TRB Standing Committees

ACS10 – Transportation Safety Management Systems

ACS20 – Safety Performance Analysis

Synthesis Report on Safety-Related Papers

presented at the 101st 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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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/

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Juan Medina, University of Utah
Yusuf Mohamedshah, Federal Highway Administration (FHWA)
Chris Monsere, Portland State University

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1 Introduction

This report is mainly aimed at facilitating access to Committees ACS10-ACS20 related presentations and events at the 101st 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 in order to promote better interaction between ACS10, ACS20 and these other Committees. Indeed, highway safety is a worldwide major social challenge that requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

This year, twenty-five events sponsored by ACS10 and ACS20 are planned:

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

The Committee meetings will be held on Monday afternoon, January 10, from 1:30 PM to 5:30 PM (ACS20) and Wednesday morning, January 12, from 8:00 AM to 12:00 PM (ACS10).

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

a) Crash Data and Data Analysis (136 papers and 11 PhD presentations);
b) Network Screening (13 papers);
c) Safety Performance Functions (41 papers);
d) Crash Severity Prediction (40 papers);
e) Crash Modification Factors (11 papers);
f) Surrogate Measures of Safety (35 papers); and
g) Transportation Safety Management (30 papers).

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

Table 1 ACS10 and ACS20 Committee Meetings

Schedule	Title	Details
Monday, January 10 1:30 PM-5:30 PM ET	Safety Performance and Analysis Committee, ACS20	https://annualmeeting.mytrb.org/OnlineProgram/Details/16608
Wednesday, January 12 8:00AM – 12:00PM ET	Transportation Safety Management Systems Committee, ACS10	https://annualmeeting.mytrb.org/OnlineProgram/Details/16607

Table 2 ACS10 and ACS20 Subcommittee Meetings

Schedule	Title	Details
Monday, January 10 7:30PM – 10:00PM ET	Emergency Response, AMR00(1), Joint Subcommittee of AMR00, ACS10, and ACP10	https://annualmeeting.mytrb.org/OnlineProgram/Details/16814
Monday, January 10 6:00PM – 7:30PM ET	School Transportation Subcommittee, ACS10(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/16982
Tuesday, January 11 6:00PM – 7:30PM ET	Rural Road Safety Policy, Programming, and Implementation Subcommittee, ACS10(4), Joint Subcommittee of ACS10, ACS20, AKD30	https://annualmeeting.mytrb.org/OnlineProgram/Details/16983
Tuesday, January 11 6:00 PM-7:30 PM ET	Pedestrian and Bicycle Safety Analysis, ACS20(4), Joint Subcommittee of ACS20, ACH10, ACH20	https://annualmeeting.mytrb.org/OnlineProgram/Details/16987
Wednesday, January 12 8:00 AM-9:30 AM ET	Surrogate Safety Measures Subcommittee, ACS20(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/16986
Tuesday, January 11 8:00 AM-9:30 AM ET	Safety Performance and Analysis User Liaison Subcommittee, ACS20(2)	https://annualmeeting.mytrb.org/OnlineProgram/Details/16985
Monday, January 10 10:30 AM-12:00 PM ET	Safety Analytical Methods Subcommittee, ACS20(1)	https://annualmeeting.mytrb.org/OnlineProgram/Details/16984
Tuesday, January 11 6:00 PM-7:30 PM ET	Rural Road Safety Policy, Programming, and Implementation, ACS10(4), Joint Subcommittee of ACS10, ACS20, AKD30	https://annualmeeting.mytrb.org/OnlineProgram/Details/16983

Table 3 ACS10 and ACS20 Workshops

Schedule	Title	Details
Sunday, January 9 9:00AM - 12:00PM ET	(1003) Making Safe Systems a Reality: Planning to Implementation	https://annualmeeting.mytrb.org/OnlineProgram/Details/17056
Thursday, January 13 9:00 AM-12:00 PM ET	(1431) Do You Count If You Are Not Counted?: An Exploration of Systematic Bias in Crash Data Systems	https://annualmeeting.mytrb.org/OnlineProgram/Details/17059
Thursday, January 13 9:00AM - 12:00PM ET	(1432) Traffic Law Enforcement at a Crossroads: How Can Research Help?	https://annualmeeting.mytrb.org/OnlineProgram/Details/17057
Sunday, January 09 9:00 AM-12:00 PM ET	(1003) Making Safe Systems a Reality: Planning to Implementation	https://annualmeeting.mytrb.org/OnlineProgram/Details/17056

Table 4 ACS10 and ACS20 Lectern Sessions

Schedule	Title	Details
Monday, January 10 8:00AM – 9:30AM ET	(1049) Emergency Responder Safety and Next-Generation Traffic Incident Management	https://annualmeeting.mytrb.org/OnlineProgram/Details/17159
Monday, January 10 10:30AM – 12:00PM ET	(1073) The Role of Speed in a Safe System	https://annualmeeting.mytrb.org/OnlineProgram/Details/17562
Monday, January 10 4:00PM – 5:30PM ET	(1162) Translating Safety Research to Real-World Solutions	https://annualmeeting.mytrb.org/OnlineProgram/Details/17156
Tuesday, January 11 10:30 AM-12:00 PM ET	(1246) Doctoral Student Research in Transportation Safety	https://annualmeeting.mytrb.org/OnlineProgram/Details/17577

