant. Based on these significant variables, k-means clustering was performed to understand the threshold for the significant values for which the number of conflicts is significantly increased. Results from k-means clustering and two sample binomial proportion t-tests revealed that when absolute acceleration crossed 0.8 m/s 2 , conflict probability increased by 8 percentage points. Moreover, when the yaw rate crossed 8 degrees/s, the conflict probability doublesd. Besides, vehicles traveling at more than 140% of the recommended speed limit increased conflict probability by 7 percentage points.

Authors	Maryam Hasanpour, Ryerson University Bhagwant Persaud, Toronto Metropolitan University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-03755
Paper Title	**Estimation of crash frequency by severity levels based on video-derived traffic conflicts at signalized intersections**
Abstract	Due to the limitations of conflict-based crash frequency analysis, advanced statistical methods for predicting crash frequency by severity using conflict measures have gained interest. The statistical-based methods suffer from the complexity of defining the dependence structure for these two safety indicators. Yet, a considerable amount of research used statistical models, while the estimation of crash frequency by severity using data-driven methods has received relatively little attention in the field of traffic safety. This research aims to address this gap and develop a data-driven-based methodology to estimate the severity of crashes utilizing traffic conflicts, thereby overcoming the limitations of traditional methods. After a thorough review of the recent advances in the related data-driven techniques in transportation and various other engineering fields, this study explores a candidate data-driven model of crash frequency and severity based on conflicts between left-turning vehicles and opposing through vehicles at signalized intersections. To develop this approach, a database of these left turn opposed traffic conflicts was assembled from video observations at signalized intersections. Then, extreme conflicts in different severity levels were determined by jointly modeling the indicators of crash frequency, namely, post encroachment time (PET) and crash severity, namely, predicted post-collision change in velocity (Delta-V), using autoencoder neural network. Finally, linear regression models were developed to relate crashes at the same intersections to the correspondingly classified extreme conflicts. The results of this research, though preliminary, demonstrate the potential of using data-driven methods to quantify the safety of an intersection based on extreme conflicts.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-03777
Paper Title	**An Experimental Analysis using Automated Trajectory Data to Evaluate Motorcyclist Interaction at Unsignalized Interaction**
Abstract	In a developing country like India, where the share of motorcyclists is increasing exponentially, their accidents are also rising at an alarming rate. Most of these road accidents occur at unsignalized intersections. Therefore, the present study aims to analyze the safety of motorcyclist at unsignalized three-arm intersections under heterogenous traffic environment using a fully automated trajectory data analysis. To do so, firstly the study examines which interactions are more commonly observed between motorcyclists and other road users at unsignalized intersection. Then, the study investigates how motorcyclist are interacting with other vehicles and how other vehicles are interacting with motorcyclists in terms of their speed during an interaction. Finally, as a supervised classification technique, Support vector machine (SVM) was used for categorizing the interactions into severe, moderate and safe on the basis of surrogate safety measures (SSM) and maximum interacting speed of vehicle. The results indicates that rear-end conflict were the most commonly occurring conflict at the unsignalized intersection, followed by crossing conflicts. Further, the results reveal that at an unsignalized intersection, most of the severe interaction occurred during rear-end conflicts between motorcycle-motorcycle and motorcycle-car interaction. Overall, the research provides an essential insight into the motorcyclist safety at an unsignalized three-arm intersection which can be used as a base to implement interventions aimed towards reducing motorcyclist accidents and for evaluating countermeasure effectiveness for motorcyclists at unsignalized intersection.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04001
Paper Title	**Proactive Safety Analysis using Roadside Lidar based Vehicle Trajectory Data: A Study on Rear-end Crashes.**
Abstract	This paper presents a methodology to detect rear-end conflicts at signalized intersections with the help of roadside LiDAR sensors. Raw data collected in the point cloud format from the sensors was processed using a series of data processing algorithms to obtain vehicle trajectories. Time-based (MTTC), deceleration-based (SDI) and severity-based (CSI) surrogate safety indices were calculated from the vehicle trajectories to identify the conflict threats at every frame of the dataset, which were further aggregated together to evaluate the risk exposure and risk severity at different temporal segments of the leader/follower car-following period to obtain a rear-end conflict index (RECI). The identified conflicts were compared with the historical crash records using Negative Binomial models. The results indicate correlation between the identified conflicts and the crashes, and further provide new information about the rear-end crash risks at the intersection which could support the proactive approach of traffic safety analysis.

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Sponsoring Committee	Standing Committee on Bicycle Transportation (ACH20)
Session Number	3211
Session Title	**Advances in Data and Methods Related to Modeling Bicyclist and Micromobility User Behavior and Safety**
Paper Number	23-04188
Paper Title	**DERIVATION OF SURROGATE SAFETY MEASURES FROM LATERAL PASSING DISTANCE BETWEEN VEHICLES AND BICYCLES**
Abstract	Surrogate safety measures (SSMs) are important indicators for assessing traffic safety. They allow estimation of crash occurrence risk or crash severity without relying on historical crash data, which can be scarce and unreliable. There are several validated SSMs from driver's safety perspective (e.g., time-to-collision, post-encroachment time, and deceleration rate). However, only few cyclist-oriented SSMs have been proposed and validated. This paper contributes to the advancement of bicycle-specific SSMs for safety assessment by proposing SSMs derived from lateral passing distance (LPD) between vehicles and bicycles. We collected naturalistic cycling data using a multi-sensor device, BSafe-360, mounted to a bicycle. From the data collected, we extracted passing events and their LPDs. Critical LPD events were identified by establishing a threshold LPD. Then, they were mapped and matched to segments of the studied route. We used three thresholds (100 cm, 150 cm, and 50 cm) for sensitivity analysis. Other two SSMs were derived from critical LPD, the mean and standard deviation of LPD of critical LPD events per segment. The SSMs were validated by correlation with crash frequency and number of cyclists injured using Spearman Rank Coefficient. The 100 cm and 150 cm thresholds had positive and moderate correlation between critical LPD events and crash frequency when considering only segments without protected bicycle lanes, with $\rho = 0.36$ and $\rho = 0.37$, respectively. Thus, critical LPD events have potential to be used as bicycle-oriented SSM indicators for safety evaluation. Further investigations are needed for segments with bicycle lanes, as their results were inconclusive.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3196
Session Title	**Safety Impacts of Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	23-04347
Paper Title	**Extreme Value Theory Estimation of Vehicle-Pedestrian Safety Surrogates at Intersection with Right-Turn Flashing Yellow Arrow Indication**
Abstract	Traffic conflicts and surrogate safety measures (SSM) have been used as an alternative to crash-based methods to study roadway safety. Extreme value theory (EVT) offers a modeling framework that can be used to expand the use SSM to conduct proactive safety evaluations. This study explores the EVT modeling approach to analyze vehicle-pedestrian interactions and compare safety risks between a site with a right-turn flashing yellow arrow (RT FYA) indication and sites with a permissive circular green indication. Using trajectory data extracted from video using a frame-by-frame analysis approach, post-encroachment-time (PET) values were determined along with an obstructed right turn time (ORTT) measure which is defined as the time it takes a vehicle to complete a right turn maneuver when a conflicting pedestrian is present. At-site univariate and bivariate extreme value theory models were developed using the block maxima (BM) approach and the peak over threshold (POT) approach. Additionally, joint-site univariate and bivariate Bayesian hierarchical models were developed for each approach. Using the resulting estimates, the number of crashes was estimated for each model and compared to the observed crashes. Results showed that models using ORTT produced a better fit model with their covariates indicating that ORTT helps describe traffic interactions objectively. The number of crashes estimated from the Bayesian hierarchical models was found to also be closer to the observed number of crashes than those from other models. Particularly, Bivariate Bayesian hierarchical models outperformed the at-site models (univariate and bivariate) and the univariate joint-site model in terms of crash estimation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2220
Session Title	**Infrastructure-Related Connected and Automated Safety Performance**
Paper Number	23-04369
Paper Title	**Evaluation of Conventional Safety Indicators for Connected and Automated Vehicles in Car Following at Signalized Intersections**
Abstract	Driving behaviors of connected and automated vehicles (CAVs) will be different from that of human-driven vehicles (HDVs) since the CAVs' driving decisions will be controlled by computers instead of a human. Researchers and practitioners have employed surrogate safety indicators to assess the safety impacts of CAVs due to the paucity of crash data. However, the current literature employs the same safety indicators that were used for HDVs to evaluate the CAVs' safety impacts. This might have inaccurate safety implications because the assumptions about unsafe human driving behavior may not apply to CAVs. This paper compares and evaluates eight different safety indicators often used for evaluating the safety of CAVs in the literature: time to collision (TTC), post-encroachment time (PET), time-exposed TTC (TET), time-integrated TTC (TIT), deceleration rate to avoid a crash (DRAC), crash-potential index (CPI), rear-end collision risk index (RCRI), and potential index for collision with urgent deceleration (PICUD). Real vehicle trajectories and simulation generated CAV trajectories are used to evaluate the safety indicators on an approaching lane of signalized intersections. The findings suggest that the conventional safety indicators can lead to different safety implications for CAVs due to their driving characteristics. The safety indicators need to consider the small-gap operation feature of CAVs with the speed and deceleration capabilities of CAVs. Without such considerations, car followings in a small gap can be simply interpreted as dangerous traffic situations for CAVs: in particular, PET and PICUD may result in opposite safety implications relative to other indicators.

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Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications
Session Number	4080
Session Title	**Artificial Intelligence Applications in Transportation Planning**
Paper Number	23-04690
Paper Title	**ROCO: A Roundabout Traffic Conflict Dataset**
Abstract	Traffic conflicts have been studied by the transportation research community as a surrogate safety measure for decades. However, due to the rarity of traffic conflicts, collecting large-scale real-word traffic conflict data becomes extremely challenging. In this paper, we introduce and analyze ROCO - a real-world roundabout traffic conflict dataset. The data is collected at a two-lane roundabout at the intersection of State St. and W. Ellsworth Rd. in Ann Arbor, Michigan. We use raw video dataflow captured from 4 fisheye cameras installed at the roundabout as our input data source. We adopt a learning based conflict identification algorithm from video to find potential traffic conflicts, and then manually label them for dataset collection and annotation. In total 557 traffic conflicts and 17 traffic crashes are collected from August 2021 to October 2021. We provide trajectory data of the traffic conflict scenes extracted using our roadside perception system. Taxonomy based on traffic conflict severity, reason of the traffic conflict, and its effect on the traffic flow is provided. With the traffic conflict data collected, we discover that failure to yield to circulating vehicles when entering the roundabout is the largest contributing reason for traffic conflicts. ROCO dataset will be made public in the short future.

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Sponsoring Committee	Standing Committee on Information Systems and Technology (AED30) Joint Subcommittee on Sensing Technologies (with AED40) (AED30(1)) Standing Committee on Geographic Information Science (AED40)
Session Number	4064
Session Title	**Emerging Sensor Technologies for Critical Transportation Data Needs**
Paper Number	23-04737
Paper Title	**Transit Safety System Evaluation and Hotspot Identification Empowered by Edge Computing Transit Event Logging System**
Abstract	Transit-related near-crash events and the associated metadata are critical sources for various smart transit applications, such as being surrogate safety measures for transit safety research. Sponsored by the Federal Transit Administration (FTA), the STAR Lab at University of Washington developed an edge computing system that processes onboard videos for near-crash detection. This paper extended our previous work by answering two research questions: First, how to leverage the near-crash detection system to synthesize the rich data sources on transit vehicles; Second, how to use the smart data hub to support transit operation and safety studies. To this end, this paper proposes procedures for event-based transit data collection, evaluation of the performance of commercial collision avoidance warning (CAW) technologies, and transit safety hotspot identification. The performance of CAW system was assessed and benchmarked on four transit buses operated for nearly a year in Pierce County, WA. Additionally, meta-information of the near-crash events facilitates the analysis of hotspots and several exemplar clusters that can be explained by driver behavior and roadway geometries. The experiments demonstrate the promising performance of the system, as well as its applicability to answering various transit operational questions.

Authors	Qikang Zheng, Southeast University Yuxuan Wang, Southeast University Chengcheng Xu, Southeast University Pan Liu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-04773
Paper Title	**A Highway Conflict Prediction Framework based on Empirical Trajectory Data**
Abstract	This paper proposed a framework of highway conflict prediction method using empirical trajectory data and compared the contribution of traffic characteristic features extracted by different methods. Two data aggregating approaches were applied for traffic flow features extraction from the highD dataset in a 30 s time interval. Traffic flow features were categorized into virtual loop detector variables and target section variables. Logistic Regression models and XGBoost models were developed with the two types of variables and also with the entire variables. Four resampling methods (RENN, SMOTE, SMOTEENN, and SMOTETomek) were utilized for dataset rebalancing. SHAP technique was used to visualize the relationships between traffic flow features and conflicts. The results show that: (1) Models with only loop detector variables perform better than models with only target section variables; (2) With the help of SHAP, the relationship between traffic conflicts and traffic flow variables can be interpreted more visually. The proposed approach could be used to identify the hotspots with high conflict risks on highway.

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Sponsoring Committee	Standing Committee on Accessible Transportation and Mobility (AME50)
Session Number	3207
Session Title	**Innovation in Accessible Transportation and Mobility**
Paper Number	23-04778
Paper Title	**An Observational Study on Walking Speeds and Surrogate Road Safety of People with Disabilities and Reduced Mobility Using a Video-based Computer-vision Approach**
Abstract	Vulnerable population groups, such as people with disabilities (PWDs), including persons on wheelchairs or using canes, and people with reduced mobility (PWRm), such as persons walking with a stroller or carrying a baby, are growing in Latin America and worldwide. However, despite the important literature on the accessibility needs and safety issues of PWDs and PWRm when walking in outdoor urban environments, very few studies use automated methods to collect large quantities of data. More important, studies investigating walking speeds and safety measures across different pedestrian subgroups and built environments (sidewalks and crosswalks) are also very limited. This paper introduces a video-based methodology to collect data and investigate the accessibility needs and road safety issues of PWDs and PWRm in a set of locations (crosswalks and sidewalks) in the proximity of public transit stations and health services in the City of São Paulo. The methodology proposes an observational video-based approach in which speeds and surrogate safety indicators are automatically derived for pedestrians walking in real conditions. The mean and median walking speeds of PWDs and PWRm are lower than those used for pedestrian facility design. The observed mean speed of PWDs has a general median speed of 4.1km/h. Moreover, pedestrian speeds vary significantly across age groups, gender and built environment (crosswalks vs sidewalks) after controlling for other factors. Using vehicle-pedestrian conflicts as a surrogate safety indicator, conflict interactions are riskier for PWDs and PWRm, and risk varies across vehicle types.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-04785
Paper Title	**A Conflict-based Rear-End Collision Prediction Model for Unsignalized Intersections under Mixed Traffic Using Machine Learning**
Abstract	Rear-end collisions at high-speed unsignalized intersections are one of the primary causes of crash fatalities. In recent years, Time to Collision (TTC) has been widely used for traffic conflict-based proactive safety evaluation of rear-end collisions. However, in developing countries like India, identifying rear-end conflicts utilizing a single time-based indicator could be pretty misleading because different vehicle classes have distinct dynamic characteristics and travel at varying speed. Consequently, this study used three proximal indicators: TTC, deceleration rate (DR), and relative speed of leader-follower vehicles to identify rear-end conflicts along intersections' approaches from two crash-prone unsignalized junctions located in the National Capital Region, India. Trajectory profiles of each leader-follower vehicle pair extracted using a semi-automated tool were used for estimating these indicators. Rear-end conflicts were further classified into "severe" and "non-severe" groups based on K-mean clustering and indicators' threshold values applicable to mixed traffic conditions. Results showed that the highest percentage of severe conflict was observed at a 4-legged intersection compared to a 3-legged one. Considering, different vehicle types, Light Motor vehicles (LMV) were majorly involved in severe conflicts. This study further developed crash-prediction models to predict rear-end collisions at high-speed unsignalized intersections using seven machine learning (ML) techniques. Among all, the Random Forest (RF) algorithm performed the best for both sites. Study outcomes suggested that despite the lack of reliable crash data in developing nation like India, the combination of proximal safety indicators and machine learning algorithms could create reliable rear-end collision prediction models without depending solely on historical crash data

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-04799
Paper Title	**A Framework for Estimating Dynamic Critical Threshold for Crossing Conflicts at Unsignalized Intersections**
Abstract	Surrogate safety measures use thresholds to distinguish between critical and non-critical conflicts. The critical conflict thresholds explain the near-crash scenarios by its conflict estimation mechanism, and the thresholds also indicate the various possible severity levels by conflict-crash correlation. When the crash data is non-reliable, the established crash-conflict relationship will not represent the ground truth. In such cases, the present proposes an alternative framework for establishing the critical thresholds of conflicts for crossing conflicts at unsignalized intersections by using the survival function at two urban and one rural unsignalized intersection. PET is modeled using Random Intercept Weibull AFT models as a function of the accepted gap, vehicle speeds, and compositions. The random intercepts account for unobserved heterogeneity and provide a better model fit than the fixed parameter model. The survival model developed estimated the critical thresholds at the 50th percentile, with equal chances of survival and failure. The influence of the vehicular compositions was also considered, and the thresholds were estimated by weighted average. The present study established a threshold of 1 second for the rural and urban intersections. The developed framework is easy to understand and adopt and considers the conflict mechanism of PET to derive the critical thresholds.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-04838
Paper Title	**Investigating the Impact of Construction Work-Zone on Rear-End Conflicts by Vehicle Type under Mixed Traffic Conditions**
Abstract	Road transportation is a critical mode of transportation because of its mobility characteristics. Road construction work zones (WZ) are widespread on the roads because of the increased travel demand. Thus, studying traffic safety for the WZ and regular sections is necessary. In this study, traffic safety is analysed regarding the conflict probability at selected roads with WZ and without work-zone (WWZ) sections along the same road. Vehicular trajectory data for three traffic flow levels (free-flow, near capacity, and congestion) were extracted using the newly developed machine learning-based semi-automated trajectory extractor tool. Using MATLAB, the derived trajectory data from both sections were used to identify the leader-follower vehicle pairs. To avoid a collision, two surrogate safety measures were estimated to compute the rear-end conflicts: time-to-collision and deceleration rate to avoid a collision. Hence, the variation of the rear-end conflicts was further examined using the generalized extreme value theory. It is found that the conflict probability is more in the WWZ section than the WZ section, which may be attributed to the variation in speed and acceleration. It is also found that the conflict probability for WWZ and WZ sections is reduced as the angle between the two vehicles increases. The results of this study should help highway authorities to implement suitable safety measures to reduce conflicts and crashes in the work zones

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts**
Paper Number	23-04876
Paper Title	**Modeling motorized and non-motorized vehicle conflicts using Multiagent Inverse Reinforcement Learning approach**
Abstract	Microsimulation models provide an efficient way for analyzing road users interaction behaviour and can be used to evaluate traffic safety and facilities' performance in mixed traffic conditions. However, limited studies have developed simulation models for studying the conflicts between motorized and non-motorized vehicles. This is due to the complexity and heterogeneity in the mixed traffic conditions and the difficulty in capturing the road users' avoidance maneuver mechanism. Therefore, this study aims to develop a novel multiagent simulation model to replicate road users (i.e., motorized and non-motorized vehicles) microscopic behaivour and their collision avoidance mechanisms in conflict situations. Traffic data from two study sites in China are extracted by means of automated computer vision techniques. The conflicts are modeled using the Markov Game framework. Road users reward functions are recovered by the multiagent adversarial inverse reinforcement learning approach. The multiagent Actor-Critic deep learning algorithm is applied to estimate road users optimal policies and predict trajectories. The results show that the multiagent simulation model led to high accuracy in predicting road users trajectories and avoidance mechanisms. Furthermore, results show that the modeled conflict indicator (time to collision, TTC) in the simulated trajectories highly correlates with that in the actual trajectories.

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Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	2118
Session Title	**Advanced Statistical and Econometric Methods for the Analysis of Travel Choices, Lifestyles, and Safety**
Paper Number	23-04906
Paper Title	**A Non-stationary Extreme Value Modeling Framework to Identify Suitable Traffic Conflict Measures for Right-turn Crashes at Signalized Intersections**
Abstract	A wide range of traffic conflict measures has been investigated for different crash types in conflict-based safety studies, with a predominant focus on rear-end crashes. In contrast, it is relatively less known about the suitable set of traffic conflict indicators for right-turn crashes (i.e., left-turn crashes for the United States). This study aims to identify appropriate traffic conflict measures to estimate right-turn crash frequencies applying extreme value models within the video-based traffic conflict techniques. Right-turn conflict data is extracted from two days (12 h each day) of video recordings of four permissible right-turn approaches at three signalized intersections in Brisbane, Australia. Three conflict measures, namely, post encroachment time (PET), supplementary time-to-collision (T 2min), and gap time (GT), are examined within both univariate and bivariate Generalized Extreme Value (GEV) models. To account for the non-stationarity, different exposure variables (conflicting volume, right-turning volume, through volume) and evasive action-based variables (deceleration, relative velocities) measured at the signal cycle level are included in the model. Results suggest that a bivariate model with PET and GT as the traffic conflict measures performs better than a single conflict indicator in a univariate model or any other combination of traffic conflict indicators in the bivariate for predicting right-turn crash frequencies. This combination of conflict measures is also found to predict right-turn crash frequencies by severity levels when combined with post-collision velocity difference (Delta-V). This study demonstrates the importance of accounting for right-turning interactions at different stages using appropriate conflict measures to accurately predict crash risks.