Table 5 ACS10 and ACS20 Poster Sessions

Schedule	Title	Details
Wednesday, January 12 8:00AM – 9:30AM ET	(1376) Safety Studies on Low-Volume Roads	https://annualmeeting.mytrb.org/OnlineProgram/Details/17412
Wednesday, January 12 8:00AM – 9:30AM ET	(1384) Emergency Response, Responder Safety, and Traffic Incident Management Research	https://annualmeeting.mytrb.org/OnlineProgram/Details/17173
Wednesday, January 12 8:00 AM-9:30 AM ET	(1376) Safety Studies on Low-Volume Roads	https://annualmeeting.mytrb.org/OnlineProgram/Details/17412
Tuesday, January 11 10:30 AM-12:00 PM ET	(1268) TRB Minority Student Fellows Research Presentations	https://annualmeeting.mytrb.org/OnlineProgram/Details/17150
Tuesday, January 11 4:00 PM-5:30 PM ET	(1340) Advancing New Methods and Data	https://annualmeeting.mytrb.org/OnlineProgram/Details/17590
Tuesday, January 11 1:30 PM-3:00 PM ET	(1304) Safety Performance and Strategies	https://annualmeeting.mytrb.org/OnlineProgram/Details/17589
Monday, January 10 8:00 AM-9:30 AM ET	(1056) Safety of Motorcyclists and Active Transportation Modes	https://annualmeeting.mytrb.org/OnlineProgram/Details/17578

2 Crash Data and Data Analysis

Mohamad Banihashemi
FHWA

"Crash Data and Data Anaysis" section contained many papers in wide variety of subjects in highway safety. Of over 200 papers submitted to the ACS10 and ACS20 Committees for 2022 Annual Meeting, there are **136 papers and 11 PhD presentations** that fit in this major category, with papers grouped into several sub-categories listed below:

Pedestrians, Bicyclists, Other Vulrerable Road Users (VRU) Safety, and Safe System: This sub-category has 21 papers presented in the Annual Meeting.

Ghomi, H. and M. Hussein (TRBAM-22-00639) conducted research on the safety involving pedestrian spatial violations (jaywalking) at mid-blocks. Hossain A. et al. (TRBAM-22-00813) studied the ecceft of lighting in pedestrian safety. Lu, M. et al. (TRBAM-22-01216) conducted research on the pedestrian and bicyclists safety by incorporating several exposure metrics that capture nonmotorized and public transportation use. Tamakloe, R. et al. (TRBAM-22-01365) and M. Gupta and N. Velaga (TRBAM-22-02913) studied the safety of Powered Two-Wheeler (PTW) vehicles while H. Chai et al. (TRBAM-22-02933) conducted research on the safety of bicycles and e-bikes at non-signalized intersections. Li, Y. et al. (TRBAM-22-02737) conducted research on the Vulnerable Road User (VRU) safety analysis through crash database improvement. Zhan, Y. et al. (TRBAM-22-02948) used conflict-based methods to study the safety of pedesterians at Actuated Signal Control Intersections. Mahmoud, N. et al. (TRBAM-22-03376) Identified pedestrian and bike crash hotspots considering the context cassification for multi-lane arterials. Yang, R. et al. (TRBAM-22-03684) studied motorcycle crashes on horizontal curves using Recursive Bivariate Probit Analysis. Zhang, Q. and X. Hu (TRBAM-22-03730) conducted safety analysis on pedestrian-vehicle exit interactions at non-signalized intersections. Gooch, J. et al. (TRBAM-22-03819) analyzed systemic mid-block pedestrian crashes. Agyemang, W. et al. (TRBAM-22-04196) and D. Ammar et al. (TRBAM-22-04321) conducted pedestrian crash analysis at Inter-Urban Highways and inersections, respectively. Ammar, D. et al. (TRBAM-22-04269) conducted a research identifing factors related to crash Injury Levels involving Bicyclists. Goswamy, A. et al. (TRBAM-22-04393) evaluated the safety effectiveness of Rectangular Rapid Flashing Beacons (RRFB) and C. Kadeha et al. (TRBAM-22-04437) evaluated the safety performance of midblock pedestrian crossing treatments. Wang, M. (TRBAM-22-04613) studied different of factors contributing to motorcyclist fatality in single and multiple vehicle crashes and R. Sanders and T. Nelson (TRBAM-22-04849) studied near crashes and crashes of e-escooters and bikes. And finally J. Anderson et al. (TRBAM-22-01227) investigated how to use systemic safety to imptove older pedestrian safety. Amdad Hossen, M. et al. (TRBAM-22-04109) studied the effectiveness of vision zero initiatives on cyclists' safety. Shi, G. et al. (TRBAM-22-04229) studied the effect of the implementation of Safe Systems on highway safety, especially pedestrians and bicyclists safety in Netherlands and in Sweden. Figliozzi, M. et al. (TRBAM-22-01087) presented a before and after analysis of the impact of posted speed limit changes on passenger car speeds on roads with a high percentage of cyclists. Sheykhfard, A. et al. (TRBAM-22-01484) studied the safety effects of traffic signs on the school students safety in suburban (ourskirt) areas. Kodi, J. et al. (TRBAM-22-03406) studied hotspots of crashes involving vulnerable aging road users and their spatial relationship with the built environment.