8 Real-Time Safety Prediction

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Studies related to real-time safety prediction aim to enhance traffic safety by identifying the real-time locations with high probability of crashes. The studies focus on predicting safety related parameters in real-time such as crash frequency, crash likelihood, and vehicle conflicts. The subcommittee identified **twenty-two papers** that are related to real-time safety prediction. The papers are classified by the prediction parameter. Some papers focus on traffic prediction based on conflicts in real-time to enhance roadway safety. While other papers focus on crash prediction, crash likelihood, and incident detection in real-time.

Multiple papers analyzed real-time crash risk and roadway safety based on traffic conflicts (23-00264, 23-00280, 23-00487, 23-01107, 23-03598). Papers (23-04327, 23-02101) focused on real-time traffic incident detection/prediction. Further, paper (23-04915) focused on using the actual incident duration time to predict real-time traffic restoration time after a crash occurrence. While paper (23-04284) developed a hazard-based model to estimate incident durations. In addition, paper (23-04956) developed an application to predict the likelihood of secondary crashes in real-time.

Some studies introduced **distinct data sources** into the real-time safety prediction. For instance, paper 23-03105 proposed a framework to analyze real-time Waze data for Public Safety Answering Points (PSAPs). While paper 23-04691 presented methods to determine potential crash risks in real-time during hurricane evacuation using connected probe vehicle data. Further, paper 23-03598 utilized traffic flow variables that are derived from the trajectory data for real-time safety evaluation. Moreover, paper 23-01805 utilized abnormal driving behavior data and connected vehicle data in predicting real-time crash potential on freeways. On the other hand, paper 23-04956 utilized incident data, speed data from the HERE real-time flow Extensible Markup Language feed every minute, and rainfall data are obtained from NEXRAD every 4-6 minutes to predict the likelihood of secondary crashes in real-time. Two papers (23-04327 and 23-04691) utilized probe vehicle data in their real-time safety prediction. In summary, the analysis was conducted using data from highways and freeways (23-00280, 23-00280, 23-04327, and 23-01805), expressways (23-02149), and signalized intersections (23-01496 and 23-00487).

Study (23-03084) aimed to add to current knowledge by attempting to improve model explainability in the context of real-time crash occurrence by proposing the use of SHapley Additive exPlanations (SHAP) and Counterfactual Explanations (CE). Further, study (23-02149) proposed a feature-weighted minority sample oversampling technique (FWMOTE)

incorporating machine learning methods to conduct real-time crash prediction research based on the abnormal driving behavior data on expressways.

Multiple methodologies were proposed to predict safety parameters in real-time. Most of the studies adopted machine learning and deep learning techniques such as Artificial Neural Network (ANN) and Convolution Neural Network (CNN) (23-04327), Support Vector Machine (SVM) (23-00280 and 23-03598), K-means clustering (23-04265), Long Short-Term Memory (LSTM) (23-01805 and 23-01106), Multi-structured Graph Neural Network (MSGNN) (23-02101), Deep Neural Networks (DNNs) (23-03084), and machine-learning-based incident detection algorithm followed by a semi-parametric proportional hazard function (23-04284). In addition, some studies adopted tree-based data-driven methods such as LightGBM and CatBoost (23-01107), Random Forest (RF) (23-03598), eXtreme Gradient Boosting (XGB) XGBoost (23-03598, 23-02148, 23-01107 and 23-04915), and Gaussian Process Boosting (23-04691). On the other hand, three studies proposed statistical approaches such as automated covariate extraction algorithm (23-01496), the prior probability and posterior probability of the Bayesian networks (23-02764), and Random parameters logit models with heterogeneity in the means and variances (23-01107). Finally, two studies utilized simulation in their analysis. For instance, Monte-Carlo-based microsimulation approach was utilized in study (23-00487), and VR driving simulator and eye tracker was utilized in study (23-02518).

Below, for each of the twenty-two papers involving real-time safety prediction, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Sirajum Munira, Center for Transportation Research Michael Moore, University of Texas, Austin Natalia Juri, University of Texas, Austin Kristie Chin, University of Texas, Austin
Sponsoring Committee	Standing Committee on Freeway Operations (ACP20)
Session Number	2035
Session Title	**Freeway Operation 2023**
Paper Number	23-03105
Paper Title	**A Framework to Analyze the Value of Real-Time Waze Data for Public Safety Answering Points (PSAPs)**
Abstract	Real-time information is critical when it comes to responding to crashes, road debris, and other traffic incidents. Public safety answering points (PSAPs), or 911 call centers, are eager to use Waze data in order to improve response times and location accuracy; however, there have been few studies analyzing the efficacy of Waze data and quantifying its value add. This research analyzes one month of Waze and PSAP data along I-30, a 23-mile corridor between Dallas and Fort Worth, Texas. It uses a novel approach to reclassify the Waze events and separate them by event type, which allows for a more nuanced analysis of crashes, road hazards, and other events. Furthermore, when clustering Waze instances and matching them to a PSAP event, a data-based approach was used to select individual spatial and temporal parameters for crashes and for road hazards separately. The use of different parameters for each event type provided the insight that PSAPs typically receive the first report for crashes an average of seven minutes earlier, while Waze receives the first report for road hazards an average of 30 minutes earlier. Additionally, when Waze does receive the first crash report, it is an average of 4.5 minutes earlier—time that has critical safety implications. As a result, PSAPs can now quantify the benefit of integrating Waze data into their response plans for different events. The methodology and results of this research are a significant contribution that can inform other public agencies seeking to improve real-time operations.

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Sponsoring Committee	Standing Committee on Freeway Operations (ACP20)
Session Number	2035
Session Title	**Freeway Operation 2023**
Paper Number	23-04327
Paper Title	**Real-time Traffic Incident Detection on Freeways Using Crowdsourced Probe Vehicle Data: A Deep Learning Approach**
Abstract	Incident detection is a key step in traffic incident management (TIM) to ensure safe and quick clearance of traffic incidents and restoration of traffic. Automatic incident detection (AID) is a method of detecting incidents automatically in live traffic flow using predefined AID algorithms. However, the existing AID algorithms have a few limitations: First, most AID algorithms are developed based on loop detector data limited to specific road segments; Second, using one AID algorithm to detect all types of traffic incidents neglects the fact that different incident types may have various impacts on traffic patterns; Third, existing AID algorithms are unable to classify incident sub-types. This study uses a statewide live traffic database from HERE to detect the freeway traffic incidents. This database provides speed information updated every minute based on crowdsourced probe vehicles in the road network. Three types of AID algorithms are built based on image-like spatial-temporal speed matrices extracted from HERE using Artificial Neural Network (ANN) and Convolution Neural Network (CNN): AID Model 1 to detect the occurrence of all-type incidents; AID Model 2 to detect traffic incident that has significant impacts on traffic speed; AID Model 3 that further classifies incident sub-types. The results show that incidents (e.g., crashes and vehicle fire) that have significant impacts on traffic can be detected and classified with high confidence by the algorithms developed in this study. For different incidents, different algorithms (ANN and CNN) may be preferred for higher prediction or classification accuracy. More implications are discussed in the paper.

Authors	Handong Yao, University of South Florida Qianwen Li, University of South Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	23-00264
Paper Title	**Physics-informed multi-step real-time conflict-based vehicle safety prediction**
Abstract	Real-time vehicle safety prediction is critical in roadway safety management as drivers or vehicles can be altered beforehand to take corresponding evasive actions and avoid possible collisions. This study proposes a physics-informed multi-step real-time conflict-based vehicle safety prediction model to enhance roadway safety. Physics insights (i.e., traffic shockwave properties) are combined with data-driven features extracted from deep-learning techniques to improve the prediction accuracy. A time series of future vehicle safety indicators are predicted such that vehicles/drivers have enough time to take precautions. The safety indicator at each time stamp is a continuous value that the sign reflects the presence of conflict risks, and the absolute value indicates the conflict risk level to advise different magnitudes of evasive actions. A customized loss function is developed for the proposed prediction model to give more attention to risky events, which are the focus of safety management. The prediction superiority of the proposed model is proven through numerical experiments by comparing it with two benchmarks constructed based on the literature. Further, sensitivity analysis on key model parameters is carried out to advise parameter selections in developing real-world conflict-based vehicle safety prediction applications.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	23-00280
Paper Title	**Conflict-based Real-time Road Safety Analysis: Sensitivity to Data Collection Duration and its Implications on Model Resilience**
Abstract	Conflict-based approaches to real-time road safety analysis can provide several benefits over traditional crash-based models. In particular, as traffic conflicts are much more frequent than crashes, models can be trained with significantly shorter data collection periods. As the existing literature never investigated the sensibility of real-time conflict prediction models (RTConfPM) to data collection duration, here we aim to fill this gap and discuss the implications in terms of model resilience. A real-world highway case study was analyzed. Methodologically, various traffic variables aggregated into 5-minute intervals were selected as predictors; synthetic minority oversampling technique (SMOTE) was applied to deal with the unbalanced classification issue; support vector machine (SVM) was chosen as classifier; recall, specificity, and AUC were used to evaluate performance. The dichotomous response variable separated safe and unsafe intervals into two classes; the latter were defined considering a minimum number of rear-end conflicts within the interval, which were identified using a surrogate measure of safety (time-to-collision). Several RTConfPMs were trained and tested, considering different data collection durations and different criteria to define the unsafe situation class. The results show that the models were able to provide reliable predictions with just 3-5 days of data, and that the improvement in performance with collection periods longer than 10-15 days was negligible. These findings can be generalized by considering the number of unsafe situations corresponding to the data collection period of each tested model; they highlight the relevance of RTConfPM as a more flexible and resilient alternative to the crash-based approach.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	23-00487
Paper Title	**Estimating the Collision Probability of a Real Traffic Conflict via Monte-Carlo Based Microsimulation: A Proof of Concept Study**
Abstract	During driving in real traffic, often conflict situations arise which did not lead to an accident, however, they offer a good indication of traffic (un)safety. There are many methods and indicators for classifying whether a current driving situation can be considered as a conflict or not (e.g. TTC, PET or other conflict indicators). However, not many approaches are there to predict how such conflicts will evolve once they have been identified and what the collision probability would be given the conditions of the conflict. Current available methods make strong assumptions about driver behavior during the conflict, usually do not consider all participants involved in the conflict (only two vehicles) and have limited applicability to various types of real conflicts. In this paper, a Monte-Carlo-based microsimulation approach is proposed to estimate the probability of collision for a conflict of any type. Unlike previous approaches, the proposed method can be used to simulate any type of conflict with an arbitrary initial conflict condition and an arbitrary number of vehicles in conflict. The method was developed based on real-world video data of a complex signalized intersection in Delft, from which conflicts were identified with the DOCTOR method. As proof of concept, the proposed method is applied to a real conflict involving four vehicles which was extracted from these video data. The results show that our approach is capable of simulating real conflicts of various types with multiple participants and predicting their probability of collision.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	23-01107
Paper Title	**Predicting Real-time Crash Risks Based on Traffic Conflicts: Accommodating the Influence of Temporal Shifts**
Abstract	Conventional conflict-based studies contributed to the knowledge by extending the traditional crash-based risk prediction to conflict-based, whereas they seemed to overlook the influence of the temporal instability. Consequently, this paper aims to investigate the temporal shifts of the determinants influencing different traffic conflict severities. Using the conflict observations with crash potential, the current study further determines four conflict severity outcomes to interpret the causality and predict conflicts at a disaggregated level. Random parameters logit models with heterogeneity in the means and variances are estimated to investigate the influence of contributors determining peak crash-prone conflicts and non-peak crash-prone conflicts at different severity levels. Temporal instability between the peak and non-peak periods is captured through two groups of likelihood ratio tests. This paper also compares out-of-sample and within-sample prediction to understand the impact of temporal shifts on predicting the conflict severities for peak and non-peak periods. Additionally, three tree-based data-driven methods are applied including XGBoost, LightGBM and CatBoost to predict the real-time conflicts with crash potential with two data resampling techniques. SHAP is also utilized to interpret the feature importance. The results present that the temporal instability may result in contrary effects of some variables conflict severities such as choosing the deceleration lane as the initial lane and maximum acceleration of the following vehicle. The combination of CatBoost and SMOTE outperforms other approaches. This study provides some insights into the temporal shifts in predicting real-time crash risks based on traffic conflicts, and it also outlines some directions for future research.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2036
Session Title	**What Can I Learn by Studying Vehicle Conflicts?**
Paper Number	23-03598
Paper Title	**Novel Traffic Conflict-Based Framework for Real-Time Traffic Safety Evaluation Under Heterogeneous and Weak-Lane Discipline Traffic**
Abstract	The present study proposed a real-time traffic safety evaluation framework using macroscopic flow variables. To this end, open access extended vehicle trajectories are employed. Rear-end traffic conflicts and macroscopic traffic flow variables are derived from the trajectory data and are integrated for real-time safety evaluation. The proportion of Stopping distance (PSD) accounts for all types of interactions (both safe and unsafe) in the traffic stream; hence, the same was adopted to analyze the rear-end traffic conflicts. A macroscopic indicator termed "time spent in conflict (TSC)" is derived to evaluate the rear-end traffic conflicts. Machine learning models, namely, Random Forest (RF), Support Vector Machines (SVM), and eXtreme Gradient Boosting (XGB), are employed to predict TSCs using macroscopic traffic flow variables. The results revealed that the TSC computed based on PSD exhibit a reliable and explainable relationship with the macroscopic traffic flow variables. TSC computed based on PSD revealed that intermediately congested traffic flow conditions are critical in traffic safety and can be attributed to complex traffic phenomena such as traffic hysteresis, traffic oscillations, and increased speed variance. Moreover, a stable relation between traffic safety and traffic flow was suggested for varying threshold values. Among different machine learning models, the RF model was observed as the best-fitted model to predict TSC based on macroscopic traffic variables. The developed machine learning model facilitates the monitoring of traffic safety in real-time.

Authors	Xiaohan Xia, Southeast University Jian Lu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2037
Session Title	**Safety Implications of Risky Driver Behavior**
Paper Number	23-02148
Paper Title	**Investigating the Impact of Abnormal Driving Behaviors Using Real-time Crash Risk Prediction Models and Model Interpretation Tools**
Abstract	Real-time crash prediction model is an emerging method to give early warning of hazardous traffic state and explaining the mechanism of crash occurrence. This study established a real-time crash prediction model based on XGBoost algorithm. To fill the gap in real-time crash prediction model with high interpretability based on the driving behavior data, the number, speed and acceleration of four abnormal driving behavior, which are sharp lane change to the left, sharp lane change to the right, sharp acceleration and emergency brake, were put into the model as explanatory variables. The AUC is 0.872 and the accuracy is 0.833. Partial dependence plots and SHAP were applied to interpret the model. The result shows that the increase of average maximum acceleration of emergency brake behavior 250 meters downstream would make the probability of crash higher, and the increase of average maximum acceleration of sharp acceleration behavior 250 meters upstream or downstream means the increase of its average maximum speed and the decrease of crash risk. The crash risk will increase if the average maximum speed of emergency brake downstream is closer to a special value which is close to the average value, and will decrease if the average maximum speed of sharp acceleration upstream or downstream is closer to a value which is higher than average. Different from previous study, the real-time crash prediction model of this study is entirely based on abnormal driving behavior data, increasing the potential of driving behavior data and exploring the impact of different driving behavior.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	23-01805
Paper Title	**Predicting Real-Time Crash Potential on Freeways with Connected Vehicle Data**
Abstract	The real-time crash potential prediction model is one of the important components of proactive traffic management systems. Over the years numerous models have been proposed to predict crash potential and achieved promising results using input data from roadside detectors. However, the detectors are normally installed at certain locations with limited coverage, while the connected vehicle data can provide city-wide mobility information. Previous studies have found that driver event variables such as hard braking, hard accelerations, etc. are correlated with crash potential on the road segments. Nevertheless, the existing studies are mostly conducted at the aggregated level, and the data are mostly collected from commercial vehicles such as taxis or buses traveling in the urban areas. This paper proposes a bidirectional long short-term memory (LSTM) model with two convolutional layers to predict real-time crash potential on freeways. The input data including traffic flow variables from detectors, and driver event variables from connected vehicle (CV) data, are aggregated at the one-minute level. The model achieves a recall value of 0.772 and an AUC value of 0.857. In this study, we proved the usefulness of the connected vehicle data in the prediction of real-time crash potential, and the possibility of using it without detector data once the penetration rate increases to a reasonable level.

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Sponsoring Committee	Standing Committee on Transportation Network Modeling (AEP40)
Session Number	2152
Session Title	**Mega Poster Session on Transportation Network Modeling**
Paper Number	23-02101
Paper Title	**MSGNN: A Multi-structured Graph Neural Network Model for Real-time Incident Prediction in Large Traffic Networks**
Abstract	This study addresses the problem of predicting traffic incidents across a large-scale road network to support network-wide real-time traffic management. Traditional approaches either build a separate model for each target link across the network or build one big model containing all the links in the network, which are costly and inefficient for network-wide incident prediction. Instead, we propose a sub-area level incident prediction model that can predict an incident occurrence within `any' given sub-area across the network using a single model, where this single network-wide model learns incident patterns from many randomly sampled sub-areas across the whole network. Hence, we develop a Multi-structured Graph Neural Network (MSGNN) model that effectively captures spatio-temporal relationships among links within each sub-area, where multiple graphs with different structures are formed to represent data sources for the same geographic sub-area and the combined graph embeddings from those multiple graphs are taken as input to predict a binary classification label for incident occurrence as output. We conduct a comprehensive set of experiments for model evaluation. When compared with benchmark models, which are chosen from classical to recent learning models, our model outperforms the other models in most of the test cases, showing superior performance consistently across various parameter settings and study networks. We demonstrates the benefit of the multi-structured graph input architecture in flexibly fusing heterogeneous data sources to enhance the accuracy, in conjunction with a novel clustering-based data imputation method that allows us to fully leverage even a sparse dataset with many missing data

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Sponsoring Committee	Standing Committee on Human Factors of Infrastructure Design and Operations (ACH40)
Session Number	2226
Session Title	**Research on Human Factors of Infrastructure Design and Operations**
Paper Number	23-02518
Paper Title	**Effects of Driver's Braking Response by the Real-Time Pedestrian Scale Warning System**
Abstract	Various attempts have been made to ensure the safety of pedestrians at signal intersections where RTOR (Right Turn on Red) is permitted. The most representative is to provide the driver with information about the surrounding traffic environment in a V2X manner. It has been reported that information on pedestrian-dense areas induces a driver's early deceleration. Still, there is a drawback in that information on the pedestrian scale cannot be provided in real-time. Therefore, this study proposes a real-time pedestrian scale warning system to improve pedestrian traffic safety. VR driving simulator and eye tracker were used to investigate driver behavior and cognitive response according to the warning system. As a result of the experiment, the proxy safety index (TTZ) of vehicles equipped with warning systems increased by up to 40%, and the braking reaction time decreased by up to 46%. Also, it was confirmed that the larger the scale of the pedestrian, the safer the braking. This study suggests that real-time pedestrian scale information can be applied to system design for urban traffic safety improvement.