Specific Improvements, Models, and Secondary Cashes: There are about 14 papers related to this category in the Annual Meeting.

Zhou, Y. et al. (TRBAM-22-01847) and Y. Tang (TRBAM-22-04367) studied the safety effects of road diet. Camerena, L. (P22-20513) and M. Sharafeldin et al. (TRBAM-22-00572) studied the effect of pavement friction on safety. Bia, E. et al. (TRBAM-22-03517) studied the impact of bus rapid transit on traffic safety. Robinson, J. et al. (TRBAM-22-00844) investigated the safety of Freight Intermodal Connectors (FICs) that link freight-intensive land uses to main freight routes. Mayes. M. et al. (TRBAM-22-01011) conducted the safety analysis of near intersections parking. Mcadoo. N. et al. (TRBAM-22-00845) used Hurdle Models (HM) to study the secondary crashes and K. Pecheux et al. (P22-20101) looked into the data related to the secondary crashes affecting responders. Molina, J. et al. (TRBAM-22-03735) studied the relationship between daylight saving time and traffic crashes. Megat Johari, M. U. (TRBAM-22-01064) studied the safety effects of advisory speed reductions on freeway exit ramps. Asaduzzaman, M. et al. (TRBAM-22-01097) studied the safety and operational effectiveness of protected only versus protected/permitted leftturn signal phase. Saleem, T. And R. Srinivasan (TRBAM-22-03185) studied the safety effect of changing speed limit from 55 mph to 60 mph on two-lane, two-way road segments. Abohassan, A. et al. (TRBAM-22-01507) studied the effects of inclement weather events on Road Surface Conditions and Traffic Safety.

Analysis of Emerging and Big Data and Naturalistic Driving Study (NDS) Data: There are 13 papers related to this sub-category.

Hamilton, I. et al. (TRBAM-22-00872) applied emerging data sources to analyze pedestrian safety. Mahmoudi, J. et al. (TRBAM-22-01032) used Bog Data to model the frequency of pedestrian and bicyclist crashes at intersections. Portillo, J. et al. (TRBAM-22-00319) studied the pedestrian and bicycle crashes using patterning demographic and socioeconomic data. Hyde, A. et al. (TRBAM-22-00902) explored the relationship between credit ratings and crash risk. Okaidjah, D. et al. (TRBAM-22-03530) conducted spatial analysis of the relationship between intersection crashes and the urban built environment. Alisan, O. et al. (TRBAM-22-03644) studied the relations of crashes with built environment variables such as population, bus stops, employment entropy, and motorized and non motorized modes parameters. Wang, X. et al. (TRBAM-22-02716) conducted causation analysis of crashes and near crashes using NDS data. Hoover, L. et al. (TRBAM-22-03304) used a multi-level random parameter binary logit model to analyse the NDS data for safety. Feng, M. et al. (TRBAM-22-03923) used environmental and electric vehicle Big Data to predict hourly crashes. Mao, S. et al. (TRBAM-22-04756) used vehicle trajectory Big Data to analyze the safety of ride-hailing drivers and improvement strategies. Padinjare Venthuruthiyil, S. and M. Chunchu (TRBAM-22-04784) conducted proactive safety assessment of 3D road geometries using NDS data. Zung, S. et al. (TRBAM-22-02476) used unmanned aerial vehicles (UAVs) to track vehicles and assess the collision risks at interdections. Islam, Z. et al. (TRBAM-22-00783) used audio data to detect real-time emergency vehicle events.

Conventional Safety Analysis and Data: What are presented in these papers are closer to the conventional safety analysis. There are 29 papers presented in the Annual Meeting in this sub-category.

Mahmud, A. et al. (TRBAM-22-00053) estimated crashes by type for collector segments. Li, X. et al. (TRBAM-22-00234) studied the traffic violations seriusness. Himes, S. et al. (TRBAM-22-00658) studied the safety of freeway facilities with high occupancy lanes. Himes, S. et al. (TRBAM-22-01141)

developed project-design SPFs for freeway segments. Kay, J. et al. (TRBAM-22-01173) studied the safety performance of unsignalized median u-turn intersections. Posada-Henao, J. J. et al. (TRBAM-22-02324) analyzed the influence of license plate number restriction ("peak and plate") on vehicular circulation (congestion) and crash rates in urban areas. Fei, Y. et al. (TRBAM-22-02434) studied the safety of toll plaza areas. Hossain, M.J., et al. (TRBAM-22-02934) Investigated the spatial transferability of alternative parameterizations for the dispersion function in negative binomial models predicting crashes. Khodadadi, A. et al. (TRBAM-22-03136) used and compared different negative binomial-lindley variations in predicting crashes. Avelar, R. et al. (TRBAM-22-04494) studied the sample size effect on the quality of the calibration factors for the Highway Safety Manual (HSM) crash prediction models. Al-Kaisy, A. and K. Huda (TRBAM-22-00222) investigated the application of the Empirical Bayes (EB) method Highway Safety Manual (HSM) predictive methodology on low-volume roads. Zhang, C. et al. (TRBAM-22-00295) explored relationships between months and different types of traffic accidents. Hu, Y. et al. (TRBAM-22-00919) used a copula-based joint approach to model conflict risk with real-time traffic data. Mehrara Molan, A. et al. (TRBAM-22-01057) conducted before-after safety evaluation of coordinated ramp metering system using empirical bayes approach. Yang, K. and Constantinos Antoniou (TRBAM-22-02165) used reinforcement learning tree to develop the real-time traffic safety management framework. Bell, M. et al. (TRBAM-22-03151) mapped the risk of Wildlife-Vehicle crashes across the State of Montana. Wang, X. et al. (TRBAM-22-03672) used bayesian method to update crash prediction models for freeways. Ahmed, I, and M. Ahmed (TRBAM-22-04681) studied the safety effectiveness of wildlife-vehicle crash countermeasures using a bayesian approach. Cho, H. et al. (TRBAM-22-00545) studied the effects of systemic safety improvements on roadway departure crashes on two-lane rural roads. Baig, F. and Jaeyoung Lee (TRBAM-22-00929) conducted a scientometric analysis on trends of traffic safety studies between 2010 and early 2021. Neki, K. et al. (TRBAM-22-01072) studied the trend of road fatalities in Low- and Middle- Income Countries (LMICs) between 2006 and 2016 focusing on motorcycle safety. Ampadu, V. et al. (TRBAM-22-01341) estimated the average annual cost of crashes on wyoming downgrades using time series analysis and forecasting. Claros, B. et al. (TRBAM-22-01905) studied the safety and economic evaluation of the Highway Safety Improvement Program (HSIP). Dowler, N. and Cody Stolle (TRBAM-22-01906) conducted research on the performance cable barriers and evaluated factors contributing to right-side (roadside) departures. Dong, Y. and J. Wood (TRBAM-22-02261) provided an analysis of factors that contribute to crash occurrence based on two national datasets in the US (CISS and NASS-CDS) the years 2017-2019 and 2010-2015, respectively. Wang, X. et al. (TRBAM-22-03030) studied the traffic fatality trends of seven countries since 1970. Grossman, J. et al. (TRBAM-22-04028) studied the intersection sight distance adjustments for horse-drawn vehicles. Carrick, G. and S. Srinivasan (TRBAM-22-03793) studied the incident responder crashes involving move over law violations. Lestari, F. et al. (TRBAM-22-02133) conducted study on how to improve service coverage for three-wheeled mobile fire units in Pari Island, Indonesia.

Human Behavior, Human Factors COVID-19 Effects: There are 23 papers related to this sub-category.

Gao, J. et al. (TRBAM-22-01509) studied the drivers' risky behavior and its effects on safety. Intini, P. et al. (TRBAM-22-01750) Studied the relationships between urban crash-related factors and aberrant behaviors of drivers. Wang, J. et al. (TRBAM-22-02572) modeled aggressive driving behavior based on graph construction. Yasmin, S. et al. (TRBAM-22-02574) studied the effect of speed enforcement on crash risk and crash severity. Tawfeek, M. (TRBAM-22-03214) studied the drivers' reaction times in car following situations on curves and tangent segments. Adavikottu, A. and N. Velaga (TRBAM-22-03348)

studied the collision avoidance maneuvers and risk assessment of aggressive and nonaggressive drivers at intersections. Rahman Shaon, M. R. et al. (TRBAM-22-03921) conducted driver behavioral safety analysis using integrated multidisciplinary data and countermeasure development. Wang, X. et al. (TRBAM-22-03926) conducted a longitudinal safety comparison of the urban roadway in using the Bayesian negative binomial model framework. Jefferson, A. and J. Daniel (TRBAM-22-04188) conducted an analysis on crashes with parked vehicles. Adanu, E. et al. (TRBAM-22-04220) Studied the effects of COVID-19 pandemic on road crashes. Jalayer, M. And S. Hasan (TRBAM-22-04264) conducted distracted driving crashes study by reviewing on data collection, analysis, and crash prevention methods. Li, Y. et al. (TRBAM-22-01786) used large-scale gps trajectory data to explore driving styles. Chen, Q. et al. (TRBAM-22-02777) analyzed lane-changing behaviors using vehicular trajectory data. Mbugua, L. et al. (TRBAM-22-02957) studied the effect of reducing speed limits on road fatalities and injuries in low- and middle-income countries. Agarwala, R. and V. Vasudevan (TRBAM-22-02510) conducted research on the role of high-speed roads and vehicle ownership on traffic fatalities. Pei, Y. et al. (TRBAM-22-02875) assessed the relations between violations and crashes in a reginal level. Shakir Mahmud, M. et al. (TRBAM-22-03589) evaluated the driver response to dynamic speed feedback signs on rural highways curves.