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Sponsoring Committee	Standing Committee on Intelligent Transportation Systems (ACP15)
Session Number	3093
Session Title	**Toward the Next Generation of Intelligent Transportation Systems**
Paper Number	23-04956
Paper Title	**Real-Time Secondary Crash Prediction Algorithm**
Abstract	This research developed an application to predict the likelihood of secondary crashes in real time. The application uses incident data from SunGuide®, traffic data from HERE, rainfall data from the Next-Generation Radar Level-II network (NEXRAD), and roadway geometric characteristics data from the Florida Department of Transportation. The algorithm estimates the impact area of an incident and predicts the likelihood of secondary crashes in real time. It consists of an Internal Storage Database, which stores incident, speed, and rainfall data collected in real time. It also archives the secondary crash prediction results, historical databases, secondary crash prediction equation, and secondary crash likelihood parameters. The second part of the application is Backend Applications for collecting, parsing, and saving incident, traffic, and rainfall data in real time. One of the applications continuously accesses the SunGuide® database every two minutes and ping new incidents. Speed data are retrieved from the HERE real-time flow Extensible Markup Language feed every minute. Rainfall data are obtained from NEXRAD every 4-6 minutes. The information from the Internal Storage database and Real-time Data Backend Programs are combined using the Secondary Crash Prediction Application to predict the likelihood of secondary crashes every 15 minutes until the incident is cleared.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-01106
Paper Title	**A Risk Field-based Approach for Driving Risk Assessment: Focusing on the Generalized and Realtime Application**
Abstract	This study provides a generalized method for assessing the driving risk encountered by on-road vehicles for driver support and automation systems design. To this end, this effort employs artificial field theory to unify longitudinal and lateral conflicts. We define any impediment to an ego vehicle as a finite scalar cost field modeled by the predictive occupancy of the impediment. Then the conflict field is formulated as a product of the cost field and the driver's risk field (DRF), which captures the driver's subjective risk perception so as to quantify the level of conflict. We verify the proposed method for three driving situations (i.e., car-following, yielding, and lane changing) using highway naturalistic driving data and show its relevance to the time to collision (TTC) and post encroachment time (PET). The risk sum derived from the conflict field quantitatively captures the risk profile of the situation and is generally consistent with PET. Further, the risk sum provides an interpretable basis to assess driving safety by decomposing the risk of each adjacent vehicle. Lastly, a sensitivity analysis was performed on the prediction model's performance to evaluate the effect of bias and variance on the LSTM-based model. The major innovative aspect of this study assesses the various types of conflict between adjacent vehicles individually, even in highly uncertain situations. The proposed driving risk assessment model can thus be used as a component of intelligent vehicle safety applications and as a unified multi-context conflictbased safety measure to use for assessing traffic safety.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04739
Paper Title	**Where are we with Real-Time Safety Research?**
Abstract	Proactive safety research is replacing the traditional reactive safety approaches in order to improve safety on roads. However, there are some research questions that need to be answered in the domain of crash likelihood, crash severity, crash types, secondary crash, and traffic restoration period to advance real-time safety studies. After reviewing the earlier research, this study attempted to respond to these questions by summarizing the key contributions, data processing techniques, and modeling techniques used to conduct these studies to pinpoint the current research gaps and future research direction. The findings from this review revealed that there is still a need to develop a complete real-time crash likelihood prediction framework. Real-time crash severity, crash types, and secondary crash studies have not reached yet the acceptable prediction accuracy. Real-time traffic restoration time after crash occurrence related studies is at the rudimentary stage, and advanced techniques to real-time update the variables and models for the traffic management authority are to be investigated. In addition, there is a need to investigate data preprocessing techniques to improve model performance in each of these domains. Overall, this study summarizes the present contributions of the real-time safety studies and identifies the research gaps to advance this research direction. This study has the potential to refine the research approach in real-time crash prediction and contribute to advancing proactive safety research.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04915
Paper Title	**Real-time Traffic Restoration Time Prediction based on the Estimated Traffic State**
Abstract	The study developed an approach to predict the traffic restoration time after a crash occurrence based on the estimated traffic state. The contribution of this study is threefold: first the study developed models to predict the traffic state after a crash incident; second, the study predicted the traffic restoration time based on the estimated post-crash traffic state; third, the study validated the proposed traffic restoration time using the actual incident duration time. To accomplish these tasks, the study considered a 220 miles section of Interstate-75 of Florida, USA. Traffic, crash, weather, and emergency facility data were collected for the road from 2017 to 2019. 24,448 events and 65 real-time features were used to develop the traffic state prediction model. Total eight traffic state prediction models were developed using the XGBoost machine learning technique. Then the estimated traffic state was used to calculate the congestion state of pre-crash and post-crash condition. Then pre-crash and post-crash congestion states were compared to capture the time when traffic returned to normal operating condition. The estimated traffic restoration time was validated by comparing it with the actual incident duration data. A cosine similarity metric was used to find the similarity between these actual and predicted times, and the results showed that 82.40% similarity was obtained. To the best knowledge of the authors such an approach to estimate traffic restoration time is new in real-time safety research and has the potential to contribute to real-time traffic management after a crash.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-03084
Paper Title	**Demystifying the black box in deep learning based real-time crash prediction models**
Abstract	Real-time crash prediction is heavily studied for its value to predict and anticipate crash. Potential losses of lives could be prevented if intervention like Variable Speed Limit (VSL) is promptly deployed. Deep learning (DL) models such as Deep Neural Networks (DNNs) have been the state-of-art models to predict crashes. However, unlike statistical models (e.g., logistic regression), DL models are criticized for being "black-box" models, with limited exploratory power. This paper adds to current knowledge by attempting to improve model explainability in the context of real-time crash occurrence by proposing the use of SHapley Additive exPlanations (SHAP) and Counterfactual Explanations (CE). To predict crash, real-time disaggregated traffic data along the UK M1 Motorway in 2017 between Junctions 1-30 were utilized. The dataset utilized in the model is naturally imbalanced with 257 crash cases and 16,359,163 non-crash cases. Wasserstein Generative Adversarial Network (WGAN) is adopted to synthetically oversample crash cases whereas non-crashes are undersampled to 500,000 cases. A DNN is trained and five representative crash cases originating from cluster analysis are explained through SHAP and CE for the feature attribution towards crash and the magnitude of corrections required to correct the predicted crash to non-crash. Findings of this study suggest that higher-than-average aggregated flow (i.e., $2\sigma \geq \mu$) and lower-than-average variance of flow (i.e., $2\sigma \leq \mu$) contributes highly on crash prediction. This study demonstrated the ability of model-agnostic methods to overcome black box issues in DL models, while findings can aid traffic managers to deploy countermeasures when crashes are predicted.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-04265
Paper Title	**A Real-time Framework to Predict Crash Likelihood and Cluster Crash Severity**
Abstract	This study proposes a three-stage framework for real-time crash likelihood and severity prediction. Firstly, a real-time crash likelihood prediction model was developed. Secondly, a real-time crash severity clustering model was proposed to cluster the crashes into different severity levels. Thirdly, a severity clustering validation model was developed to assess the performance of the proposed severity clustering model. Extensive data processing techniques were employed to collect real-time features from State Road 408 in Orlando, Florida, and a total of 6,750,072 events (625 crash events and 6,749,447 non-crash events) along with 24 real-time features were used. To develop the crash likelihood prediction model, nine machine learning techniques were attempted, and the convolutional neural network model was found to provide the best result with sensitivity (0.916), false alarm rate (0.111), and area under the ROC curve (0.967). DaviesBouldin Index criteria was used to find the detector location that generated the most accurate traffic information to cluster the crashes into severity levels, and based on this traffic information, K-means clustering was applied to develop the severity clustering model. Finally, a severity clustering validation model was developed after investigating nine machine learning techniques to validate the developed severity clustering model, and the decision tree model provided the best results based on three levels of sensitivity and specificity values. The developed framework has the potential to help traffic management center to warn road users or develop TSM&O strategies in real-time to avoid crashes or minimize the severity and thus, can significantly contribute to improving road safety.

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Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Section - Transportation Systems Resilience (AMR00)
Session Number	4035
Session Title	**Emergency Case Study and Human Behaviors**
Paper Number	23-04284
Paper Title	**From Traffic Analysis to Real-Time Management: A Hazard-Based Model to Estimate Incident Durations Extracted Through AI Modeling and Traffic Detector Data Anomaly Identification**
Abstract	When incidents occur, information on their time, location and characteristics is needed to distribute real-time traveler information, and dispatch timely police and emergency service for traffic control and safety mitigation purposes; however, the corresponding clearance and recovery time is still an important and under-studied subject of research. Existing studies modeling incident durations mainly utilized the duration data gathered and provided by authorities through the joint efforts of individual agents (e.g., traffic operators and patrol officers), which may suffer coverage and consistency issues and thus the reliability of the resulting model estimations. In addition, the explanatory variables considered are static, i.e., observed at the incident formation stage and assumed to be consistent over the incident periods. Such setup, however, overlooks the traffic flow dynamics as time-varying variables during the incident episodes in affecting incidents being cleared and the associated disruptions being recovered (i.e., the end of incidents) and thus the durations of incidents. In line with the above limitations, the objective of this study is to utilize hazard-based modeling to explain incident durations mined from traffic detector data while factoring in traffic flow dynamics. The 2014-2016 Virginia statewide traffic detector data were utilized to extract incident durations by implementing a machine-learning-based incident detection algorithm followed by a semi-parametric proportional hazard function accommodating the time-varying variables descriptive to traffic flow dynamics for incident duration modeling. The resulting hazard can help traffic operators and drivers make better decisions while coping with the uncertainty during incident events.

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Sponsoring Committee	Standing Committee on Disaster Response, Emergency Evacuations, and Business Continuity (AMR20) Section - Transportation Systems Resilience (AMR00)
Session Number	4035
Session Title	**Emergency Case Study and Human Behaviors**
Paper Number	23-04691
Paper Title	**Predicting Crash Risks in Real Time during Hurricane Evacuation Using Connected Probe Vehicle Data**
Abstract	With ubiquitous sensors and communication technologies, it is possible to retrieve micro-level vehicular data containing individual vehicle trajectory and speed information. Such large-scale vehicle data, available in real time, can be used to assess prevailing traffic safety conditions. Using vehicle speed and acceleration profile, potential crash risks can be calculated in real time. Previous studies on real-time crash risk prediction mainly used data available from infrastructure-based sensors which may not cover a large number of road segments. In this paper, we present methods to determine potential crash risks from an emerging alternative data source known as connected probe vehicle data. Such data contain vehicle location, speed, and acceleration information collected in every 30 seconds. To predict potential crash risks, we utilize a dataset collected during the evacuation period of Hurricane Ida on Interstate-10 (I-10) in the state of Louisiana. We divided the studied road into 124 segments and for each segment we calculated different traffic features and weather features every 5-minute intervals from the vehicular data. We tested multiple machine learning models and found Gaussian Process Boosting model to perform better in predicting a potential crash event than other models with a precision of 0.82 and recall of 0.96. The real time vehicular data for crash risk assessment will make it possible for traffic manager to utilize resources more efficiently and proactively take safety measures.

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Sponsoring Committee	Standing Committee on Statistical Methods (AED60)
Session Number	4065
Session Title	**Emerging Methods and Best Practices in the Statistical and Econometric Analysis of Transportation Data: Evidence from Safety, Travel Behavior, and Activity Choice Modeling**
Paper Number	23-01496
Paper Title	**Estimating real-time vehicle-pedestrian crash risk for signalised intersections: A Bayesian non-stationarity extreme value model**
Abstract	This study proposes a novel real-time vehicle-pedestrian crash risk modelling framework for signalised intersections. At the core of this framework, a Bayesian Generalised Extreme Value modelling approach is employed to estimate crash risk in real-time from traffic conflicts captured by post encroachment time. A Block Maxima sampling approach, corresponding to a Generalised Extreme Value distribution, is used to identify pedestrian conflicts at the traffic signal cycle level. Several signal level covariates are used to capture the non-stationarity of traffic extremes in the extreme value model. The unobserved heterogeneity associated with crash risk of different cycles is also addressed within the Bayesian framework. The proposed framework is operationalised using a total of 144 hours of traffic movement video data from three signalised intersections in Queensland, Australia. To obtain signal cycle-level covariates, an automated covariate extraction algorithm is proposed that fuses three data sources (i.e., trajectory database from the video feed, traffic conflict database, and signal timing database) to obtain different covariates used to explain time-varying crash risk across different cycles. Results show that the developed model provides a good estimate of historical crash records at the study sites. In addition, the proposed model provides real-time crash estimates at the signal cycle level and is capable of differentiating safe and risky signal cycles. The real-time crash risk model also helps understand the differential crash risk of pedestrians across different periods. This study demonstrates the efficacy of the proposed real-time framework in estimating the vehicle-pedestrian crash risk at signalised intersections.

Authors	Fan Ye, Southeast University Jian Lu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2098
Session Title	**Safety Effects of Roadway Characteristics and Treatments**
Paper Number	23-02149
Paper Title	**Crash Predication on Expressway Incorporating a Feature-weighted Oversampling Approach Based on Abnormal Driving Behavior**
Abstract	Real-time crash prediction helps identify and prevent traffic crashes from occurring. For years, various real-time crash prediction models have been investigated to provide effective information for active traffic management. But most previous studies have been based on traffic flow data of expressways to predict the real-time crash, and the impact of abnormal driving behavior on crash prediction has been less considered. Before crash prediction modeling, we need to take into account the class imbalance of the data. Existing processing methods such as SMOTE, assume that the weights of feature parameters are the same when defining the neighborhood of minority samples, which is not valid for most machine learning methods. This study assumed that the model performance in the presence of noisy or redundant features can be improved by changing the feature weights in the data processing method. A feature-weighted minority sample oversampling technique (FWMOTE) was proposed, and incorporating machine learning methods to conduct real-time crash prediction research based on the abnormal driving behavior data on expressways. The results show that the data processing method proposed in this paper achieves better prediction results than classical oversampling methods. It is also confirmed that some abnormal driving behaviors can have a significant impact on traffic crashes. Through this study, new insights have been gained in the field of class-imbalanced data processing, a development in the use of abnormal driving behavior data for traffic crash prediction on expressways and support has been provided for active traffic safety management.

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Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)
Session Number 3215
Session Title **Safety Models: New, Evolving, and Refreshed**
Paper Number 23-02764

Paper Title **Relationship analysis between traffic flow, risky driving behavior, and crash probability in spatiotemporal using a dynamic Bayesian network**

Abstract Active crash prevention is a challenging problem in traffic safety study. Implementing preventive measures based on the precursory characteristics of crash is crucial to reducing traffic crash rates. The widespread use of in-vehicle navigation terminals enables real-time data collection on risky driving behavior and the traffic status of the entire roadway. Therefore, we used these data and extracted traffic flow and risky driving behavior data for 30 min before a crash in three road segments. A dynamic Bayesian network model was used to determine the relationships between traffic flow, risky driving behavior, and crash probability in time and space. The prior probability and posterior probability of the Bayesian networks were used to obtain the temporal and spatial relationships before the crash. The results showed that the model achieved a crash sensitivity of 83.24% with a false alarm rate of 15.75%, and the crash classification accuracy of 84.16%. The traffic flow and risky driving behaviors had distinct temporal and spatial characteristics before the crash, and their changes led to an increase in the probability of traffic crashes. Temporally, a higher crash probability occurred in the 10 min before the crash. Spatially, changes in the traffic flow and risky driving behavior in the downstream segment were associated with higher crash probabilities. The results show that we can infer the probability of traffic crashes from the temporal and spatial changes of traffic flow and risky driving behavior. And then provide help for the formulation of precise traffic crash prevention measures beforehand.

9 Safety Effects of Connected and Automated Vehicles

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Connected and Automated Vehicles (CAVs) are thought to be the future of transportation, bringing several benefits to traffic operation. One of the most outstanding improvements addressed by the CAVs is related to safety. This statement is based on the possibility that vehicles can interact among them in real-time preventing dangerous situations, but also because they will not rely on unpredictable human behavior, but only on rule-based algorithms and sensors, that will react instantaneously and in a predetermined and precise way to external inputs.

The subcommittee identifies **seventeen papers** related to the Safety Effects of Connected and Automated Vehicles. The main topics related to the papers can be categorized as follows: **Surrogate Safety Measures** applied to CAVs (22-00630, 23-01658, 22-03255, 23-05024, 22-01347, 22-04369); **Traffic simulations** to predict safety aspects related to CAVs (22-03255, 23-05024, 22-00630; 23-01658; 23-02299); **Analysis of crash datasets** including CAVs data or used to indirectly infer insights about them (22-00506, 23-05272, 23-04006, 22-01805, 22-03216, 22-00186, 22-02769, 23-02479, 22-04369, 23-048806, 23-03952).

The **Surrogate Safety Measures** are analyzed from a twofold perspective, predicting the likelihood of crashes through using the output trajectories from simulations (22-03255, 23-05024) or investigating the potential of such Measures in CAV research (22-01347, 22-04369). In the latter case, the differences in meaning of SSMs and their application for CAVs or Human-driven Vehicles (HdVs) were highlighted (22-04369), as well as the chance of relying on real-time data from CAVs to define a SSM and use it to predict crashes at specific sites (22-01347).

The analysis of scenarios through traffic **simulations** was made in mixed traffic conditions (e.g,, 23-05024), thought as the most dangerous scenario. Still, the presence of CAVs can represent an enormous advantage related to safety. The most probable collision type recorded through simulations in a mixed traffic environment is the rear-end collision. The same result was also highlighted by conducting **Analyses of crash datasets** including CAVs (22-00506, 22-00186, 23-02479, 23-03952, 23-05272, 23-04006).

The other investigations of crash datasets have emphasized that more detailed evidences about CAV collisions are needed, in order to improve their performance. Nevertheless, the

CAVs can fail and be involved in collisions: a comparison between HvD collisions (85% related to human errors, 23-04806) and CAV collisions provides promising results: fatal crashes could be reduced by 95% if traffic is made only of fully automated vehicles.

All collision analyses are deployed at **intersections**. Based on new European regulations, a comparison between urban and rural intersections with CAVs was made (22-02769) pointing out that strict standards may result in homogenous CAV behaviors in every condition.

The **interactions between Vulnerable Road Users (VRUs) and CAVs** (23-03952, 23-02299) were highlighted in the context of a safe implementation of CAVs in the urban environment. Moreover, in this regard, research has shown a crucial finding: **low-speed collisions** are the most probable for CAVs (22-00630; 22-03216).

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	22-00186
Paper Title	**Advancing Investigation of Automated Vehicle Crashes Using Text Analytics of Narratives and Bayesian Analysis**
Abstract	Vehicle automation, manifested in self-driving cars, has the promise to provide safe mobility by reducing human errors. While the testing of automated vehicles (AVs) has improved their roadway performance in recent years, automation technologies are facing challenges such as uncertainty of safety impacts in mixed traffic with human-driven vehicles. This study aims to investigate AV safety performance by conducting a thorough analysis of recent AV crash data. Based on 148 AV collision reports from California in 2019 and 2020, this study extracted key variables from crash records, crash locations, and, importantly, a text analysis of crash narratives reported by AV manufacturers. Using a path-analytic framework with the frequentist and Bayesian approaches, this study explores the interrelationships among pre-crash conditions, AV driving modes, crash types, and crash outcomes. Results show that 60.1 percent of crashes had a rear-end collision. Particularly, AVs are found to become more vulnerable to rear-end collisions in the automated driving mode. On the other hand, the automated driving mode would not make any significant difference in the chance of a sideswipe collision or crash outcomes. Another interesting finding is that manual disengagement is more likely to happen when an AV is interacting with a transit vehicle. The risk factors identified in this study can be considered in AV safety assessment scenarios as well as in future operations of mixed traffic. Further, this study provides the implication that AV crash narrative data can be leveraged to improve knowledge of AV safety performance.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	22-00630
Paper Title	**Safety impacts of autonomous shuttle bus with different operational speeds towards increasing market penetration rate of connected and automated vehicles**
Abstract	The current study aims at evaluating the impacts of different operational speeds of an autonomous shuttle bus service on road safety by increasing Connected and Automated Vehicles (CAV) Market Penetration Rate (MPR) and combining network characteristics. A microscopic simulation analysis was performed in order to quantify the impact of road safety of an automated shuttle bus service within traffic. In the traffic network of Villaverde, Madrid, several scenarios were simulated using the Aimsun Next software considering the various CAV MPRs (0-100%), and the different operational speeds of the service, namely 15, 30, and 45 km/h. From the microscopic simulation, the vehicle trajectories were extracted and analyzed using the Surrogate Safety Assessment Model (SSAM) software that identified conflicts. Statistical analysis was then performed using negative binomial regression and specifically the dependent variable was the frequency of conflicts that the shuttle bus service was involved in. The analysis revealed that the conflict frequency is lower when the shuttle bus operates at 45 or 30 km/h compared to 15 km/h, with the 45 km/h speed showing the largest reduction due to the shuttle bus adapting more easily to the average traffic speed and is more synchronized with traffic flow. Furthermore, greater CAV MPR results in steadily decreased conflict frequency probably due to the automated shuttle's adaptability and collaboration with automated and connected traffic vehicles. The current study establishes a solid relationship for the conflict frequency of AV shuttles enabling stakeholders to optimize road safety towards a future of automated traffic.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	22-01347
Paper Title	**Using Harsh Braking Data from Connected Vehicles as a Surrogate Safety Measure**
Abstract	Surrogate safety measures are a means of safety analysis for the purpose of identifying high-risk road infrastructure. Surrogate safety measures allow for proactive safety analysis, meaning that the analysis may take place prior to crashes occurring. Safety improvements may in turn be implemented proactively to prevent crashes and the associated injuries and property damage. Existing surrogate safety measures primarily rely on data generated by microsimulations, but the advent of connected vehicles has allowed for the incorporation of data from actual cars into safety analysis with surrogate safety measures. In this study, commercially available connected vehicle data is used to develop crash prediction models for crashes at intersections and segments in Salt Lake City, Utah. Harsh braking events are identified and counted within the influence areas of sixty study intersections and thirty segments and then used to develop crash prediction models. Other intersection characteristics are considered as regressor variables in the models. These models may be used as a surrogate safety measure to analyze intersection safety proactively. The findings are applicable to Salt Lake City, but similar research methods may be employed by researchers to determine if these models are applicable in other cities and to determine how the effectiveness of this method endures through time.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	22-01805
Paper Title	**Predicting Real-Time Crash Potential on Freeways with Connected Vehicle Data**
Abstract	The real-time crash potential prediction model is one of the important components of proactive traffic management systems. Over the years numerous models have been proposed to predict crash potential and achieved promising results using input data from roadside detectors. However, the detectors are normally installed at certain locations with limited coverage, while the connected vehicle data can provide city-wide mobility information. Previous studies have found that driver event variables such as hard braking, hard accelerations, etc. are correlated with crash potential on the road segments. Nevertheless, the existing studies are mostly conducted at the aggregated level, and the data are mostly collected from commercial vehicles such as taxis or buses traveling in the urban areas. This paper proposes a bidirectional long short-term memory (LSTM) model with two convolutional layers to predict real-time crash potential on freeways. The input data including traffic flow variables from detectors, and driver event variables from connected vehicle (CV) data, are aggregated at the one-minute level. The model achieves a recall value of 0.772 and an AUC value of 0.857. In this study, we proved the usefulness of the connected vehicle data in the prediction of real-time crash potential, and the possibility of using it without detector data once the penetration rate increases to a reasonable level.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2038
Session Title	**Infrastructure-Related Safety Effects for Connected and Automated Vehicles**
Paper Number	22-03255
Paper Title	**Exploring Freeways Interchanges Performances under Connected and Automated Vehicles Environment. An Application for North-American and Italian Road Network**
Abstract	The implementation and deployment of CAVs on motorways is challenging. One of the main concerns is the mixed traffic situation where CAVs and manual vehicles share the road and the effects of these interactions on traffic performance and traffic safety. While there is literature to provide evidence that human drivers adapt their behaviours when interacting with CAVs, the causes for the change of behaviour and the extent of the risk involved is not yet well understood. Such issues are highlighted at freeway junctions, characterized by significant speed variations, especially during maintenance interventions. Our study examines the interactions between CAVs and manual vehicles (MVs) through microsimulation analysis and a traffic conflict identification process using surrogate safety assessment measures (SSAM) software. We focus on traffic safety and network performance and the advantages and disadvantages of various geometric configurations of interchanges in Italy and the USA. Chosen samples for this study were selected considering junctions belonging to ring-roads located in heterogeneous urban context, but associable both to Italy and USA roadway design standards. The simulation tools also provide an estimation of the effects of rehabilitation interventions on traffic safety within this context. The findings suggest that implementation of auxiliary lanes on arterial roads facilitates the reduction of risk, mainly for CAVs and the potential for rear-end collisions. The study also points toward the further development of tools for suitability analyses of various urban morphologies and geometrical configurations to minimize the potential for conflicts in a mixed environment with manual vehicles.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2220
Session Title	**Infrastructure-Related Connected and Automated Safety Performance**
Paper Number	22-00506
Paper Title	**A Comparative Study of Rear-end Collision between ADS-Controlled Vehicles and ADAS-Controlled Vehicles**
Abstract	With the increasing number of vehicles equipped with Automated Driving System (ADS) being tested on the public road and the expanding market share of vehicles equipped with Advanced Driving Assistance System (ADAS), the number of ADS- or ADAS-involved crashes increases. Thus, it is necessary to investigate the distribution of ADS- and ADAS-involved crashes and the factors leading to them. The rear-end collision has been found to dominate among ADS-involved crashes. However, no research has explored the conditions when ADS-involved rear-end collisions are more likely to happen and no research has investigated ADAS-involved rear-end crashes. Based on 130 ADS-involved crashes and 84 ADAS-involved crashes extracted from a dataset collected by National Highway Traffic Safety Administration (NHTSA) between July 2021 and May 2022, this study explored the crash patterns, especially rear-end crashes of ADS- and ADAS-controlled vehicles. Results show that the rear-end collisions dominate both the ADS- and ADAS-involved crashes and this is especially the case for ADAS-involved crashes. The type of ADS-involved and ADAS-involved crashes were both affected by the speed of the ego-vehicle relative to the posted speed limit. Further, the type of ADS-involved crash was affected by the pre-crash movement of the crash partner; while the type of ADAS-involved crash was further associated with the road type. The findings can provide insights into the design of ADAS and ADS control algorithms, the external human-machine interface design of the vehicles with ADS or ADAS, and the training program of human road users to improve traffic safety in mixed traffic.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2220
Session Title	**Infrastructure-Related Connected and Automated Safety Performance**
Paper Number	22-02769
Paper Title	**Investigation of Drivers' Behaviour in Unsignalized Intersections, Based on the New European Regulation for Automated Vehicles**
Abstract	Accidents at intersections have been widely studied. Commonly, those studies are based on statistical correlations of infrastructure characteristics to accidents, or in identifying the near-misses and traffic conflicts that are precursors of accidents. While such studies focus on the most extreme events, such as accidents or conflicts, the advent of automated driving motivates the investigation of the nominal maneuvers. Automated vehicles navigating intersections, on top of avoiding accidents, should respect the safety distances of human drivers, especially in case it is oncoming traffic from a privileged direction in unsignalized intersections. They can go through if the distances are long enough. If they accept short distances, surrounding human drivers could perceive the situation as risky and react harshly. In this regard, the European Commission has recently established a regulation for the Automated Driving Systems, containing specific requirements about the minimum separation to ensure in case of crossing and merging with privileged traffic at unsignalized intersections. In the present work, we evaluated the actual minimum separation accepted by the human drivers, according to the regulation framework, for not privileged crossing and merging events. The real-world maneuvers have been extracted from two different datasets, concerning urban and not urban unsignalized intersections. The results show that the level of safety registered in the two datasets is comparable. The similarity between the two datasets is evident in case the minimum separation between the vehicles is rated based on the parametrization proposed in the regulation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2220
Session Title	**Infrastructure-Related Connected and Automated Safety Performance**
Paper Number	22-03216
Paper Title	**A Comparison of Traffic Crash and Connected Vehicle Event Data on a Freeway Corridor with Hard-Shoulder Running**
Abstract	Traditionally, police-reported crash data are a primary resource for research and the development of projects aimed at improving traffic safety. Reliance on crash data is generally reactive in nature, which is an inherent limitation in crash data analysis, however the learnings from this type of analysis continues to be an invaluable tool for learning about real-world crash scenarios. Connected vehicle (CV) driving event data provides a promising means for addressing these limitations as information about CV events can be obtained both at larger scale and in a timelier manner as compared to crash data. This study evaluated the relationship between CV driving event data and traffic crash data on the US-23 corridor in southeastern Michigan. This corridor uses the inside (left) shoulder as a temporary travel lane during peak periods and also provides dynamic advisory speeds based upon traffic congestion levels as monitored by microwave vehicle detection systems. The results show strong correlation between mean traffic speeds and frequency of CV driving events. Both crashes and CV driving events were most likely to occur during periods of low speeds. The occurrence of both crashes and CV driving events generally exhibited similar relationships with traffic volume irrespective of whether the inside shoulder was open to traffic or not. CV events occurred much more frequently and, as such, there was significantly less variability in counts from location to location. The CV events also showed a closer relationship with changes in travel patterns that occurred following travel restrictions imposed by the COVID-19 pandemic.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2220
Session Title	**Infrastructure-Related Connected and Automated Safety Performance**
Paper Number	22-04369
Paper Title	**Evaluation of Conventional Safety Indicators for Connected and Automated Vehicles in Car Following at Signalized Intersections**
Abstract	Driving behaviors of connected and automated vehicles (CAVs) will be different from that of human-driven vehicles (HDVs) since the CAVs' driving decisions will be controlled by computers instead of a human. Researchers and practitioners have employed surrogate safety indicators to assess the safety impacts of CAVs due to the paucity of crash data. However, the current literature employs the same safety indicators that were used for HDVs to evaluate the CAVs' safety impacts. This might have inaccurate safety implications because the assumptions about unsafe human driving behavior may not apply to CAVs. This paper compares and evaluates eight different safety indicators often used for evaluating the safety of CAVs in the literature: time to collision (TTC), post-encroachment time (PET), time-exposed TTC (TET), time-integrated TTC (TIT), deceleration rate to avoid a crash (DRAC), crash-potential index (CPI), rear-end collision risk index (RCRI), and potential index for collision with urgent deceleration (PICUD). Real vehicle trajectories and simulation generated CAV trajectories are used to evaluate the safety indicators on an approaching lane of signalized intersections. The findings suggest that the conventional safety indicators can lead to different safety implications for CAVs due to their driving characteristics. The safety indicators need to consider the small-gap operation feature of CAVs with the speed and deceleration capabilities of CAVs. Without such considerations, car followings in a small gap can be simply interpreted as dangerous traffic situations for CAVs: in particular, PET and PICUD may result in opposite safety implications relative to other indicators.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3215
Session Title	**Safety Models: New, Evolving, and Refreshed**
Paper Number	23-01658
Paper Title	**An Analytical Investigation of Traffic Safety and Stability Based on Car-following Model**
Abstract	Road traffic safety has long been a focal issue in the field of transportation research. The theoretical analysis of road traffic safety is still limited. In addition, the previous literature regards traffic string stability as an indicator of traffic safety. However, the detailed relationship between traffic safety and stability is still unclear, and there is a lack of relevant research. This study aims to analytically derive the traffic safety criterion based on a generic car-following (CF) model, and compare the traffic stability criterion and traffic safety criterion. In particular, both the real collision and the potential collision risk which is often quantified by surrogate safety measures (SSM), are adopted to assess traffic safety performance. The results of theoretical analysis are validated by simulations. Moreover, this work also obtains a specific and explicit relationship by comparing the traffic stability and safety criterion. The results show that regarding the infinite-size fleet, traffic string stability criterion is equivalent to non-crash criterion. While string stability is a sufficient but unnecessary condition for the non-crash criterion of a fleet with a finite number of vehicles. This study also demonstrates that string stability is a necessary but insufficient condition for traffic safety when SSMs are adopted as the traffic safety indicator. The findings of this research have the potential to not only improve the theoretical traffic safety analysis, but also provide guidance for automated vehicle design and safety assessment of human driving behaviors.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3216
Session Title	**A Fresh Look at Crash Characteristics**
Paper Number	23-02479
Paper Title	**Analysis of Pre-crash Scenarios and Contributing Factors for Autonomous Vehicle Crashes at Intersections**
Abstract	Intersections are high-risk spots for autonomous vehicles (AVs). Crash causation analysis based on pre-crash scenarios provides new insights into these crashes. This study analyzed AV precrash scenarios, the faults of the AVs, and the contributing factors for AV crashes at intersections. Analysis of 197 AV crashes and 1925 conventional vehicle crashes at intersections revealed 30 types of scenarios for AVs and 36 for conventional vehicles. Several AV scenarios involving single-vehicle crashes have not been identified because of limited AV crash data. Significant differences between the AV and conventional vehicle scenarios were verified by statistical analysis. AVs being rear-ended by conventional vehicles at intersections (34.01%) occurred with a frequency 3.18 times that of rear-ended conventional vehicles. For the rear-end scenario that occurred most frequently, three fault patterns of AVs were identified: at fault, possible fault, and no fault. The five contributing factors: intersection-related area, traffic signal control, mixed-use or public land, weekdays, and autonomous mode, strongly related to AV crashes in the rear-end scenario were determined based on the association rules algorithm. The findings provide new insights into AV crash causation, and can be used in the development and optimization of AV automated driving systems (ADSs) at intersections, as well as in guiding traffic safety agencies when proposing regulations to improve safety.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-02299
Paper Title	**Analysis of Intelligent Vehicle Technologies to Improve Vulnerable Road User Safety from Cars and Trucks in Urban Areas**
Abstract	As advanced vehicle technologies become available, we have more reliable solutions to improve the safety of all traffic agents, especially vulnerable road users (VRUs). We need to know how these Intelligent Vehicle Technologies (IVTs) can improve VRU safety in different environments and conditions (e.g., sight distance and traffic flows) at signalized intersections. However, there are limited studies on technical and operational differences between these various IVTs, and on technology adoption rates for safety improvement. To address these knowledge gaps, this study first develops a simulation model to mirror realworld driver/VRU perception limitations and then implements four IVTs in micro-level traffic simulations. According to the simulation results, Intersection Safety (INS) is the most efficient technology amongst the four studied IVTs to reduce average collision counts for passenger cars and trucks under seven predefined collision types involving VRUs and vehicles. Blind Spot Detection (BSD) has the most minimal effects on those types. The safety improvement of VRU Beacon Systems (VBS) and Bicycle/Pedestrian to Vehicle Communication (BPTV) are between INS and BSD. More importantly, results indicate that IVTs can significantly reduce the collision probability when sight distance is under a threshold and also improve safety under good sight conditions if collisions happen right in front of vehicles. Additionally, this research conducts a sensitive analysis of traffic volume. For some collision types, INS and BPTV can even reduce approximately 50% of collisions when traffic volume is extremely high.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04806
Paper Title	**Potential Reduction of Fatal Crashes in South Carolina due to Automated Vehicles**
Abstract	Since 1995, several countries and states have implemented roadway traffic safety projects with the goal of achieving a highway system with no fatal or serious injury crashes. South Carolina's Target Zero plan is multifaceted in that it identifies several preventative measures to reduce fatalities. A common thread of these programs is that they are aspirational, and there is not an expectation that zero fatalities will ever be a reality. While there are many contributors to fatal crashes, by far the biggest contributor is driver error. In South Carolina (SC), the first contributing factor in nearly 85% of fatal crashes is driver related. Thus, to approach a target of zero fatalities will require eliminating drivers from the equation—or at least making drivers error free. This research focuses on how 2019 SC fatal crash data could be impacted hypothetically by different scenarios of autonomous vehicle (AVs) safety applications. A detailed review of contributing factors to over 900 2019 fatal crashes in SC along with a review of site characteristics for each crash was conducted. A deterministic approach was used to calculate the effects of different AV levels on each of the fatal crashes. The approach was based primarily on literature findings regarding the safety effectiveness of vehicle characteristics for each level. The reduction in fatal crashes ranged from 10% to 23% for level 1 to nearly 95% for level 5 AVs. The underlying assumption in terms of AV level is that the entire population of vehicles fall within that AV category.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-05272
Paper Title	**Comparison of Crash Types in Automated Vehicles with Different Levels of Automation**
Abstract	Many car manufacturers have been putting their effort into producing automated vehicles (AV). Automated Driving Systems (ADS) are a representation of higher levels of automation and these cars are not publicly available yet. ADS vehicles are expected to outperform Advanced Driver Assistance Systems (ADAS) in terms of crashes and make roads safer. However, NHTSA has recently published crash reports of both ADAS and ADS technology vehicles, showing that the number of crashes for ADS vehicles is still high. This study aims to compare crash types of ADS and ADAS technologies. Intersection crashes are selected for comparing these two technologies to consider the same environmental characteristics. Results reveal that the contact area for 72.4% of ADS-equipped vehicle crashes at intersections is the rear of the vehicle and the contact area for 94.7% of ADAS-equipped vehicle crashes is the front of the vehicle, meaning that ADS vehicles are being hit by other vehicles on the road most of the time. Results illustrate that these two automation technologies are acting vastly different from each other in similar environments. Additionally, Results suggest that in the rear-ended ADS crashes, these vehicles were stopped or proceeding straight 81% of the time, showing a low rate of adoption in a mixed environment. This is the first study that compares collision types between ADS and ADAS technologies based on real-world crashes. Overall, this study contributes by comparing ADAS and ADS crash types as it is critical for enhancing transportation safety and important for safety practitioners.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-05024
Paper Title	**Evaluating the Safety Impacts of Autonomous Vehicles under Mixed Traffic Conditions.**
Abstract	Advances in artificial intelligence and machine learning may transform the notion of Autonomous Vehicles (AVs) into a reality in the near future. Past studies have evaluated the safety and travel time benefits of AV inclusion under homogeneous traffic conditions. Whereas the mixed traffic conditions are yet to be thoroughly investigated. This study considered Indian mixed traffic conditions, with lane changes permitted for overtaking. The micro simulation software VISSIM was used in this study to simulate mixed traffic conditions at varying AV penetration rates ranging from 0% to 100%. The study considered five volume levels to account for volume variations, i.e., base volume (volume near free flow conditions (LOS A)), 1.25*base volume, 1.5*base volume, 1.75*base volume, and 2*base volume (volume under forced flow conditions (LOS F)). A roundabout and an uncontrolled T-intersection were considered in the study. Surrogate safety assessment model (SSAM) was used for safety evaluation. Findings show that there is no significant effect ($p < 0.05$) of AV inclusion on number of conflicts and travel time at low traffic volume (base volume). At the roundabout, the conflicts reduced by 46-74% at high traffic volume (2*Base volume), corresponding to an AV penetration rate of 50 to 100%. Also, at the uncontrolled T-intersection (at high traffic volume (2*base volume)), a 10-20% increase in the frequency of conflicts at 10-50% AV penetration rates was observed and subsequently a 36% reduction in conflicts was recorded at 100% AV penetration rate. The study illustrated the significant safety impact of AVs at higher penetration rates.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-04006
Paper Title	**Safety in Higher Level Automated Vehicles: Investigating Edge Cases in Crashes of Vehicles Equipped with Automated Driving Systems**
Abstract	With emerging Automated Driving Systems (ADS) representing high automation levels (SAE Levels 3 or 4), several Automated Vehicle (AV) manufacturers are testing their vehicles nationwide on public roadways. The safety performance of these vehicles has become a major concern for the transportation safety industry. In recent years, several ADS crashes have been reported to the National Highway Traffic Safety Administration. Scrutinizing such crashes can reveal rare circumstances called “edge cases” where unusual AV crashes occurred. Identifying edge cases among ADS crashes helps AV companies prepare AVs to avoid such crashes and, as such, enhance safety. To this end, first, an unsupervised machine learning technique, K-means clustering, is used to cluster the crashes. Second, the observations on each edge cluster are ranked based on the critical or rare events, and the highest one (the most unusual crash) is selected as an edge case. Statistics show that 53% of ADS crashes occurred at intersections, and 82% were noinjury crashes. The most frequent ADS crash type was rear-end accidents in which conventional vehicles were proceeding straight while AVs stopped on the roadway. The identified edge cases show that different factors such as unmarked roads, problematic traffic signs, road debris (e.g., tire debris), slippery road surface, traffic spikes, and speed bumps can result in edge case crashes. In addition, in most of the edge case crashes, AVs made contact with heavy vehicles. While most AV crashes happened at intersections, most critical accidents happened in other locations, such as traffic circles, parking lots, and streets.

Authors	Pei Li, UW Madison: University of Wisconsin Madison
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	23-03952
Paper Title	**Exploring Latent Topics from Autonomous Vehicles Crashes and Analyzing Their Relationships with Crash Metadata**
Abstract	Autonomous vehicles (AVs) are expected to bring huge benefits to society, while safety is one of the most important factors. However, existing AVs are not crash-free yet. AV crashes may have undiscovered patterns which differentiate them from conventional crashes that involved normal vehicles. This study analyzed real-world AV crash data in California by exploring latent topics among AV crashes. The structural topic model (STM) was used in this study as it allows the consideration of metadata (i.e., the type, severity, and year of crashes) while developing the model. In total, 20 topics have been identified from the AV crash data, which can be divided into behavior-based, party-based, location-based, and general topics. The extracted topics are closely related to crash metadata. For example, the topic that contains rear and bumper has a high proportion in rear-end crashes. The topic that describes lane-changing behaviors has a high proportion in sideswipe crashes. Results from this study suggest that several important aspects need to be considered by AV manufacturers to improve AV safety, including interactions between AVs and vulnerable road users, AV's operation while driving near stop signs, and AVs' ability to handle turning and lane-changing behaviors.

10 Transportation Safety Management

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Fifty-seven papers describing diverse perspectives of transportation safety management will be presented in Lectern Session 2219 titled **Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**, Lectern Session 3010 titled **Moving Safety Research into Practice**, Lectern Session 3062 titled **Paper Awards: Transportation Safety Management Systems**, Poster Session 3149 titled **Transportation Safety Management Systems from Start to Finish**, and Poster Session 3097 titled **TRB Minority Students Fellows Poster Session** at the 2023 TRB Annual Meeting. The following is a brief overview of the papers.

Nine papers investigated **traffic safety of vulnerable road users**. Kumfer et al. (23-00991) presented the results of a systemic safety analysis producing two pedestrian-related safety performance functions for Montgomery, Maryland. The first model is for motor vehicle crashes involving pedestrians at intersections at night; and the second one is for through-movement motor vehicle crashes with pedestrians traveling along segments. Sakib et al. (23-01889) assessed university students' safety behavior on three-wheel electric rickshaw in Bangladesh. The study adopted various theoretical insights including Theory of Planned Behavior, Awareness Interest Desire Action, and Health Belief Model to identify factors to the behavior. Qian et al. (23-02299) studied intelligent vehicle technologies to enhanced safety of vulnerable road users in urban areas. The study developed a simulation model to mirror real-world driver/vulnerable road user perception limitations and implemented four intelligent vehicle technologies to reduce collision frequencies for passenger cars and trucks under seven predefined collision types. Shangguan et al. (23-02767) explored whether traffic countermeasures would improve safety of vulnerable road users at signalized intersections. The study used a combination of case-control and cross-sectional approaches using video-based trajectory data and surrogate safety measures. Schneider et al. (23-03154) investigated the value of linking police-reported crash data with emergency medical services data of Milwaukee, Wisconsin. Matched records from the two databases have a larger tendency to involve fatal and severe injuries. The study also found that the two databases provided different insights into bicyclist injury crashes. Khadem et al. (23-03588) aimed to identify safety complete street design using full-size driving and bicycle driving simulators. Zhu and Dadashova (23-03617) investigated the driver-victim pairs in pedestrian and bicyclist crashes aby latent class clustering and random forest approaches. Haque et al. (23-03670) analyzed risk perception of vehicle-to-vehicle vendors and general pedestrians based on survey questionnaires collected from Dhaka, Bangladesh. Lin et al. (23-03990) adopted traffic signal strategy for speed management and reducing pedestrian and bicyclist fatalities and severe injuries. The results showed that good progression is capable of reducing severe and fatal injury frequencies.