Matheny, S. et al. (TRBAM-22-00085) studied the impact of covid-19 pandemic on traffic safety and traffic flow patterns. Li, J. and Z. Zhao (TRBAM-22-02915) studied the impact of covid-19 travel-restriction policies on road traffic accident patterns with emphasis on cyclists. Idnan Haider, S. et al. (TRBAM-22-03145) used Convolutional Neural Network (CNN) algorithm to identify the effect of COVID-19 pandemic on crashes. Latif Patwary, A. and A. Khattak (TRBAM-22-03769) studied the changes in transportation fatalities, total crashes, and crash harm ring the COVID-19 pandemic. Milusheva, S. et al. (TRBAM-22-03847) studied the effects of COVID-19 pandemic on road safety in Nairobi. Ahangari, H. et al. (TRBAM-22-04687) investigated the impact of speeding on traffic safety outcomes during COVID-19 Pandemic in some large U.S. cities.

Safety of Work Zone Areas, Wrong Way Driving (WWD), Parkings, and Traffic Incident Management (TIM): There are 9 papers related to these topics.

Zhang, Z. et al. (TRBAM-22-01452) studied the effect of work zone areas characteristics on crash risk. Das, S. et al. (TRBAM-22-02066) studied the patterns of contributing factors in encroachment-related work zone crashes. Zhao, L. et al. (TRBAM-22-02205) studied the safety effects of traffic managment plans of the long-term work zone areas. Cheng, Y. et al. (TRBAM-22-03731) used AI to predict crashes on work zones.

Ahmed, A. et al. (TRBAM-22-02290) explored the major Wrong Way Driving (WWD) crash contributing factors related to local and non-local drivers.

Vazquez, M. et al. (TRBAM-22-02308) conducted safety evaluation of parking facilities by considering at self-driving and self-parking features.

Noble, A. (P22-20099) studied the efficieny of the “Move Over” law. Witherspoon, J. (P22-20102) studied the benefits of the Next Generation TIM. Morecock Eddy, M. (P22-20100) conducted research on the use of TIM in rural environment.

Connected and Automated Vehicle Safety and the use of Emerging Techniques, including Machine Learning and Deep Learning: There are 27 papers presented in the Annual Meeting in this sub-category.

Cazares, J. And Ivan Damnjanovic (TRBAM-22-00641) evaluated safety benefits of V2X sensor sharing on rural highways using microscopic simulation model. Wu, D. et al. (TRBAM-22-00911) used empirical trajectory data to optimize control model parameters of Connected Automated Vehicles (CAVs). Song, Y. et al. (TRBAM-22-01878) studied the automated vehicle crash sequences. Beck, J. et al. (TRBAM-22-03105) proposed a data pipeline that takes raw data from all on-board AV sensors such as LiDAR, radar, cameras, IMU's, and GPS's to reconstruct crashes. Gu, Y. et al. (TRBAM-22-03540) used connected vehicle data to predict intersection crashes. Ren, W. et al. (TRBAM-22-04468) used Divergent Effects of Factors and a hierarchical Bayesian approach to study Crashes under autonomous and conventional driving modes. Sohrabi, S. et al. (TRBAM-22-03367) conducted an empirical analysis to evaluate the safety and equity impacts of automated vehicles.

Chen, O. et al. (TRBAM-22-02762) used machine classification techniques to predict lane change decisions. Mohaiminul Islam, A.S.M. et al. (TRBAM-22-03499) used finite mixture negative binomial-lindley to analyse heterogeneous crash data with many zero observations. Bin-Nun, A. et al. (TRBAM-22-03889) used the Swiss Cheese model and Heinrich's Triangle to support accelerated safety assessment. Fiorentini, N. et al. (TRBAM-22-00377) studied the issue of overfitting in accident prediction models. Yuan, C. et al. (TRBAM-22-00520) conducted real-time conflict risk analysis and prediction based on high-resolution trajectory data using machine learning and deep learning. Wei, Z. et al. (TRBAM-22-00855) used Artificial intelligence (AI) to conduct short duration crash prediction for rural two-lane roadways. Son, S. et al. (TRBAM-22-00933) proposed new performance measures for hotspot identification based on data mining. Li, P. and M. Abdel-Aty (TRBAM-22-01252) used transfer learning approaches to improve spatio-temporal transferability of real-time crash likelihood prediction models. Li, P. and M. Abdel-Aty (TRBAM-22-01375) used a hybrid machine learning model to real-time secondary crash likelihood. Yuan, C. et al. (TRBAM-22-01545) used machine learning for real-time safety analysis of connected vehicles. Monjurul Karim, M. et al. (TRBAM-22-01746) used Explainable Artificial Intelligence (XAI) for early anticipation of crashes. Wei, Z. et al. (TRBAM-22-01811) applied Explainable Machine Learning (XML) techniques in to model rural interstates daily crash occurrence and severity. Abdelhalim, A. et al. (TRBAM-22-01944) used three-step gradient boosting approach for crash frequency prediction utilizing geospatial, roadway geometry, and pavement condition information. Phan, L. et al. (TRBAM-22-02211) compared logistic regression and long short-term memory for vehicular crash hotspot prediction. Mansour, U. et al. (TRBAM-22-02721) used α-Reliable Mean-Excess approach to model Modeling Reliability and unreliability of safety in the network equilibrium model. Lei, Y. et al. (TRBAM-22-02833) conducted safety analysis using a Gaussian Process Modulated Renewal Model. Islam, Z. and M. Abdel-Aty (TRBAM-22-02958) used a data augmentation technique to reproduce crash data. Yehia, A. et al. (TRBAM-22-02993) used imbalanced classification algorithm for real-time safety analysis using floating car data on expressway. Mahmoud, N. et al. (TRBAM-22-02362) conducted research on the differences between operating speed and target speed using Mixed-Effect Ordered Logit model. Dai, Z. et al. (TRBAM-22-02558) used Boosting techniques in macro-level safety modeling for predicting crashes at various times.