Eight papers explored **how certain policies affected traffic safety**. Agarwala and Vasudevan (23-00482) investigated the relationship between economic growth and traffic fatalities in 27 states and union territories of India. Ghomi et al. (23-02224) evaluated Toronto's Vision Zero strategies using a time-

series analysis and copula-based model. The study found that leading pedestrian intervals and speed limit reduction were among the most effective safety treatments in the city. Also, the findings also showed that the effects can vary between neighborhoods. Mishra et al. (23-03296) identified the key attributes of high-risk drivers in Canada and investigating their attitude toward traffic safety laws. Xu et al. (23-03541) proposed to add road safety awareness to navigation systems. Torres and Cunto (23-04009) conducted a multivariate analysis on road safety policies in Brazilian cities based on the safety system approach. The paper analyzed the influence of 28 performance indicators associated with the five actions pillars to promote road safety policies. Haque et al. (23-04010) investigated traffic safety in disadvantaged communities using crash and Justice40 initiative data. The results showed that higher fatal crash rates are associated with communities with disadvantaged health0sise, resilience-wise, and transportation-wise. Shi et al. (23-04731) explored road safety in New York after Vision Zero policy for different land-use contexts. The study identified that a large and growing discrepancy in fatality rates between pedestrians, bicyclists, and car occupants at places with different land-use features. Wang (23-04741) explored whether Vision Zero in Los Angeles was effective using ARIMA model. The results showed that the Vision Zero policy was not a failure, but the effectiveness differ by time, road user, etc.

Six papers investigated **effects of speed on traffic safety**. Alomari et al. (23-00106) analyzed speeding violations using machine learning methods including random forest, classification and regression tree, and multi-layer perceptron neural network approaches. Son et al. (23-01668) investigated safety effectiveness of decreasing the speed limit in urban areas. There were about 22-33% reductions in serious and fatal injury crashes at the location of speed limit reduction, and 17-20% reductions in adject sections. Mahmoud et al. (23-02447) explored the impact of target speed on pedestrian bicycle, and speeding crash frequency. The results revealed a significant reduction in three crash types when using the target speed. Yang et al. (23-04333) investigated the roles of speeds in traffic crashes based on geospatial modeling approach. The study's results show the significant correlates of injury severities are different in two types of crashes (involving over-speeding or driving too fast for conditions), and the correlates from both models vary substantially across the space. Avelar et al. (23-04939) assessed the safety of raising speed limits using interrupted time-series approaches. The results displayed significant increases in seven crash types in rural freeways in Texas after the speed limit increase (~10-39%). Rahman et al. (23-04962) identified attribute associations in fatal speeding crashes using latent class clustering and association rule mining approaches.

Six papers explored **traffic safety during the COVID-19 pandemic**. Wang and Tefft (23-01013) compared fatal crashes in the US during the COVID-19 pandemic to forecasts based on pre-existing trends. Papadimitriou and Afghari (23-01036) explored common attributes between traffic safety pandemic and the COVID-19 pandemic. The results showed that structural socioeconomic indicators play a key role in the outcomes of both pandemics. Yang (23-02610) investigated the impact of COVID-19 on traffic safety. The findings suggested that the crash frequency is significantly less than that of the pre-pandemic during the whole course of the pandemic. But it increases during the later stage owing to the relaxed restrictions. Marshall et al. (23-03136) leveraged probe data to model speeding on limited access highway segments during the COVID-19. The findings showed that the improved level of service and higher odds or speeding. Das and Khodadadi (23-03152) analyzed short-duration crash modeling comprehend impacts of operating speed on freeway crashes during the COVID-19 and found that the impacts vary before and after the COVID-19 outbreak. Shahlaeegilan et al. (23-04224) modeled the impact of the COVID-19 pandemic on speeding at rural roadway facilities in Maine. Using

short-term speed and traffic count data, the study found that the odds of speeding by more than 15 mph increased by 34% for rural major collectors, 32% for rural minor arterials, and 51% for rural principal arterials during the stay-at-home order in April and May of 2020 (compared to the same months in 2019).

Five papers evaluated **automated vehicle's safety effectiveness**. Li (23-03952) explored latent topics from automated vehicle crashes and analyzing the relationships with crash metadata. The structural topic model identified 20 topics from AV crash data, and the extracted topics were closely related to crash metadata. Moradloo et al. (23-04006) studied traffic safety in higher level automated vehicles. Kohneh et al. (23-04806) probed potential reduction of fatal crashes in South Carolina, US due to automated vehicles. Singh et al. (23-05024) evaluated safety impacts of automated vehicles under mixed traffic conditions. Taherkhani et al. (23-05272) compared crash types in automated vehicles with different levels of automations using the data from NHTSA.

Five papers worked on **prioritization for safety treatment**. Aminghafouri and Fu (23-02844) adopated a joint confidence region approach to rank hotspot location considering uncertainty in the expected risk estimates using data from Kitchener, Ontario, Canada. Shaon et al. (23-02861) developed a data-driven network screening procedure for systemic safety approach using data from Connecticut, USA. Matata et al. (23-03379) explored the choice of sliding window parameters to identify dangerous roadway segments. Tanzen and Souleyrette (23-03875) developed an automation tool for highway safety project prioritization. Izadi et al. (23-04432) developed an open-source web toll to prioritize safer streets.

Four papers focused on **risk assessment methodologies**. Harwood and Hans (23-00217) compared safety system assessment methods including road assessment program and Australian safe system assessment framework. Joo et al. (23-01106) employed a risk field-based approach for driving risk assessment. The study focused on the generalized and real-time applications. Hossain and Medina (23-02091) demonstrated a methodology for systemic analysis tools, which is suitable to calibrate the usRAP risk assessment formulation when analyzing non-intersection crashes including run-off road and head-on crashes. Pineda-Mendez et al. (23-02170) adopted a risk-based highway safety management system for rural interstate freeway highways in Indiana.

Four papers analyzed **safety of motorcycles**. Ganga et al. (23-00194) probed the cost of unhelmeted motorcycle injury. The study was a nationwide scoring-based analysis of helmet safety legislation. The result showed that a universal helmet law is an effective way to decrease unhelmeted motorcycle fatality. Lee et al. (23-00709) prosed strategies for reducing motorcyclist injuries in Tennessee based on evidence-based working countermeasures. Jang et al. (23-04087) explored the relationship between motorcyclist attitudes and behaviors towards safe riding and self-reported crash experiences based on questionnaire survey. Das et al. (23-04325) conducted a motorcycle crash severity analysis using a Bayesian network.

Three papers assessed **traffic safety related to school**. Forrest and Heydari (23-00526) estimated the effect of proximity to school on cyclist injury frequencies. The study revealed that the presence of a school was associated with an increase in cyclist injuries. Wu et al. (23-02386) explored the associations between built environment and traffic crash risk of children when they go to school. Burbidge (23-03111) measured the effectiveness of safety routes to school projects. The results include: (1) no significant change in the number of non-motorized crashes; (2) the probability of minor injury

non-motorized crashes increased after construction; (3) crashes occurring in wet or snowy weather were less severe, and most severe injury crashes occurred during the day; (4) bicycle crashes resulted in less severe injuries than pedestrian crashes and were less common after construction.

Two papers specifically analyzed **wrong-way driving**. Song et al. (23-03753) studied trends and odds of wrong-way driving fatal crashes on freeways from 2004 to 2020 in the USA. Song et al. (23-04059) presented the national survey on wrong-way driving solutions, policy and guidance in the USA.

Two papers studied **real-time safety**. Islam et al. (23-04739) reviewed real-time safety research studies and revealed that there is still a need to develop a complete real-time crash probability prediction as the previous studies' prediction accuracy is not high enough. Islam et al. (23-04915) developed an approach to predict traffic restoration time after a crash occurrence based on the estimated traffic state.

A single paper by Goyal et al. (23-03087) surveyed the **relationship between transportation network companies** (or ridesharing companies) and safety. The results suggested that there is not significant association except for fatal and injury crashes.

A single paper by Islam et al. (23-04894) considered **distraction as a major factor in safety**. The results indicated that there is a complex interaction of driver characteristics, driver actions, a driver without violation, , road/environmental conditions, vehicle characteristics, and temporal features.

A single paper by Sohrabi and Lord (23-04824) explored **navigation routing considering traffic safety**. The study examined the problem by comparing the safest and shortest routes between five metropolitan areas in Texas, USA. The result indicated that the shortest route is not necessarily the safest, where an 8% decrease in travel time was associated with a 23% higher risk of crash occurrence.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-23-00106
Paper Title	Analysis of Speeding Violations Using Different Machine Learning Methods
Abstract	Speeding is one of the risky driving behaviors. It affects every person on the road and causes property damage. This work investigated speeding violations and the factors that may affect them in the United States. Several factors related to driver, environment, vehicle, road, and weather were studied. Three types of machine learning algorithms were used; Random Forest (RF), Classification and Regression Tree (CART), and Multi-Layer Perceptron (MLP) were applied to predict speeding violations using Waikato Environment for Knowledge Analysis (WEKA) software. The analysis results indicated that age, accident year, road alignment, weather, accident time, and speed limits are the most influential factors. The algorithms' performance was examined using the evaluation metrics: accuracy, F-measure, Kappa statistic, Root Mean Squared Error (RMSE), Area Under Curve (AUC), and Receiver Operating Characteristic (ROC). The algorithms showed a good ability for analyzing and predicting speeding violations, especially the RF algorithm.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-23-00194
Paper Title	The Cost of Unhelmeted Motorcycle Injury: A Nation-Wide, Scoring-Based Analysis of Helmet Safety Legislation
Abstract	Motorcycle collisions comprise a large portion of motor vehicle injuries and fatalities. Unhelmeted riders have worse outcomes and generate billions of dollars in costs. Despite helmets having been shown to lower the risk of injury and death, legislation concerning helmet use varies widely across the US. In this study, we reviewed statutes to evaluate the stringency of helmet policies across the country using a legislative scoring system termed the Helmet Safety Score (HSS) ranging from 0-7 points, with higher scores denoting more stringent statutes. Regression modeling was used to predict unhelmeted mortality in all jurisdictions using our safety scores. The mean score across all jurisdictions was 4.73. We found that states with higher helmet safety scores generally had lower percentages of unhelmeted fatalities in terms of total fatalities as well as lower unhelmeted fatalities per 100,000 people and registered motorcycles. In contrast, some lower-scoring states had over 100 times more unhelmeted fatalities than higher-scoring states. Our helmet safety scores significantly predicted unhelmeted motorcycle fatalities per 100,000 people (β = -0.228 per 1-point HSS increase, $p < .0001$) and per 100,000 registered motorcycles (β = -6.17 per 1-point HSS increase, $p < .0001$). Aspects of our score concerning helmet exemptions for riders and motorcycle-type vehicles independently predicted fatalities ($p < .0001$). Universal helmet laws are an effective mechanism for maximally decreasing unhelmeted mortality. We advocate for a federal, universal helmet law to decrease motorcycle-related injury and fatality burden. In states with existing helmet laws, we advocate for elimination of exemptions.

Authors	Douglas Harwood, Harwood Road Safety LLC Zachary Hans, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-00217
Paper Title	Comparison of Safe System Assessment Methods
Abstract	This paper compares two methods for assessing the need for crash countermeasures based on safe system principles. These methods are the Road Assessment Program (RAP) methodology and the Australian safe system assessment framework (SSAF). Both methods were applied to the same set of rural roadways in North Carolina. Comparison of the results from applying the two methods show that both methods can be effective in identifying sites with potential need for crash reduction improvements. However, the SSAF scores do not appear to be useful in distinguishing between sites where the countermeasures identified with the RAP methodology have higher benefit cost-ratios and those with lower benefit-cost ratios. The results indicate that the SSAF method involves subjective judgements, and the ratings from the SSAF methodology may not be repeatable. The SSAF results are dependent on the expertise and interpretations of the individual safety professionals assigned to do the ratings. By contrast, the RAP methodology, while incorporating a few judgement-based ratings, is less subjective and more likely to repeatable. The SSAF results are useful to safety professionals as a guide for identifying countermeasures, while the RAP methodology provides additional output that identifies specific crash countermeasures and estimates their benefits, costs, and benefit-cost ratios. While its lack of repeatability is a limitation in its usefulness, the SSAF methodology appears to be a valuable tool in educating users about the nature of the safe system concept and showing how to understand and utilize safe system principles.

Authors	Ruchika Agarwala, Indian Institute of Technology, Bombay Vinod Vasudevan, University of Alaska, Anchorage
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-00482
Paper Title	Influence of Economic Growth on Traffic Safety in Developing Countries: Insights from Indian Household-Level Survey Data
Abstract	With the growth of the economy of a region, the vehicle ownership increases thereby improving mobility. While economic growth has historically been associated with increased mobility, its impact on traffic safety has not been studied in detail, especially in developing countries. In this study, the relationship between economic growth and traffic fatality is studied for a total of 27 states and union territories of India. Two separate models are developed, one in which all the regions are combined together and one in which the regions are grouped based on NSDP per capita. A new economic indicator, Monthly Per capita Consumption Expenditure is considered. Results obtained confirmed a positive relationship between economy and traffic fatality. However, contrasting results are obtained for the group-wise models. This study points to the importance of incorporating adequate infrastructure and other facilities to accommodate the increased number of vehicles due to economic growth in developing nations.

Authors	Michael Forrest, University of Southampton Shahram Heydari, University of Southampton
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-00526
Paper Title	Estimating the Effect of Proximity to School on Cyclist Injury Frequencies
Abstract	The safety of cyclists is a universal concern and identifying factors which affect the frequency of cycling injuries is crucial in understanding how to target interventions to improve cycling safety. Safety around schools is a particular point of concern and as such these locations are often the subject of safety interventions. However, it is difficult to estimate the impact of proximity to school on traffic safety due to an inherent endogeneity of the presence of a school which might be associated with safety (e.g., cyclist injury frequencies) and other site characteristics at the same time. This paper uses a simultaneous econometric approach to estimate the effect of proximity to a school on cyclist injuries at signalized intersections while accounting for endogeneity. It was found that a number of exposure and built environment factors had a significant association with cyclist injury frequency and the presence of schools at intersections. We found that the presence of a school was associated with an increase in cyclist injuries and this association was stronger when endogeneity was accounted for in the model, confirming the importance of considering endogeneity in studies of school safety interventions. This research offers policy implications based on the findings of the analysis including the need for safety interventions at intersections with high turning vehicle counts and those in proximity to public transport stops. A safety-in-numbers effect is also found for cyclists in the study area and period, suggesting that as volume increases the rate of injuries per cyclist decreases.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-00709
Paper Title	Strategies for Reducing Motorcyclist Injuries in Tennessee: Relevance of Evidence-Based Countermeasures That Work
Abstract	One of the recent issues in transportation safety is the rise in fatalities and severe injuries among motorcyclists. Since motorcyclists are far more vulnerable than enclosed vehicle users on the road, they are substantially more likely to be injured given a crash. While countermeasures against motorcycle crashes are available, this study aims to shorten the implementation cycle by thoroughly investigating motorcyclist injury severity, exploring flashpoint locations, and relating the findings from this study to countermeasures that are based on recent evidence from quality studies. According to recent motorcycle crash data (N=14,677) in Tennessee, 73.4% of motorcycle crashes resulted in rider injuries, with 5.1% causing fatalities. Statistical analysis with an ordered probit model reveals that improper use of a DOT-compliant helmet is associated with severer injuries, compared with properly wearing a DOT-compliant helmet. Not wearing a helmet and wearing a non-compliant helmet are also associated with higher injury risk, given a crash. Other injury risk factors include impaired riding and riding on undivided two-way roads. The provision of lighting in the dark could help mitigate the severity of motorcyclist injuries. High-frequency motorcycle crash flashpoints are located in large cities, but also on the Great Smoky Mountains National Park with tight curves and elevation changes. The findings from this study are a valuable reference to help prepare and apply evidence-based countermeasures that can deal with rider-related and environmental risk factors to prevent motorcyclist injuries in the future.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3062
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-00991
Paper Title	A Systemic Predictive Safety Analysis of Pedestrian Crashes for Montgomery County's Vision Zero Program
Abstract	The goal of Vision Zero is the prevention of all traffic fatalities and serious injuries. While traditional transportation planning has been reactive to locations where these serious crashes occur, some agencies are taking a more proactive approach to safety with the hopes that locations with high expected crashes can be improved before someone is seriously injured or killed. This paper presents the results of a systemic safety analysis that produced two pedestrian-related safety performance functions for Montgomery County, Maryland, including 1) motor vehicle crashes with pedestrians at intersections at night and 2) through-movement motor vehicle crashes with pedestrians traveling along segments. Both models identify key transportation-related exposure variables, including motor vehicle and pedestrian traffic volumes, proximity to transit, and crosswalk locations and also present land use contexts that may explain where pedestrians are likely to walk and be exposed to crash risks. These results build on the existing systemic safety literature and demonstrate the data collection and analysis methods that can be used in a Vision Zero context to improve safety for all who walk. This paper summarizes the analysis approach, including exposure modeling; developing crash models, and applying those models to identify both high-risk locations and potential mitigations. Considerations for equity and long-term planning are also discussed.

Authors	Meng Wang, University of Massachusetts, Amherst Brian Tefft, AAA Foundation for Traffic Safety
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-01013
Paper Title	Comparing Fatal Crashes in the United States During the COVID-19 Pandemic to Forecasts Based on Pre-Existing Trends
Abstract	After initial reductions early in the COVID-19 pandemic, traffic fatalities in the U.S. surged in 2020 to their highest levels in over a decade. The purpose of the current study was to quantify the involvement of specific crash, vehicle, and driver-related factors in fatal crashes during May-December 2020 relative to what would have been expected in the absence of the pandemic based on models of pre-existing trends. Data from all fatal crashes in the U.S. from January 1, 2011 through December 31, 2020 were used to develop Seasonal Autoregressive Integrated Moving Average models of monthly counts of fatal crashes through December 2019, which were used to forecast how many fatal crashes would have occurred in May-December 2020 had the pandemic not occurred. The main outcome measures were the difference and ratio of the actual versus forecasted counts. Separate models were developed for total fatal crashes and for categories of crash, vehicle, and driver factors. Total fatalities in May-December 2020 exceeded the forecast by 3,083 (12.1%). The increase was not uniform across factors examined. Actual counts exceeded forecasts by large amounts in both difference and ratio for late night/early morning crashes, single-vehicle crashes, speeding drivers, drivers aged 25-34, drivers with suspended/revoked/no license, drivers of vehicles registered to others, and vehicles 15+ years old. Crashes during hours 6-10AM and involvements of drivers aged 55+ were fewer than forecast. Results can inform deployment of countermeasures intended to slow or reverse the increase in traffic fatalities that occurred during the COVID-19 pandemic.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-01036
Paper Title	Exploring Common Attributes Between the Traffic Safety "Pandemic" and the COVID-19 Pandemic: A Global Macroscopic Analysis
Abstract	This paper aims to explore common attributes between two ongoing pandemics: the Covid-19 pandemic which onset on year 2020, and the traffic safety ‘pandemic’ which – although not formally declared as such – has a comparable burden of 1.35 million fatalities annually. For that purpose, we apply the SUNflower ‘pyramid’ for both causes of mortality, to link structural and socioeconomic indicators, exposure, policy and measures, as well as Key Performance Indicators (KPIs) of the operational level of risk, with the mortality rates due to both causes. Data for >100 countries are collected from international databases and other official sources, including indicators that correspond to each layer of the pyramid. Log-linear regression models are developed for the mortality rates and individual or composite variables of different layers. The results suggest that structural socioeconomic indicators such as GDP per capita, share of paved roads and ageing of the population play a key role in the outcomes of both pandemics. Moreover, exposure, either traffic (e.g. urbanization, vehicle fleet) or epidemiological (e.g. number of infections), taking explicit account of vulnerable populations, has a strong positive effect on both final outcomes. On the other hand, an opposite impact of measures and KPIs was found in the two pandemics: while traffic enforcement decreases traffic mortality, a higher government stringency index on Covid-19 measures increased covid19 mortality rate. This may be attributed to higher perceived urgency, lack of experience and more variability of the measures in the Covid-19 pandemic, possibly resulting in reactive rather than proactive management.

Authors	Yang-Jun Joo, Seoul National University Eui-Jin Kim, Seoul National University Dong-Kyu Kim, Seoul National University Peter Park, York University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-01106
Paper Title	A Risk Field-Based Approach for Driving Risk Assessment: Focusing on the Generalized and Real-Time Application
Abstract	This study provides a generalized method for assessing the driving risk encountered by on-road vehicles for driver support and automation systems design. To this end, this effort employs artificial field theory to unify longitudinal and lateral conflicts. We define any impediment to an ego vehicle as a finite scalar cost field modeled by the predictive occupancy of the impediment. Then the conflict field is formulated as a product of the cost field and the driver's risk field (DRF), which captures the driver's subjective risk perception so as to quantify the level of conflict. We verify the proposed method for three driving situations (i.e., car-following, yielding, and lane changing) using highway naturalistic driving data and show its relevance to the time to collision (TTC) and post encroachment time (PET). The risk sum derived from the conflict field quantitatively captures the risk profile of the situation and is generally consistent with PET. Further, the risk sum provides an interpretable basis to assess driving safety by decomposing the risk of each adjacent vehicle. Lastly, a sensitivity analysis was performed on the prediction model's performance to evaluate the effect of bias and variance on the LSTM-based model. The major innovative aspect of this study assesses the various types of conflict between adjacent vehicles individually, even in highly uncertain situations. The proposed driving risk assessment model can thus be used as a component of intelligent vehicle safety applications and as a unified multi-context conflict based safety measure to use for assessing traffic safety.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-01668
Paper Title	Safety Effectiveness Evaluation for Decreasing Speed Limits of Urban Areas
Abstract	This study develops a set of crash modification factors (CMFs) to evaluate the effects of lowering urban-road speed limits on vehicle and pedestrian safety. Cross-sectional methods and observation before-after methods are used to develop CMFs. In general, a CMF estimates the expected change in the frequency of crashes after specific countermeasures are applied on the road. In this study, the safety improvement effect in the section adjacent to the applied section, as well as the section for which the policy to lower the speed limit was applied, were evaluated. The results indicate that lowering the speed limit is effective in reducing the number of crashes. In particular, the CMFs for crashes involving serious injury and death are 0.6656 to 0.7804 in the application sections and 0.7979 to 0.8273 in the adjacent sections. This means that lowering the speed limit can reduce not only the number of crashes but also the occurrence of serious crashes. This study can be used to promote safety by analyzing the effect of the policy to lower the speed limits in the future and can be applied to the evaluation of the effectiveness of various safety policies in cities.

Authors	Nazmus Sakib, Ahsanullah University of Science and Technology Tonmoy Paul, Ahsanullah University of Science and Technology Md Tawkir Ahmed, Tongji University Khondhaker Al Momin, University of Oklahoma Md Rakibul Islam, University of Central Florida Ling Wang, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-01889
Paper Title	Evaluating University Students' Safety Behavior on Three-Wheel Electric Rickshaw
Abstract	Three-wheel electric rickshaw (TWER) is an environmental-friendly and energy-efficient mobility option which have gained popularity in recent times. However, the increasing number of TWERs has led to serious concerns about the safety behavior of the passengers. This study is the first research exploring the safety behavior on TWER for university students in Bangladesh. This study synthesizes the theoretical insights from the Theory of Planned Behavior (TPB), Awareness Interest Desire Action (AIDA), and Health Belief Model (HBM) to identify the factors influencing users' safety behavior. Structural equation modeling (SEM) and Bayesian structural equation modeling (BSEM) were used to investigate the safety perception of 798 participants from 5 universities in Gazipur. The two alternative statistical models are used for comparison between results and suggestions for future use. Results reveal safety behavior is directly influenced by perceived severity and perceived susceptibility furthermore safety awareness has a positive significance on the perceived severity and susceptibility of harm related to unsafe behavior. Hence, users' safety behavior is considered indirectly influenced by safety awareness which is further affected only by their attitude. Based on the model fitness and result, BSEM performs better than SEM. This research concludes by discussing implications for transportation planners and policymakers to enhance TWER safety on road.

Authors	Fahmid Hossain, McMahon Associates, Inc. Juan Medina, University of Utah
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	23-02091
Paper Title	Calibration of Segment-Level Risk Assessments from usRAP – A Methodology for Systemic Analysis Tools
Abstract	The United States Road Assessment Program (usRAP) provides a systemic approach to estimate the risk of severe injury and fatal crashes along roadway segments based on expected safety performance dictated by roadway and roadside characteristics. As the adoption of usRAP grows in the U.S., calibration of the methodology and proposed risk assessments is of significant value, not only to identify strengths and limitations within the U.S. context, but also to consolidate usRAP as an additional tool available to roadway agencies. This paper demonstrates a methodology suitable to calibrate the usRAP risk assessment formulation when analyzing non-intersection crashes, including run-off road and head-on crashes. The analysis focuses on the interactions between contributing factors, which by default in usRAP are multiplicative factors with the same weight in the overall crash risk formulation. Relaxation of the functional form to allow for different interactions indicates potential improvements in the risk estimation to match long-term safety performance observed in the field. The methodology presented in this paper opens possibilities for calibration to local conditions beyond those offered by the original usRAP methodology, and is suitable to calibrate other systemic safety analysis tools.

Authors	Raul Pineda-Mendez, Purdue University Qiming Guo, Purdue University Andrew Tarko, Purdue University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-02170
Paper Title	Risk-Based Highway Safety Management Systems: A Case Study for Rural Interstate Freeways in Indiana
Abstract	In highway safety management, road hazards are methodically identified and reduced to reflect a lower crash frequency and diminish the severity of crash-related injuries. For this purpose, aggregate count-based crash models, e.g., safety performance functions, have been widely adopted in engineering practice. This study evaluates the potential use of disaggregate safety analysis combined with emerging high-resolution data sources to supplement conventional count-based crash models used by safety management systems. A methodology is proposed to identify and assess time-dependent safety issues such as weather conditions and operational speed characteristics, which are typically omitted in traditional safety management systems. This methodology is illustrated in a case study on rural interstate freeways in Indiana. In addition to fixed safety factors, the effect of time-dependent variables on the hourly crash probability and injury severity is estimated. For this purpose, a sequential binary logit model with random effects was used to assess the impact of multiple contributing factors on crash occurrence and injury severity. Results from the sequential binary mixed logit model are then used to illustrate a group of analytical safety dashboards for implementing risk-based safety management. Finally, other applications in various highway safety management tasks are discussed.

Authors	Haniyeh Ghomi, McMaster University Mohamed Hussein, McMaster University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-02224
Paper Title	A Joint Effectiveness Evaluation of Toronto's Vision Zero Strategies: A Time-Series Analysis and Copula-based Model
Abstract	The current study proposed an integrated time-series modeling technique and a copula-based model to evaluate the safety benefits of multiple safety treatments implemented in the City of Toronto as part of the city's Vision Zero commitments. In this regard, the Vision Zero Mapping Tool was utilized to obtain the pedestrian-vehicle collision records that occurred in the City of Toronto between 2017 and 2020, along with the implemented safety treatments. The City of Toronto was divided into 158 neighborhoods. Fatal and serious injury pedestrian collisions and the density of the different safety treatments were aggregated to the neighborhood level. First, the proposed time-series technique, Bayesian Vector Autoregressive (BVAR), was employed in each neighborhood to investigate the safety impacts of the selected safety measures over the analyzed period. The model results showed that leading pedestrian intervals and speed limit reduction were among the most effective treatments implemented in the city. However, the results also showed that the effects of the treatments can vary between neighborhoods. As such, a copula-based negative binomial model was developed for each countermeasure in order to investigate the association between the neighborhood characteristics and the treatment performance. The results of the copula models demonstrated an association between the performance of the implemented safety treatments and a wide range of neighborhood characteristics, including built-environment factors, land use, and road network characteristics.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-02299
Paper Title	Analysis of Intelligent Vehicle Technologies to Improve Vulnerable Road User Safety from Cars and Trucks in Urban Areas
Abstract	As advanced vehicle technologies become available, we have more reliable solutions to improve the safety of all traffic agents, especially vulnerable road users (VRUs). We need to know how these Intelligent Vehicle Technologies (IVTs) can improve VRU safety in different environments and conditions (e.g., sight distance and traffic flows) at signalized intersections. However, there are limited studies on technical and operational differences between these various IVTs, and on technology adoption rates for safety improvement. To address these knowledge gaps, this study first develops a simulation model to mirror real-world driver/VRU perception limitations and then implements four IVTs in micro-level traffic simulations. According to the simulation results, Intersection Safety (INS) is the most efficient technology amongst the four studied IVTs to reduce average collision counts for passenger cars and trucks under seven predefined collision types involving VRUs and vehicles. Blind Spot Detection (BSD) has the most minimal effects on those types. The safety improvement of VRU Beacon Systems (VBS) and Bicycle/Pedestrian to Vehicle Communication (BPTV) are between INS and BSD. More importantly, results indicate that IVTs can significantly reduce the collision probability when sight distance is under a threshold and also improve safety under good sight conditions if collisions happen right in front of vehicles. Additionally, this research conducts a sensitive analysis of traffic volume. For some collision types, INS and BPTV can even reduce approximately 50% of collisions when traffic volume is extremely high.

Authors	Yaxin Wu, Harbin Institute of Technology Xiaofeng Ji, Kunming University of Science and Technology Xiaowei Hu, Harbin Institute of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-02386
Paper Title	Exploring the Associations between Built Environment and the Traffic Accident Risk of Children in School Commuting
Abstract	Understanding how built environment attributes are associated with traffic accident risk in school commuting is essential for planners to improving school travel safety through land use and transportation policies. The measurement model of accident scale was conducted to quantify accident risk in school commuting. This study established three models, spatial Durbin model (SDM), geographically weighted regression (GWR) and multi-scale geographically weighted regression (MGWR), to analyze the influence direction, degree and path of the built environment on traffic accident risk in school commuting at different school/scale/time windows. The results show that the accident scale can represent the traffic accident risk in school commuting accurately. The built environment within the 200-meter buffer has a more significant impact on the traffic accident risk in school commuting. With the increase of grades, the key built environment variables affecting the risk of school traffic accidents increased: secondary (9) > primary (7) > preschool (6). Only the road network density and educational facilities density have a significant impact on the traffic accident risk in any school, the former is positively correlated. The built environment factors that affect the traffic accident risk of secondary school mainly include 6 factors of traffic system and school factors, especially the traffic system factors account for the largest proportion (66.67%). There are 4 key built environment factors that affect the traffic accident risk of secondary school in leaving school, 50% of which belong to school factors. These findings offer nuanced guidance for transit-oriented school site selection street planning and neighborhood planning.

Authors	Nada Mahmoud, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Amr Abdelraouf, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-02447
Paper Title	The Impact of Target Speed on Pedestrian, Bike, and Speeding Crash Frequency
Abstract	This research aims to investigate the influence of adopting the target speed concept on different types of crashes including pedestrian, bike, and speeding related crashes. The Target speed is the highest speed that vehicles should operate on a roadway segment in a specific context. Based on the reviewed literature, this is the first study to investigate the relationship between target speed and crash frequency. Hence, big data including probe-vehicle data, traffic characteristics, geometric features, and land use attributes were utilized to develop crash prediction models. The main contributions of this research are to quantify the impacts of target speed on traffic safety considering context categories and to conclude the potential recommendations to lower different types of crash. The 85th percentile speed was calculated and utilized in the developed models. Three crash prediction models were developed for pedestrian, bike, and speeding related crashes. They were used in the analysis to quantify the impact of adopting target speed on different crash types. The results showed a significant reduction in the three crash types when using the target speed. Most of the improvements took place in three context categories: C3C-Suburban Commercial, C3R-Suburban Residential, and C4-Urban General. Hence, this research recommends adopting target speed specifically in urban and suburban areas. Further, it suggests considering some measures to lower vulnerable road users' and speeding related crashes. Following the recommendations of this research would help to reduce different types of crash frequency, hence, improve the mobility and safety for all users in different context classifications.

Authors	Yaobang Gong, University of Utah Pan Lu, North Dakota State University Xianfeng Yang, University of Maryland, College Park
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-02610
Paper Title	Investigating the Impact of COVID-19 on Traffic Safety: From "Lockdown" to the "New Normal"
Abstract	COVID-19 pandemic has placed pronounced and prolonged impacts on traffic safety. Many studies found the crash frequency reduced but the severity level increased during the earlier "Lockdown" period. However, there is a lack of studies investigating the pandemic's impact on traffic safety during the later stage of the pandemic. Therefore, this study employs statistical methods to investigate whether the impact of COVID-19 on traffic safety differs during the different stages. Pairwise t-tests were conducted to compare the crash frequency and crash severity levels before, during the earlier stage, and the later stage of the pandemic. Negative binomial models and binary logit models were utilized to study the effects of the pandemic on the crash frequency and severity respectively while accounting for the exposure, environmental and human factors. The results show that the crash frequency is significantly less than that of the pre-pandemic during the whole course of the pandemic. However, it significantly increases during the later stage due to the relaxed restrictions and possibly drivers' behavioral changes. Crash severity levels increased during the earlier pandemic due to the prevalence of risky driving behavior and increased presence of commercial vehicles, but it reduced to a level comparable to the pre-pandemic later. Statistical models show that the impacts of the pandemic on drivers' behavior are decaying, leading to the insignificance of all pandemic quantifiers during the later stage of the pandemic when accounting for the exposure, weather, and economic factors.

Authors	Qiangqiang Shangguan, Tongji University Jessica Keung, University of Waterloo Liping Fu, University of Waterloo Lana Samara, Transoft Solutions, Inc. Junhua Wang, Tongji University Ting Fu, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3062
Session Title	Paper Awards: Transportation Safety Management Systems
Paper Number	23-02767
Paper Title	Do Traffic Countermeasures Improve the Safety of Vulnerable Road Users at Signalized Intersections? A Combination of Case-control and Cross-sectional Studies Using Video-based Trajectory Data and Surrogate Measures of Safety
Abstract	Driven by the vision to eliminate road fatalities, Vision Zero initiatives have been widely adopted by many cities around the world, with significant investments of resources in various safety programs and countermeasures. However, there is still a lack of reliable quantitative evidence on the effectiveness of those countermeasures and their relation to various external factors. This research attempts to address this challenge with a combination of case-control and cross-sectional studies, aiming at quantifying the safety effects of three commonly applied Vision Zero countermeasures, namely, Leading Pedestrian Interval (LPI), No Right Turn On Red (NRTOR), and installation of a dedicated Bicycle Lane (BL). A case study was conducted using video trajectory data from ten signalized intersections in the City of Toronto. The traffic interactions between vehicles and vulnerable road users (VRUs) were extracted using a video data processing platform and two surrogate measures of safety, including post-encroachment time (PET) and conflict speed, were obtained and then used to classify the conflict severity into different levels. A comparative analysis using mixed-effects negative binomial regression was conducted to quantify the impacts of different treatments on the frequency of traffic conflicts under specific road weather and traffic conditions. The results show that these three types of traffic countermeasures can effectively reduce the frequency of high-risk and moderate-risk traffic conflicts, moderated by various, traffic exposure, weather and environmental conditions, and accessible pedestrian signals (APS). These findings could help road safety engineers and decision makers make better informed decisions on their road safety initiatives and projects.

Authors	Reza Aminghafouri, University of Waterloo Liping Fu, University of Waterloo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	23-02844
Paper Title	A Joint Confidence Region Approach to Ranking Hotspot Locations Considering Uncertainty in the Expected Risk Estimates
Abstract	Network screening or crash hotspots identification is an essential task of all road safety improvement programs. The most common approach to network screening is to use statistical models to predict the expected risk at the locations of interest and then rank them on the basis of the predicted risk. The predicted risk used for ranking is mostly in the form of point estimates without any consideration of the inherent uncertainty with the estimates, which could lead to identifying a wrong list of crash hotspots. This study aims to fill this research gap by employing a frequentist approach to finding a joint confidence region of risk for ranking of locations and identification of hotspots. A case study on three-legged stop-controlled intersections in Kitchener, Ontario, is conducted to illustrate the proposed approach. Crash risk is modeled using a combination of a hierarchical full Bayesian negative binomial model and a multinominal Logit model, which are then used to estimate the 95% confidence interval of the expected risk. For each location, the confidence region of rankings is obtained on the basis of the expected risk estimates. The results show that considering uncertainty in the crash hotspots identification process can lead to varied ranking positions with different probabilities since the true value of its estimated crash risk follows a distribution.

Authors	Mohammad Razaur Rahman Shaon, University of Connecticut Shanshan Zhao, University of Connecticut Kai Wang, University of Connecticut Eric Jackson, Connecticut Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3010
Session Title	Moving Safety Research into Practice
Paper Number	23-02861
Paper Title	Developing a Data-Driven Network Screening Procedure for Systemic Safety Approach
Abstract	Systemic analysis is considered an important safety analysis approach that is complementary to the Highway Safety Manual hotspot analysis. The network screening step in systemic analysis is to identify sites with characteristics that are associated with the highest risks. Traditionally, determining the risk scores involve subjective criteria. This research aims to develop a data-driven approach to replace the subjective method used in the past. To obtain the research objective, this study collected roadway and crash data from the Connecticut Department of Transportation. A data-driven crash risk factor categorization methodology was proposed to accurately estimate the performance measures indicating crash risks. Moreover, this study proposed and compared four different risk-scoring matrices to identify an optimal risk-scoring method that attunes with the principles of the systemic approach to safety as well as provides additional insights on justifying the systemic safety analysis results. The proposed methodology was implemented to conduct network screening for severe roadway departure crashes and later validated using severe aggressive driving related crashes. Risk-based network screening results indicated that risk scores derived from normalized crash over-representation provide additional emphasis on sites with low traffic volume that are associated with high severe crash counts. The highest modified crash rate was obtained using normalized overrepresentation based risk scores indicating the proposed network screening methodology can not only identify roadway attributes that are correlated with severe crashes but also account for low-volume roadway sites with severe crashes. The validation analysis indicated proposed method is transferrable to different emphasis areas.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03087
Paper Title	Do transportation network companies increase or decrease road crashes? Evidence from San Francisco
Abstract	In just one decade, ride hailing or Transportation Network Companies (TNCs) have revolutionized how people commute. While their impact on urban mobility, including car ownership, transit usage, and congestion, is well established, their effect on road crashes, even after many scholarly articles, is yet to be firmly ascertained. Our study aims to fill this literature gap by analyzing the impact of TNC operations on various road crash types, including total crashes, fatal and injuries, pedestrian & bicyclist, and alcohol involved road crashes. Set in San Francisco County, our study compares the YR 2016 traffic flows containing TNC trip estimates to the traffic flows for the YR 2010, where they did not exist. We use panel data regression models with fixed effects to examine whether TNC service operations are associated with road crash outcomes. Our results suggest that the association between TNC parameters and most road crash types is statistically insignificant. Except for fatal and injury crashes where each 1% additional TNC Vehicle Miles Travel decreases the road crashes occurrence by 9%. However, for the same crash type, TNC-related pick-up and drop-off instances (PUDO) result in a 7% increase in road crashes within San Francisco County. Our findings provide means to understand the direct impact of TNCs on road safety and allows city planners to rationally set policy measures to achieve the goals of safer streets and safer mobility in their respective regions.

Authors	Shaunna Burbidge, Avenue Consultants
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03111
Paper Title	Gauging the Effectiveness of Safe Routes to School Projects
Abstract	Walking to school, which was once a commonplace rite of passage, now makes up only a small minority of school trips. Multiple studies have shown that concerns are strongly linked to the physical environment that exists between home and school. Over the past decade, hundreds of projects have been funded through the Utah Safe Routes to School and Safe Sidewalk programs, however, there is currently no mechanism in place to determine how effective these projects have been at promoting safety because in most cases, once a project is funded and constructed no follow-up evaluation is conducted. This research evaluated past projects to determine which project types are the most effective at promoting safety by reviewing infrastructure projects funded under the programs and evaluating non-motorized crashes within a one-mile buffer of the project site before and after the infrastructure was put in place. The analysis found no statistical change in the number of non-motorized crashes before and after construction. The probability of minor injury non-motorized crashes increased after construction, likely due to increased volumes and exposure. Crashes occurring in wet or snowy weather were less severe, and a majority of severe injury crashes occurred during the day. Bicycle crashes resulted in less severe injuries than pedestrian crashes and were less common after construction. Future research should include volumes for both non-motorist and vehicle traffic.

Authors	Ennis Marshall, University of Maine Mohammadali Shirazi, University of Maine Amirhossein Shahlaeegilan, University of Maine John Ivan, University of Connecticut
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03136
Paper Title	Leveraging Probe Data to Model Speeding on Limited Access Highway Segments During the COVID-19 Pandemic
Abstract	Stay-at-home orders - imposed during the COVID-19 pandemic - drastically reduced traffic volumes. Despite this, the rate of fatal and serious injury crashes increased significantly across the United States due to increased speeding on roads with less traffic congestion and speed enforcement. This paper uses a mixed effect binomial regression model to investigate the impact of the lockdown on the odds of speeding for urban limited access highways in Maine and Connecticut. This paper also establishes a link between traffic density (vehicles/mile) and the odds of speeding. Hourly speed and volume probe data were collected on relevant highway segments in Maine and Connecticut to estimate traffic density. Density was combined with roadway geometric characteristics, speed limit, and dummy variables denoting the time of the week, time of the day, and COVID-19 phases (before, during and after stay-at-home order), and the interactions between them. Modeled as Level of Service, density, was found to be associated with the odds of speeding, with better levels of service, resulting in higher odds of speeding. Furthermore, we found that during the stay-at-home order, the odds of speeding by more than 10, 15, and 20 mph increased respectively by 54%, 71% and 85% in Connecticut, and by 15%, 36%, and 65% in Maine during evening peak hours. Additionally, one year after the pandemic started, during evening peak hours, the odds of speeding greater than 10, 15, and 20 mph were still 34%, 29%, and 19% greater in Connecticut and 35% 35% and 20% greater in Maine.

Authors	Subasish Das, Texas State University Ali Khodadadi, Texas A&M University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	23-03152
Paper Title	Short-duration Crash Modeling to Understand Impact of Operating Speed on Freeway Crashes during COVID-19
Abstract	Gaining an understanding of speed-crash relationships is a critical issue in highway safety research. Due to the ongoing pandemic (COVID-19) there has been a reduction in traffic volume, and some early studies explain that speeding in an environment with less traffic is associated with a high number of crashes, especially fatal and serious injury crashes. This study aims to shed light on this issue. The study conflated several databases (speed data, roadway inventory data, and crash data) that contain data from Dallas, Texas, spanning from 2018 to 2020, in order to examine the speed-crash association. Using the Negative Binomial Lindley regression model, this study showed that the trends of crash prediction models vary over the years (2018, 2019, and 2020) by different injury severity levels (i.e., fatal crashes, fatal and incapacitating injury crashes). The 2020 models show that operating speed measures (i.e., average operating speed) have a significant impact on crash frequencies. The magnitudes of the speed measures show variations across the models at different injury severity levels.