Besides the above papers there were also the following doctoral student research conducted by the following students (Lectern Session 1246). There were no ABSTRACT available for these dissertations.

Student	Paper Number	Dissertation Topic
M. Chakraborty	P22-20780	Relationship between Horizontal Curve Characteristics and Single Vehicle Crashes on Rural Two-Lane Highways
R. Yocum	P22-20781	Socialization of Safety: An Investigation into the Impact Socioeconomic Factors Have on Crash Frequency, Severity, Risk, and Cost in Pennsylvania
A. Bakhshi	P22-20782	Safety Performance Assessment of the Wyoming Connected Vehicle Pilot Deployment Program
A. Hosseinzadeh	P22-20783	Linking Motor Vehicle Crashes with Emergency Medical Services Runs and Trauma Registry for Injury Outcome Assessment
Q. Chang	P22-20784	A Machine Learning Approach to Quantify Effects of Design Features on Wrong-Way Driving Incidents at Off-Ramp Terminals of Partial Cloverlead Interchanges
Q. Ma	P22-20785	E-Scooter Safety: Understanding the Impact of Wheel Size Using Mobile Sensing Data
A. Arun	P22-20786	A Novel Road User Safety Field Theory to Estimate Crash Frequency-By-Severity: Application of Computer Vision Techniques for Automated Safety Assessment
H. Alambeigi	P22-20787	Modeling Driver Behavior During Automated Vehicle Takeovers
Y. Song	P22-20788	Traffic Crash Patterns and Causations based on Sequence of Events: Preparing for a Transition into Automated Transportation
T. Panwinkler	P22-20789	Accident of Pedelecs (Pedal Electric Bicycles) and Conventional Bicycles in Comparison: Structural and Spatial Analysis
G.Pai	P22-20791	Drivers' Hazard Avoidance During Vehicle Automation: Impact of Mental Models and Implications for Training

ASC20 Sessions

Poster Session 1056

Safety of Motorcyclists and Active Transportation Modes (36)
Monday, January 10 8:00 AM- 9:30 AM ET
Convention Center, Hall A
Cong Chen, University of South Florida
Sponsored by: Standing Committee on Safety Performance and Analysis (ACS20)