Authors	Robert Schneider, University of Wisconsin, Milwaukee Josie Willman, Civiltech Engineering, Inc. Stephen Hargarten, Medical College of Wisconsin
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3062
Session Title	Paper Awards: Transportation Safety Management Systems
Paper Number	23-03154
Paper Title	Linking Police and EMS Records: An Approach to Strengthen Bicyclist Injury Reporting
Abstract	Bicyclist injuries are underreported in police crash databases. We explored the value of linking police-reported crash data with emergency medical services (EMS) data within the City of Milwaukee, Wisconsin. Using data from 2014 to 2016, we linked records by inspection (identical date, similar time of day, and similar roadway location) and found 154 matching records between the two databases (representing 41% of the 375 police crash records and 44% of the 348 EMS injury records). Matched records were more likely to involve fatal and severe injuries according to police-assessed injury ratings. The two datasets also provided different insights into bicyclist injury crashes. Injuries captured only by police reports were significantly more likely than injuries captured only by EMS to be along high-traffic streets and commercial districts and significantly less likely to be near parks. Nearly all police records described driver and bicyclist movements (e.g., turning) and operating behaviors (e.g., failure to yield) that contributed to the crash. In addition to capturing more bicyclist injury events, EMS records revealed additional information about their causes. 23% of EMS narratives described falls. These falls involved intoxication, striking a curb, swerving to avoid automobiles or other bicyclists, doing tricks, and getting a tire caught in rail tracks. Another 11% described bicyclists striking objects, including a bus stop shelter, stop sign, fire hydrant, and fence. While there are strengths and limitations to both datasets, linking police-reported crashes with EMS records produced a broader understanding of bicyclist injuries.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03296
Paper Title	Identifying the key attributes of high-risk drivers in Canada and investigating their attitude toward traffic safety laws
Abstract	An investigation of risky driving groups on Canadian roads is conducted using self-reported number of accidents and demerit points data (Case 1), and self-reported driver behavior (Case 2) data collected using an online survey. Identification and prediction of high-risk drivers will significantly assist in the development of proactive driver education programs and safety countermeasures. The objectives of this study are twofold: (1) to predict high-risk drivers based on driver attributes, and (2) to identify the factors responsible for determining whether individuals accept additional traffic safety laws. The following multivariate analyses are performed in stages: k-means clustering for categorizing "high-risk" and "low-risk" drivers, factor analysis using EFA and CFA to aggregate safety laws into three factors “speeding", "distracted and intoxicated driving", and "red-light violation", and logistic regression to determine if driver characteristics are associated with risky driving groups and the level of support or opposition to these laws. Conclusions are as follows: (1) Driver’s region of residence in Canada contributes significantly to high-risk driver classification in Case 1 due to high levels of variation in individual driving laws and traffic rules set differently by each province, (2) In Case 2, driving frequency influences exposure to varied traffic conditions and contributes significantly to high-risk driver classification, (3) High-risk drivers in Case 1 are less likely to support traffic laws aimed at combating distracted and intoxicated driving, while high-risk drivers in Case 2 are more likely to support speeding laws, and older drivers are more likely to support red-light violations.

Authors	Flavius Matata, Florida International University Jimoku Salum, Florida International University Priyanka Alluri, Florida International University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03379
Paper Title	Exploring the Choice of Sliding Window Parameters for Identifying Hazardous Roadway Segments
Abstract	A sliding window is one of the three principal network screening methods. Although the methods for segment screening vary depending on the crash data, the sliding window ensures reliable results. The main objective of conducting a sliding window is to identify the hotspot's correct position (begin and endpoints). This study determined the optimal set of sliding window parameters by conducting a sensitivity analysis. The analysis was conducted considering the variation in the built environment (i.e., context class). The 0.1 mi and 0.5 mi were the shortest and longest window lengths, respectively. The optimal sets were chosen based on the value of crashes per mile, a ratio of excess expected average crash frequency to the window length. The higher the value, the more reliable the results. The decrease in window length was observed to be proportional to an increase in the value of crashes per mile. At a 95% confidence level, the Mann-Kendall trend tests indicated the observed trend is significant. For context classes, C1 and C2, a set with a window length of 0.2 mi and an increment length of 0.05 mi was the optimal set for all performance measures used. For C2T through C6 context classes, the optimal set had a window length of 0.1 mi and an increment length of 0.05 mi. The findings could be beneficial to transportation agencies in conducting safety analyses of their transportation networks.

Authors	Runsheng Xu, University of California, Los Angeles Shibo Zhang, Northwestern University Peixi Xiong, Northwestern University Allen Lin, Northwestern University Jiaqi Ma, University of California, Los Angeles
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03541
Paper Title	Towards Better Driver Safety: Empowering Personal Navigation Technologies with Road Safety Awareness 3 4
Abstract	Recent research has found that navigation systems usually assume that all roads are equally safe, directing drivers to dangerous routes, which led to catastrophic consequences. To address this problem, this paper aims to begin the process of adding road safety awareness to navigation systems. To do so, we first created a definition for road safety that navigation systems can easily understand by adapting well-established safety standards from transportation studies. Based on this road safety definition, we then developed a machine learning-based road safety classifier that predicts the safety level for road segments using a diverse feature set constructed only from publicly available geographic data. Evaluations in four different countries show that our road safety classifier achieves satisfactory performance. Finally, we discuss the factors to consider when extending our road safety classifier to other regions and potential new safety designs enabled by our road safety predictions.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3097
Session Title	TRB Minority Student Fellows Poster Session
Paper Number	23-03588
Paper Title	Invited Student Paper Identifying Safest Complete Street Design: A Driving Simulator
Abstract	The traditional U.S. roads are poorly designed and do not offer safe places to walk, bike, or take public transportation. This study tried to develop an efficient Complete Street (C.S.) based on the interactions among different transport modes across different population segments. This study evaluated the safety of a C.S. by simulating the interactions among bikes, cars, and transit using full-size driving and bike simulators. Participants from the different socio-demographic groups were recruited to drive the car and ride the bicycle. The results found that the effectiveness of the various road layouts strongly depends on the type of barrier applied to the road pavement to separate the car lane from the bike lane. Lateral distance analysis also revealed that most drivers increased their lateral distances with the integrated bikes when passing through them.

Authors	Chunwu Zhu, Texas A&M University, College Station Bahar Dadashova, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03617
Paper Title	Investigation on the Driver-Victim Pairs in Pedestrian and Bicyclist Crashes by Latent Class Clustering and Random Forest Algorithm
Abstract	Both driver and pedestrian/bicyclist play an important part in the occurrence of a roadway crash, while the existing literature tend to investigate the crashes from one party. Drivers and victims from similar socioeconomic backgrounds might be more likely to involved in a crash due to the similarity in their traveling behavior and proximity of residence. To find the crash patterns within the pairs of driver and victim, we employed a probability-based latent class cluster analysis on the income and ethnicity of both driver and victim and random forest algorithm to model the contributing factors to the crash patterns from crash specific information, driver's and victim's socioeconomic profile, road infrastructure, and traffic exposure. Results of the pedestrian and bicyclist crashes in Harris County, Texas, show that lower income and non-White drivers tend to be involved with lower income and non-White victims, while high income and white drivers tend to be involved with higher income and white victims in both pedestrian and bicyclist crashes. The most influential factors in determining this crash patterns include pedestrian/bicyclist exposure, driver's age, victim's age, car used year, AADT, speed limit, road width, and lane width. Crashes of lower income and non-White driver-victim pairs are more likely to happen on the road with higher traffic exposure, speed limit and road width.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	23-03670
Paper Title	Risk Perception of Vehicle-to-vehicle Vendors and General Pedestrians: A Comparative Study
Abstract	Pedestrians account for 65 percent of all traffic fatalities worldwide. A sub-category of pedestrians is vehicle-to-vehicle vendors, who pose a concern to countries with growing infrastructure. For example, 70 percent of traffic fatalities in Nigeria involve general pedestrians and vendors. Previous studies have highlighted vendors' heterogeneous road crossing and car-following demeanors. Furthermore, they create a nuisance for general pedestrians. This study contrasts the risk perception of vehicle-to-vehicle vendors and general pedestrians and analyzes vendors' grouped and ungrouped illegal crossings. A questionnaire survey was developed based on literature review and expert knowledge for extracting variables associated with risk perception. Interviews based on a questionnaire were conducted in various locations in Dhaka city to collect 1,019 responses. This procedure collected information on their demographic attributes, risk perception, aggressive behavior, near-crash experiences, and accepted yielding distances. Next, ordinal logit/probit and complementary log-log models were used to analyze the data. The findings revealed vehicle-to-vehicle vendors had a lower risk perception compared to general pedestrians. It also indicated that vendors would take a higher risk than general pedestrians. Furthermore, vendors jaywalking alone had a significantly lower perception of risk. Finally, "Gender", "Age", "Education", "Accepted Yielding Distance" and "Aggressive Behavior" were the most prominent factors affecting vendors' risk perception. Gradually separating vendors from the traffic system by shifting them to proper street markets could be a critical solution.

Authors	Yukun Song, Auburn University Huaguo Zhou, Auburn University Qing Chang, Auburn University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3062
Session Title	Paper Awards: Transportation Safety Management Systems
Paper Number	23-03753
Paper Title	Trends and Odds of Wrong-Way Driving Fatal Crashes on Freeways from 2004 to 2020 in the United States
Abstract	The purpose of this study is to conduct a comprehensive analysis of the trends, distribution, and odds of wrong-way driving (WWD) fatal crashes on divided highways in the United States. The study extracted 17 years (2004–2020) of WWD fatal crash data from the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) database. The descriptive statistical analysis was conducted to reveal general crash characteristics and update the national trends in WWD fatal crashes. The results showed that an average of 302 WWD fatal crashes occurred annually on divided highways in the United States, which resulted in a total of 6,953 fatalities during the 17 years. The number of WWD fatal crashes on divided highways remained steady with a slight increase over the years. The second part of the study was to compute the odds between WWD fatal crashes and other fatal crashes to identify factors contributing to those WWD fatal crashes. Odds ratios were computed based on a binomial logistic regression model. The significant contributing factors identified by the odds ratios include temporal variables, crash characteristics, and driver characteristics.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3010
Session Title	Moving Safety Research into Practice
Paper Number	23-03875
Paper Title	Developing an Automation Tool for Highway Safety Project Prioritization
Abstract	Transportation planning agencies need to prioritize highway safety improvement projects among a pool of proposed ones to better allocate the limited funds. In recent times, several states in the US use Excess Expected Crashes (EEC), a parameter dependent on Safety Performance Functions for ranking safety projects. However, this approach comes with several methodological limitations (e.g., the severity of the observed crashes and the magnitude of the projected crashes by the Empirical Bayes (EB) method are not considered). In 2022, Kentucky Transportation Cabinet (KYTC) developed and adopted a modified safety project scoring method for its Strategic Highway Investment Formula for Tomorrow (SHIFT) project prioritization process. This method considers crash severity and combines EB estimates and a “goal-driven” EEC metric in a multifactor score. Nonetheless, calculating a safety score for each project is a time and labor-intensive process. This paper presents an open-source automation tool that can streamline this process with better efficiency and produces insights that would help to make robust decisions. This automation tool has been tested on the KYTC’s list of potential SHIFT projects for the 2022 cycle. The source code is hosted in a public repository on GitHub which is easily accessible and customizable for a variety of potential uses.

Authors	Pei Li, UW Madison: University of Wisconsin Madison
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-03952
Paper Title	Exploring Latent Topics from Autonomous Vehicles Crashes and Analyzing Their Relationships with Crash Metadata
Abstract	Autonomous vehicles (AVs) are expected to bring huge benefits to society, while safety is one of the most important factors. However, existing AVs are not crash-free yet. AV crashes may have undiscovered patterns which differentiate them from conventional crashes that involved normal vehicles. This study analyzed real-world AV crash data in California by exploring latent topics among AV crashes. The structural topic model (STM) was used in this study as it allows the consideration of metadata (i.e., the type, severity, and year of crashes) while developing the model. In total, 20 topics have been identified from the AV crash data, which can be divided into behavior-based, party-based, location-based, and general topics. The extracted topics are closely related to crash metadata. For example, the topic that contains rear and bumper has a high proportion in rear-end crashes. The topic that describes lane-changing behaviors has a high proportion in sideswipe crashes. Results from this study suggest that several important aspects need to be considered by AV manufacturers to improve AV safety, including interactions between AVs and vulnerable road users, AV's operation while driving near stop signs, and AVs' ability to handle turning and lane-changing behaviors.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	23-03990
Paper Title	Using Traffic Signal Progression Strategy for Speed Management and Decreasing Pedestrian and Bicycle Fatalities and Severe Injuries
Abstract	Increases in travel speed can raise the severity of pedestrian and bicycle crashes. Speed control has been identified as an important treatment to prevent crashes involving vulnerable roadway users. Traffic signal progression can be used as an effective speed management strategy to reduce pedestrian fatalities and severe injuries. Although this strategy is frequently used on urban arterials to favor high progression speeds and improve mobility, it can also be used to reduce the risk of pedestrians and bicyclists being struck and killed by motor vehicles. Application of progression speed management on urban arterials are limited across the U.S. despite its greater potential. This study assessed the efficiency of three countermeasures—progression speed, progression speed management, and progression quality—for reducing severe pedestrian and bicycle crashes. A random parameter negative binomial model and Crash Modification Factors (CMFs) were developed using cross-sectional designs. Findings revealed that good progression speed management and progression quality (smooth traffic flow) can reduce the number of severe injuries and fatalities. They also show the benefits of appropriate signal design focused on both safety and mobility. Higher progression speed does not necessarily induce pedestrian and bicycle fatalities and serious injuries when signals are timed and designed properly with good progression speed management and good progression quality. Lower progression speeds are not necessarily the key to pedestrian and bicycle safety, specifically when large speed differentials exist among vehicles. Exposure levels can also affect the safety of pedestrians and bicyclists.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04006
Paper Title	Safety in Higher Level Automated Vehicles: Investigating Edge Cases in Crashes of Vehicles Equipped with Automated Driving Systems
Abstract	With emerging Automated Driving Systems (ADS) representing high automation levels (SAE Levels 3 or 4), several Automated Vehicle (AV) manufacturers are testing their vehicles nationwide on public roadways. The safety performance of these vehicles has become a major concern for the transportation safety industry. In recent years, several ADS crashes have been reported to the National Highway Traffic Safety Administration. Scrutinizing such crashes can reveal rare circumstances called “edge cases” where unusual AV crashes occurred. Identifying edge cases among ADS crashes helps AV companies prepare AVs to avoid such crashes and, as such, enhance safety. To this end, first, an unsupervised machine learning technique, K-means clustering, is used to cluster the crashes. Second, the observations on each edge cluster are ranked based on the critical or rare events, and the highest one (the most unusual crash) is selected as an edge case. Statistics show that 53% of ADS crashes occurred at intersections, and 82% were noninjury crashes. The most frequent ADS crash type was rear-end accidents in which conventional vehicles were proceeding straight while AVs stopped on the roadway. The identified edge cases show that different factors such as unmarked roads, problematic traffic signs, road debris (e.g., tire debris), slippery road surface, traffic spikes, and speed bumps can result in edge case crashes. In addition, in most of the edge case crashes, AVs made contact with heavy vehicles. While most AV crashes happened at intersections, most critical accidents happened in other locations, such as traffic circles, parking lots, and streets.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04009
Paper Title	Multivariate Analysis of Road Safety Policies in Brazilian Cities based on The Safe System Approach
Abstract	The globally accepted best-practice approach to addressing the road safety crisis is the Safe System approach. This strategy consists of a system of key actions working together to eliminate death and serious injury. Evidence-based information is required on each of these key actions in order to understand current deficiencies and opportunities in regions to promote efficient road safety policies. This paper analyzes the influence of 28 performance indicators associated with the five actions pillars to promote road safety policies. Structural Equation Models were proposed to evaluate the relation of these action pillars on the road traffic fatality rate of 110 Brazilian cities. The results indicated that policies aimed to ensure safer roads and users had the greatest and direct effect in reducing road traffic deaths. Road safety management and post-crash response policies had an indirect effect. The findings can assist in decision-making at the Brazilian cities level.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04010
Paper Title	Investigating Safety in Disadvantaged Communities by Integrating Crash and Justice40 Initiative Data
Abstract	The United States Department of Transportation's (USDOT) effort to identify disadvantaged communities (DACs) on a census tract level has evoked possibilities of transportation justice and vision zero goal achievement in DAC communities. USDOT has developed six comprehensive indicators to identify DACs based on economy, environment, equity, health, resilience, and transportation. This study will utilize these indicators to explore the association between fatal crashes and disadvantages faced by communities. Five years of fatal crash data are combined with demographic information for 72,769 census tracts of the US. Zero-inflated Negative Binomial (ZINB) model is used for the analysis. The results demonstrate that higher fatal crash rates are associated with census tracts that are disadvantaged health-wise (35.01%), resilience-wise (40.38%), and transportation-wise (48.72%). Furthermore, transportation disadvantaged tracts are associated with substantially higher impaired fatal crashes (60.00% higher). The impaired fatal crashes per 100,000 population in all disadvantaged tracts are 15.15 and 12.22 in non-disadvantaged or privileged tracts. The highest number of pedestrian and bicyclist fatalities are among Hawaiian or other Pacific Islanders. This study can provide information to support policymakers in deciding which disadvantaged community can benefit from resources for transportation improvements.

Authors	Yukun Song, Auburn University Huaguo Zhou, Auburn University Priscilla Tobias, Arora and Associates, P.C. Qing Chang, Auburn University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3010
Session Title	Moving Safety Research into Practice
Paper Number	23-04059
Paper Title	The National Survey on Wrong-Way Driving Solutions, Policy and Guidance in the United States
Abstract	This paper presents an investigation into the current and emerging solutions, policies, and guidance employed as well as the opinions on the effectiveness of wrong-way (WW) related countermeasures by different agencies to mitigate wrong-way driving (WWD) activities. A two-pronged approach was used to collect information from state transportation agencies, tollway authorities, and law enforcement. The initial step was an online survey that aimed to obtain general ideas about the current and emerging solutions, policies, and guidance employed by different agencies to mitigate WWD activities. The survey questionnaire, which contains 12 questions regarding mitigation policies, practices, and programs; crash/incident data collection and analysis; and countermeasures evaluation and application guidelines, was emailed to traffic and safety engineers for the 50 state transportation agencies and 59 tollway authorities across the nation. As a second step, follow-up phone interviews were conducted with the respondents identified from the online survey in the first step. The interview questions focused on crash/incident data collection method, crash-prone location identification, countermeasure selection and implementation, experience on ITS application, and future initiatives. The survey and interview results revealed an increasing awareness and the current practices to combat WWD. The best practices aimed at deterring WWD were introduced by different states. The valuable lessons learned from the survey and interview results from the various agencies will be used to develop systemic and systematic approaches and guidelines in the national handbook on WWD solutions.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04087
Paper Title	Relationship Between Motorcyclist Attitudes and Behaviors Toward Safe Riding and Self-reported Crash Experiences
Abstract	In July 2019, Florida had 1.33 million licensed drivers with a motorcycle endorsement and 622,347 registered motorcycles. As part of a long-standing effort to collect data on Florida motorcyclist behaviors, attitudes, and opinions, a web-based survey was issued to registered motorcycle owners in Florida during 2019. This study analyzed the results of the survey to identify relationships between motorcyclist attitudes and behaviors towards safe riding and self-reported crash experiences. A total of 1,668 surveys were used for data analysis, and 471 respondents indicated that they visited a hospital or doctor's office because they were involved in a motorcycle crash. Conventional binary logistic regression model results indicate that younger ages (under 30), riding standard motorcycles, and increased exposure to traffic in daily/weekly motorcycle trips are associated with increased crash risk. Respondents who said they were very unlikely to ride 20 mph or more above the posted speed limit and who usually wear three-quarter helmets were less likely to be involved in a crash. Interestingly, respondents who had not attended any formal motorcycle safety training courses other than a basic rider course in the past 12 months were less likely to be involved in a crash, confirming bidirectional findings regarding the effectiveness of motorcycle training programs at reducing crash outcomes. A larger scale survey, including a good representation of young motorcyclists, will help better understand motorcyclists' attitudinal and behavioral characteristics, and the findings will contribute to designing, implementing, and evaluating tailored motorcycle safety programs.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04224
Paper Title	Modeling the Impact of the COVID-19 Pandemic on Speeding at Rural Roadway Facilities in Maine using Short-Term Speed and Traffic Count Data
Abstract	The COVID-19 pandemic caused a significant change in traffic operations and safety. For instance, various U.S. states reported an increase in the rate of fatal and severe injury crashes over this duration. In April and May 2020, the comprehensive stay-at-home orders were issued across the country, including in Maine. These orders resulted in drastic reductions in traffic volume. Additionally, there is anecdotal evidence that speed enforcement had been reduced during pandemic. Drivers responded to these changes by increasing their speed. More importantly, data show that speeding continues to occur, even one year after the onset of the pandemic. This study develops statistical models to quantify the impact of the pandemic on speeding in Maine. We developed models for three rural facility types (i.e., major collectors, minor arterials, and principal arterials) using a mixed effect Binomial regression model and short duration speed and traffic count data collected at continuous count stations in Maine. Our results show that the odds of speeding by more than 15 mph increased by 34% for rural major collectors, 32% for rural minor arterials, and 51% for rural principal arterials (non-Interstates) during the stay-at-home order in April and May of 2020 compared to the same months in 2019. In addition, the odds of speeding by more than 15 mph, in April and May of 2021, one year after the order, were still 27% higher on rural major collectors and 17% higher on rural principal arterials compared to the same months in 2019.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04325
Paper Title	A Bayesian Network for Motorcycle Crash Severity Analysis
Abstract	Due to the lack of protective structural barriers and advanced restraints, motorcyclists are vulnerable road users, comparable to pedestrians and bicyclists. In 2020, motorcycle-involved fatalities occurred 28 times more frequently per vehicle mile traveled than passenger car occupant fatalities. In addition, there were 5,579 motorcycle-related fatalities in the United States in 2020 – the highest number of motorcyclists killed since in 1975. The discovery of patterns and relationships between important contributing elements can aid in the development of strategies for reducing motorcycle-related crashes. In addition to present efforts, additional research must be performed in innovative avenues with increased funding. Bayesian Networks can better discover the relationships between potential speed compliance variables. This study used six years (2014-2019) of motorcycle crash data in Louisiana to determine the conditional probabilities of the influential factors. The findings of this study can be used for decision making and strategy development for motorcycle safety.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04333
Paper Title	Revisiting the Roles of Speeds in Traffic Crashes: A Geospatial Modeling Study
Abstract	Speeding or improper speed behaviors are unsafe on road, increasing the risk of crashes as well as the chance of severe injuries in crashes. Extensive research has been conducted to establish the role of speed in traffic safety. However, there are two types of improper speed behaviors: exceeding the posted speed limit (EPSL) and driving too fast for conditions (DTFFC) and most studies do not distinguish them. Crashes that involve these two types of behaviors may exhibit different characteristics of contributing factors and crash injury outcomes. Using a statewide crash database that records the specific improper speed behaviors, this study develops separate models to revisit and compare the correlates of injury severity in crashes involving EPSL and DTFFC, respectively. To capture the geography-related unobserved heterogeneity inherently embedded in traffic crashes, this study adopts a geospatial modeling approach, namely Geographically Weighted Logistic Regression (GWLR), to identify the correlates of injury severity by allowing the model estimates to vary across the space. This paper provides premilitary results with a limited number of variables and more variables will be incorporated in the future. Modeling results show the significant correlates of injury severities are different in two types of crashes (involving EPSL or DTFFC), and the correlates from both models vary substantially across the space. The findings of this study are expected to help agencies identify the high-risk regions for specific speeding behavior related crashes so that transportation planners can provide corresponding countermeasures for different locations.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3010
Session Title	Moving Safety Research into Practice
Paper Number	23-04432
Paper Title	Developing an Open-Source Web Tool to Prioritize Safer Streets
Abstract	Vulnerable road user traffic deaths in the United States have increased in number and proportion over the previous decade. This growing disparity points to a larger need to prioritize safety for vulnerable road users on our streets. Evaluating and predicting vulnerable road user crash risk is a data-intensive and complex process. This study aims to make safety analysis for vulnerable road users easier and more accessible by (1) developing a modeling framework with minimal data input needs, (2) converting model outputs into cost equivalents to better link the results to planning and project scoping processes, and (3) building this functionality into an online tool and dashboard. In this paper, we develop an approach to modeling vulnerable road user crash risk that uses Bayesian probability updating and Markov chain Monte Carlo simulations to blend an existing published statistical model with simple roadway and crash data inputs, which we built into an online tool and dashboard called the Safer Streets Priority Finder. We apply the tool to crash data from the City of New Orleans and describe the application of model outputs for both roadway safety planning and transit planning use cases. The paper includes validation results for New Orleans and two other jurisdictions. Overall, we found that this modeling approach performs as well or better than Sliding Window Analysis and traditional High Injury Networks, and the tool has the potential to make safety analysis easier and more accessible to planners and engineers.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04731
Paper Title	Road Safety in New York City After Vision Zero for Different Land Use Contexts
Abstract	Over the past decade, more than 45 cities have committed to Vision Zero in the United States. New York City is one of them that has made good progress in reducing car occupant fatalities but struggled to achieve similar declines in pedestrian and bicyclist fatalities. This study assesses road safety performance based on land use context at the census tract level. We use the combined density of population and jobs to categorize NYC census tracts and compare fatalities and fatality risk for different classes of road users in each group. Using aggregate crash data for 2004-2008 and 2014-2018, we track the changes before and after launch of Vison Zero in 2014. We identify a large and growing discrepancy in fatality rates between pedestrians, bicyclists, and car occupants at places with different land use features. Surprisingly, the low density group has the largest number of pedestrian fatalities compared to other density groups in 2014-2018. This is unexpected since low density areas are places where one would not expect to see large numbers of pedestrians. Fatalities per 1,000 road users and fatality risk for pedestrians and bicyclists decreased with the density of the land use. There were very little or no declines in pedestrian and bicyclist fatalities from before to after Vision Zero, expect in the highest density areas. It suggests the need for cities to better understand the relationship between land use context and traffic safety and to implement context appropriate strategies to effectively address traffic fatality issue.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04739
Paper Title	Where are we with Real-Time Safety Research?
Abstract	Proactive safety research is replacing the traditional reactive safety approaches in order to improve safety on roads. However, there are some research questions that need to be answered in the domain of crash likelihood, crash severity, crash types, secondary crash, and traffic restoration period to advance real-time safety studies. After reviewing the earlier research, this study attempted to respond to these questions by summarizing the key contributions, data processing techniques, and modeling techniques used to conduct these studies to pinpoint the current research gaps and future research direction. The findings from this review revealed that there is still a need to develop a complete real-time crash likelihood prediction framework. Real-time crash severity, crash types, and secondary crash studies have not reached yet the acceptable prediction accuracy. Real-time traffic restoration time after crash occurrence related studies is at the rudimentary stage, and advanced techniques to real-time update the variables and models for the traffic management authority are to be investigated. In addition, there is a need to investigate data preprocessing techniques to improve model performance in each of these domains. Overall, this study summarizes the present contributions of the real-time safety studies and identifies the research gaps to advance this research direction. This study has the potential to refine the research approach in real-time crash prediction and contribute to advancing proactive safety research.

Authors	Weijing Wang, University of California, Davis
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04741
Paper Title	Vision Zero is Not a Failure but a Matter of Action: Policy Intervention Analysis using ARIMA Modeling
Abstract	In the last year, the US witnessed about 43,000 traffic deaths on roads, making 2021 the deadliest year in traffic safety in the past 16 years. With surging traffic fatalities nationwide, Vision Zero has gained its rapid growth in the US with a goal of zero traffic fatalities and serious injuries. Since Chicago's commitment in 2012, to date, more than 50 localities have adopted Vision Zero. Despite increasing popularities of and dedications to the policy, some Vision Zero communities have seen rising traffic fatalities, including Los Angeles, raising a critical question: Is Vision Zero a failure or hope? To answer this question, the current study uses the Autoregressive Integrated Moving Average (ARIMA) modeling to estimate the policy impact and effectiveness of Vision Zero on traffic fatalities and serious injuries, by differing types of road users. Overall, the results suggest that Vision Zero is not a failure, in which one explanation is the outcomes of policy intervention analysis turn to be sensitive to the chosen time point at which the effects of policy intervention present. Evidence also suggests that the policy impact of Vision Zero on traffic safety differs by road users, in which compared to others, pedestrians have a potential to benefit from the policy implementation to a larger degree. The study concludes that working towards eliminating traffic fatalities and serious injuries, further efforts on concrete methods and strategies in advancing policy implementations and understanding equity impacts of Vison Zero are needed.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04806
Paper Title	Potential Reduction of Fatal Crashes in South Carolina due to Automated Vehicles
Abstract	Since 1995, several countries and states have implemented roadway traffic safety projects with the goal of achieving a highway system with no fatal or serious injury crashes. South Carolina's Target Zero plan is multifaceted in that it identifies several preventative measures to reduce fatalities. A common thread of these programs is that they are aspirational, and there is not an expectation that zero fatalities will ever be a reality. While there are many contributors to fatal crashes, by far the biggest contributor is driver error. In South Carolina (SC), the first contributing factor in nearly 85% of fatal crashes is driver related. Thus, to approach a target of zero fatalities will require eliminating drivers from the equation—or at least making drivers error free. This research focuses on how 2019 SC fatal crash data could be impacted hypothetically by different scenarios of autonomous vehicle (AVs) safety applications. A detailed review of contributing factors to over 900 2019 fatal crashes in SC along with a review of site characteristics for each crash was conducted. A deterministic approach was used to calculate the effects of different AV levels on each of the fatal crashes. The approach was based primarily on literature findings regarding the safety effectiveness of vehicle characteristics for each level. The reduction in fatal crashes ranged from 10% to 23% for level 1 to nearly 95% for level 5 AVs. The underlying assumption in terms of AV level is that the entire population of vehicles fall within that AV category.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04824
Paper Title	Navigating to Safety: Necessity, Requirements, and Barriers to Considering Safety in Route Finding
Abstract	Automotive navigation systems seek the shortest route between a given set of origin and destination points. However, although the suggested routes may help users minimize their travel times, there are certain situations in which the shortest route is not necessarily the safest one. Navigating through local roads that have higher risks of crashes—namely, those with poor geometric designs, drainage problems, lack of illumination, higher risks of wildlife-vehicle collisions, and more interruptions in traffic flow—compared to using higher classification highways is an example of the unintended consequences of routing to ensure minimum travel time. This study examined the problem by comparing the safest and shortest routes between five metropolitan areas in Texas, including more than 29,000 road segments. The study also designed a system architecture for finding the safest route and highlighted barriers to implementing such a system. The results of comparing the safest route and the shortest route between pairs of origins and destinations showed that the shortest route is not necessarily the safest, where an 8% decrease in travel time was associated with a 23% higher risk of being involved in a crash. In addition, the safest route varies according to different weather conditions. The requirements for deploying safety in route-finding systems were identified as (1) availability of real-time traffic flow and incident data for dynamic route-finding systems, (2) more accurate crash prediction models, and (3) a methodology for dealing with the trade-offs between travel time and safety to find the optimal route.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04894
Paper Title	An Exploratory Analysis of Two-vehicle Crashes for Distracted Driving with A Mixed Approach: Machine Learning Algorithm with Unobserved Heterogeneity
Abstract	Two-vehicle crashes, particularly due to distraction and impacting other vehicles, lead to a disproportionately higher number of fatalities and serious injuries over time. The intent of this study is to identify the contributing factors to driver injury severity with the assessment of the machine learning model and quantify those factors affecting injury severity outcomes for two-vehicle crashes in the US. The crash data were extracted from the Crash Report Sampling System (CRSS) from 2016 to 2018. This study applied an XGBoost to identify the top variables based on SHAP value by driver injury levels and mixed logit with heterogeneity in means and variances approach to model driver injury severity. The model results indicate that there is a complex interaction of driver characteristics, such as demographics (male drivers), driver actions (careless driving, driving over the speed limit more than 15 mph, hitting stopped vehicle), a driver without violation destroy, turning violation, drinking, roadway and traffic characteristics (non-interstate highways, undivided and divided roadways with positive barrier, curved roadways, dry surface condition), environmental conditions (rainy weather condition), vehicle characteristics (motorcycle, displacement volume up to 2500 cc, newer vehicle within 5 years from crash), temporal characteristics (afternoon peak: 4 to 6 PM, 3rd quarter of the analysis period (July to September), and analysis year of 2017). The results clearly indicate the importance of driving behavior and roadway design concerning distracted driving behavior that needs to be prioritized for driver training as well as the law enforcement, roadway design, and maintenance agency.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04915
Paper Title	Real-time Traffic Restoration Time Prediction based on the Estimated Traffic State
Abstract	The study developed an approach to predict the traffic restoration time after a crash occurrence based on the estimated traffic state. The contribution of this study is threefold: first the study developed models to predict the traffic state after a crash incident; second, the study predicted the traffic restoration time based on the estimated post-crash traffic state; third, the study validated the proposed traffic restoration time using the actual incident duration time. To accomplish these tasks, the study considered a 220 miles section of Interstate-75 of Florida, USA. Traffic, crash, weather, and emergency facility data were collected for the road from 2017 to 2019. 24,448 events and 65 real-time features were used to develop the traffic state prediction model. Total eight traffic state prediction models were developed using the XGBoost machine learning technique. Then the estimated traffic state was used to calculate the congestion state of pre-crash and post-crash condition. Then pre-crash and post-crash congestion states were compared to capture the time when traffic returned to normal operating condition. The estimated traffic restoration time was validated by comparing it with the actual incident duration data. A cosine similarity metric was used to find the similarity between these actual and predicted times, and the results showed that 82.40% similarity was obtained. To the best knowledge of the authors such an approach to estimate traffic restoration time is new in real-time safety research and has the potential to contribute to real-time traffic management after a crash.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2219
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	23-04939
Paper Title	Assessing the Safety of Raising Speed Limits using Interrupted Time Series
Abstract	Texas has recently increased speed limits to 75 mph or higher for selected high-speed facilities. This research evaluated the safety effectiveness of this change based on a large dataset developed from data provided by the Texas Department of Transportation (TxDOT) and combined with data collected using satellite and street level imagery. The evaluation was performed based on a mixed effects model accounting for differences in exposure, cross-sectional differences, and safety shifts among longitudinal subsets in the data representing the speed limit changes at different dates and with different comparison groups of sites. This paper documents the application of interrupted time series analysis, a subset of longitudinal methodology to assess the safety changes of raising speed limits to 75 mph on Texas freeways. The analysis resulted Crash Modification Factors (CMFs) indicating statistically significant increases in seven crash types in rural Texas freeways, ranging from 10.6 percent for PDO crashes up to 39.2 percent for crashes involving an overturned vehicle.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-04962
Paper Title	Identifying Attribute Associations in Fatal Speeding Crashes with Latent Class Clustering and Association Rule Mining
Abstract	Speeding has been distinguished as one of the most frequent and persistent contributing factors and is considered to be a critical contributing factor to the degree of injury severity. In the United States, at least a quarter of nationwide annual fatal crashes during the last decade involved speeding. There is still a need for an overarching look at the crashes involving speeding by considering a wider set of crash, roadway, driver, and vehicle characteristics. This paper mitigates the research gap by investigating the collective impacts of variables in homogenous crash clusters by focusing on fatal crashes with FARS data Using crash data of 2015-2019 from the fatality analysis reporting system (FARS) repository, this study applies latent class clustering (LCC) to obtain homogeneous clusters of fatal speeding crashes addressing the unobserved heterogeneity. Association rule mining (ARM) has been applied to the homogeneous clusters to find hidden patterns. The finding of association rules – such as motorcycle speeding single vehicle crashes during weekends and in dark-unlighted condition etc. The results of this research and interpretative findings are expected not only to improve the knowledge of speeding-related crash mechanism and but also to provide important insights on countermeasure development.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-05024
Paper Title	Evaluating the Safety Impacts of Autonomous Vehicles under Mixed Traffic Conditions
Abstract	Advances in artificial intelligence and machine learning may transform the notion of Autonomous Vehicles (AVs) into a reality in the near future. Past studies have evaluated the safety and travel time benefits of AV inclusion under homogeneous traffic conditions. Whereas the mixed traffic conditions are yet to be thoroughly investigated. This study considered Indian mixed traffic conditions, with lane changes permitted for overtaking. The micro simulation software VISSIM was used in this study to simulate mixed traffic conditions at varying AV penetration rates ranging from 0% to 100%. The study considered five volume levels to account for volume variations, i.e., base volume (volume near free flow conditions (LOS A)), 1.25*base volume, 1.5*base volume, 1.75*base volume, and 2*base volume (volume under forced flow conditions (LOS F)). A roundabout and an uncontrolled T-intersection were considered in the study. Surrogate safety assessment model (SSAM) was used for safety evaluation. Findings show that there is no significant effect ($p < 0.05$) of AV inclusion on number of conflicts and travel time at low traffic volume (base volume). At the roundabout, the conflicts reduced by 46-74% at high traffic volume (2*Base volume), corresponding to an AV penetration rate of 50 to 100%. Also, at the uncontrolled T-intersection (at high traffic volume (2*base volume)), a 10-20% increase in the frequency of conflicts at 10-50% AV penetration rates was observed and subsequently a 36% reduction in conflicts was recorded at 100% AV penetration rate. The study illustrated the significant safety impact of AVs at higher penetration rates.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	3149
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	23-05272
Paper Title	Comparison of Crash Types in Automated Vehicles with Different Levels of Automation
Abstract	Many car manufacturers have been putting their effort into producing automated vehicles (AV). Automated Driving Systems (ADS) are a representation of higher levels of automation and these cars are not publicly available yet. ADS vehicles are expected to outperform Advanced Driver Assistance Systems (ADAS) in terms of crashes and make roads safer. However, NHTSA has recently published crash reports of both ADAS and ADS technology vehicles, showing that the number of crashes for ADS vehicles is still high. This study aims to compare crash types of ADS and ADAS technologies. Intersection crashes are selected for comparing these two technologies to consider the same environmental characteristics. Results reveal that the contact area for 72.4% of ADS-equipped vehicle crashes at intersections is the rear of the vehicle and the contact area for 94.7% of ADAS-equipped vehicle crashes is the front of the vehicle, meaning that ADS vehicles are being hit by other vehicles on the road most of the time. Results illustrate that these two automation technologies are acting vastly different from each other in similar environments. Additionally, Results suggest that in the rear-ended ADS crashes, these vehicles were stopped or proceeding straight 81% of the time, showing a low rate of adoption in a mixed environment. This is the first study that compares collision types between ADS and ADAS technologies based on real-world crashes. Overall, this study contributes by comparing ADAS and ADS crash types as it is critical for enhancing transportation safety and important for safety practitioners.

11 Interacting Committees

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

ACH10, Pedestrians
This committee is concerned with research on pedestrians and pedestrian facilities which will provide safe, comfortable, and efficient walking environments along sidewalks, along and across roadways, and connecting to other modes of transportation. It addresses the planning, design, operation, and maintenance of roadways as they affect use of public rights-of-way by pedestrians. It aims to integrate pedestrian considerations into broader transportation issues.

ACH20, Bicycle Transportation
This committee is concerned with all aspects of bicycling and bicyclists and criteria for bicycle facilities to assure that the bicycle rider has safe, convenient and efficient travel.

ACH40, Human Factors of Infrastructure Design and Operations
The committee's activities will focus on the interactions between the road user and the surface transportation infrastructure. The aim is to support research and development activities into user-centered aspects of infrastructure planning, design, operations, and maintenance. Particular attention will be placed on infrastructure requirements relative to the needs, capabilities, and limitations of all road users. The committee's purview will include all surface transportation modes and their associated infrastructure.

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

ACP15, Intelligent Transportation Systems
The Intelligent Transportation Systems (ITS) Committee is concerned with ITS systems-level issues. Such issues include conceptual system planning and design, integration of technologies and approaches from various sub-disciplines within ITS, applications to all modes of ground transportation and to facilitate intermodal integration, and evaluation of the overall impacts of ITS on the developers, users, and operators of all parts of the ground transportation system. Activities focus on the broad planning, policy, economic, social, technological, and institutional aspects of the development and implementation of ITS. The Committee also facilitates coordination of ITS- related issues with other standing committees of TRB.

ACP55, Traffic Control Devices

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

ACS30, Traffic Law Enforcement

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

ACS40, Occupant Protection

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

ACS60, Truck and Bus Safety

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

AED30, Information Systems and Technology

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

AED40, Geographic Information Science

The scope of this committee includes all aspects of the spatial, locational and temporal data used in transportation. The committee is interested in both research into and applications of this information and its associated information systems, commonly referred to as Geographic Information Systems in Transportation (GIS-T). The committee will provide a focal point for

and promote coordination of GIS- T activities within the TRB committee structure. Relevant activities include the application of spatial data and spatial sciences across the entire domain of transportation information systems.

AED50, Artificial Intelligence and Advanced Computing Applications

The purpose of this committee is to provide a focal point for expert system research activities across the various transportation-related disciplines, and to act as a forum for the evaluation and dissemination of information relative to the benefits of the technology to the transportation profession. It is understood that other TRB committees, where appropriate, will have subcommittees on expert systems for their specific domain.

AED60, Statistical Methods

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

AJE35, Research Innovation Implementation Management

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

AKD10, Performance Effects of Geometric Design

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

AKD20, Roadside Safety Design

This committee is concerned with the development of forgiving highway roadsides through countermeasures, safety hardware, and features that will reduce the number and severity of roadway departure crashes and optimize the safety benefit to the traveling public.

AMR20, Disaster Response, Emergency Evacuations, and Business Continuity

This committee addresses issues related to managing and executing transportation, mobility, and logistical efforts associated with the preparation for, response to, and recovery from human-made and natural emergencies and disasters. Specific topics include emergency evacuations, the supply chains associated with disaster response, longer-term business and

community continuity, and humanitarian relief. Each topic is considered in terms of technical, operational, and human dimensions and policies using analytical methods, innovative techniques, and decision-making processes to plan for, respond to and recover from emergency events.