Authors	Haniyeh Ghomi, McMaster University Mohamed Hussein, McMaster University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-00639
Paper Title	**Analyzing the Safety Consequences of Pedestrian Spatial Violation at Mid-blocks: A Bayesian Structural Equation Modelling Approach**
Abstract	The objective of this study is to understand the impact of a variety of factors on the frequency and severity of pedestrian-vehicle collisions that involve pedestrian spatial violations (jaywalking) at mid-blocks. To that end, the historical collision records of the City of Hamilton between 2010 and 2017 were obtained, and collisions that occur at mid-blocks were filtered out. A Bayesian Structural Equation Modelling (SEM) framework was developed to investigate the impact of a wide range of factors on such collisions. First, a classical SEM was developed to group the different factors into sets of latent variables. Four latent variables were defined, including location amenities and attractions, pedestrian/road network characteristics, exposure parameters, and location/collision-specific factors. Then, the Bayesian SEM was implemented to investigate the relationship between the latent variables and collisions. The results showed that amenities and attractions of a location (e.g., parks, schools, bike-share stations, and bus stops) were the most influential factor on the frequency of collisions that involve jaywalking, followed by the pedestrian network characteristics. Pedestrian network characteristics and location/collision-specific factors were found to be the most influential factors on the severity of collisions. The location of bikeshare stations, pedestrian network connectivity, exposure to walkers, and the number of lanes were the four observed variables that explained the highest percent of the variance in each latent group, respectively. The results of this study should assist engineers and planners to develop better design concepts to mitigate collisions that are caused by pedestrian spatial violations in urban areas.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette Raju Thapa, Louisiana Transportation Research Center (LTRC) Julius Codjoe, Louisiana Department of Transportation and Development
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-00813
Paper Title	**Applying Association Rules Mining to Investigate Pedestrian Fatal and Injury Crash Patterns Under Different Lighting Conditions**
Abstract	The pattern of pedestrian crashes varies greatly depending on lighting circumstances, emphasizing the need of examining pedestrian crashes in various lighting conditions. Using Louisiana pedestrian fatal and injury crash data (2010-2019), this study applied Association Rules Mining (ARM) to identify hidden pattern of crash risk factors according to three different lighting conditions (daylight, dark-with-streetlight, and dark-no-streetlight). Based on the generated rules, the results show that daylight pedestrian crashes are associated with children (<15 years), senior pedestrians (>64 years), older drivers (>64 years), and other driving behaviors such as 'failure to yield', 'inattentive/distracted', 'illness/fatigue/asleep'. Additionally, young drivers (15-24 years) are involved in severe pedestrian crashes in the daylight condition. This study also found pedestrian alcohol/drug involvement as the most frequent item in the dark-with-streetlight condition. This crash type is particularly associated with pedestrian action (crossing intersection/midblock), driver age (55-64 years), speed limit (30-35 mph), and specific area type (business with mixed residential area). Fatal pedestrian crashes are found to be associated with roadways with high-speed limits (>50 mph) during the dark without streetlight condition. Some other risk factors linked with 'high-speed limit' related crashes are pedestrians walking with/against the traffic, presence of pedestrian dark clothing, pedestrian alcohol/drug involvement. The research findings are expected to provide improved understanding of the underlying relationships between pedestrian crash risk factors and specific lighting conditions. Highway safety experts can utilize these findings to conduct a decision-making process for selecting effective countermeasures to reduce pedestrian crashes strategically.

Authors	Ian Hamilton, VHB Kristin Kersavage, VHB Richard Porter, VHB Vikash Gayah, Pennsylvania State University, University Park Josie Sanchez Keith Smith, VHB Carol Tan, Federal Highway Administration (FHWA) Ana Maria Eigen, Federal Highway Administration (FHWA)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-00872
Paper Title	**Application of Emerging Data Sources for Pedestrian Safety Analysis in Charlotte, NC**
Abstract	Pedestrian safety is a growing concern for transportation planners and safety engineers at both the local and State levels. Continued advancements in data availability, data integration abilities, and analysis methodologies offer new opportunities to identify factors influencing pedestrian safety and quantify their effects to inform data-driven road safety management. The main objective of this study was to spatially integrate Highway Safety Information System (HSIS) data with multijurisdictional and emerging datasets to analyze two measures of pedestrian safety performance in Charlotte, NC: 1) the severity of a pedestrian crash that has occurred, and 2) the probability that a pedestrian crash will occur on a given roadway segment. To accomplish the study objectives, the study explored several high-priority research topics in safety data and analysis, including pedestrian exposure analysis and probe data integration. The research team developed a pedestrian count model to predict pedestrian volumes at locations without pedestrian counts and integrated speed information from probe data to supplement other roadway and contextual transportation data available from several agencies. Pedestrian exposure at a given intersection was found to be significantly influenced by demographic and socioeconomic characteristics, employment, land use, sidewalk presence, transit access, and roadway and intersection characteristics. The project team identified numerous significant factors that influenced pedestrian crash severity and probability, including outputs from the pedestrian exposure model, observed vehicle speeds, traffic volumes, intersection proximity, and other crash-related factors. The results can be used to identify locations that are more susceptible to pedestrian safety issues.

Authors	Jina Mahmoudi, University of Maryland, College Park Chenfeng Xiong, University of Maryland, College Park Mofeng Yang, University of Maryland, College Park Weiyu Luo, University of Maryland, College Park
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-01032
Paper Title	**Modeling the Frequency of Pedestrian and Bicyclist Crashes at Intersections: Big Data-driven Evidence from Maryland**
Abstract	This study leverages big location-based service data collected from mobile devices in 2019 to conduct a pedestrian and bicyclist safety analysis. Statistical models are estimated for pedestrian and bicyclist crash frequency at Maryland intersections using location-based service data as risk exposure data. The analysis is performed by employing prominent frequency modeling methodologies including Poisson, negative binomial, zero-inflated Poisson, and zero-inflated negative binomial regression techniques. The findings indicate that inclusion of big location-based service exposure data in the analysis improves the performance of the models. Further, the results suggest that key contributing factors to pedestrian and bicyclist crashes at Maryland intersections include: i) intersection design- and traffic-related attributes, such as number of intersection legs, presence of a traffic signal, average level of traffic stress rating, and safety risk exposure measures such as the average daily pedestrian, bicyclist, and vehicle volumes at the intersection; ii) travel-related attributes including public transportation and nonmotorized mode shares within the intersection's census block group; iii) land use and built environment attributes such as road network density, activity density, and extent of walkability within the census block group; iv) socioeconomic and sociodemographic attributes including the percentage of low-income workers, households with no vehicles, African American population, and senior population within the census block group. The findings of the study show how big location-based service exposure data can be utilized to identify pedestrian and bicyclist safety risks and guide data-driven, evidence-based policy decision-making to improve the safety of vulnerable road users.

Authors	Muyang Lu, Pennsylvania State University, University Park Vikash Gayah, Pennsylvania State University, University Park S. Ilgin Guler, Penn State: The Pennsylvania State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-01216
Paper Title	**Analysis of Shared Bike and Other Exposure Measures in A Macroscopic Crash Frequency Model**
Abstract	Macroscopic traffic safety models that predict crash frequency over regions of a transportation network are becoming increasingly common. However, perhaps due to data availability, these models tend to focus only on vehicle exposure attributes to the detriment of non-motorized vehicle information. A handful of studies have integrated single explanatory variables that capture non-motorized transportation use into macroscopic safety prediction models. This study seeks to extend these works by incorporating several exposure metrics that capture nonmotorized and public transportation use. A macro-level crash prediction model for the Manhattan area of New York City is developed that considers roadway and demographic variables, as well as bike share trip information, subway flows, taxi movements, and person-trips to various points of interest (POI) as measures of travel exposure. The models are developed using negative binomial regression and various functional forms are considered. The results show that the number of shared bike trips and POI visits are positively associated with increases in pedestrian and cyclist crash frequencies; however, these features are less descriptive of motorist crash frequency. In addition, the explanatory power of POI information can be improved by considering only a subset of POI categories that represent "essential" trips. These include Health Care, Miscellaneous and Grocery Stores, Schools, Transportation, and Motor Vehicle, Food and Drinking, Public Services. Route length, route density and traffic surrogate datasets are more influential to the motorists involved crashes.

Authors	Reuben Tamakloe, University of Seoul Jungyeol Hong Dongjoo Park, University of Seoul
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-01365
Paper Title	**Investigating Chains of Risk Factors Influencing Fatal Powered Two-Wheeler Crashes at Spatio-Temporal Hotspot Locations in South Korea**
Abstract	Although researchers have explored factors influencing the safety of PTW's, no study comprehensively investigates the risk factors influencing their safety at crash hotspot locations considering the fault status of the rider and the geographical extent or area associated with frequent PTW crashes. As research suggests that spatial and temporal dependencies among crashes exist and that the factors influencing crashes are likely to differ based on the fault status of the road user, it is imperative to conduct a study that explores the contributory factors of fatal PTW crashes considering the riders fault status and the location of the crash. This study employs a spatio-temporal analytic tool and the Association Rule Mining (ARM) technique to discover hidden associations between crash-risk factors that lead to fatal PTW crashes based on the fault status of the rider at statistically significant PTW crash hotspots in South Korea from 2012 to 2017. The study results indicate the emergence of consecutive fatal PTW crash hotspots primarily concentrated around the central business district of South Korea's capital, Seoul. Interestingly, while reckless riding was the main traffic violation leading to PTW rider at-fault crashes at hotspots, violations such as improper safety distance and red-light running were strongly associated with PTW rider not-at-fault crashes at hotspots. Besides, while PTW rider at-fault crashes are likely to occur during summer, PTW rider not-at-fault crashes mostly occurred during spring. Engineering, enforcement, and education-related countermeasures targeted at both PTW's, and other vehicles are suggested to help improve traffic safety at the hotspot locations.

Authors	Yuying Zhou, VHB Scott Himes, VHB Thanh Le, VHB Jeff Gooch, VHB Kayla Northup, VHB Peter Pavao, VHB
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-01847
Paper Title	**Safety Effectiveness of the Road Diet Treatment in Rhode Island**
Abstract	A Road Diet is a low-cost countermeasure which typically involves converting an existing four-lane undivided roadway to a three-lane roadway, reducing the section to two through lanes and a center two-way left-turn lane (TWLTL). The objective of this evaluation was to estimate the safety effectiveness of Road Diets by developing a Rhode Island-specific crash modification factor (CMF). To account for potential selection bias and regression-to-the-mean, an empirical Bayes (EB) before-after analysis was conducted, using reference groups of untreated 4-lane undivided roadways with similar characteristics to the treated sites. Results indicated a 29 percent decrease (CMF = 0.71) in total crashes and a 37 percent reduction in fatal and injury crashes (CMF = 0.63). The expected results of the evaluation will help RIDOT to determine a statewide direction for implementation of the countermeasure.

Authors	Yang Li, University of Wisconsin, Milwaukee Farah Al-Mahameed, John Wiley and Sons, Inc. Xiao Qin, University of Wisconsin, Milwaukee Robert Schneider, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-02737
Paper Title	**New Insights on Vulnerable Road User (VRU) Safety Analysis through Crash Database Improvement**
Abstract	To better understand the reasons behind crashes and to comply with the Model Minimum Uniform Crash Criteria (MMUCC) 5TH Edition, Wisconsin Department of Transportation (WisDOT) replaced the old version of the motor vehicle crash report form (MV4000) in 2017 with a new form (DT4000) that provides more relevant and complete information through new and expanded fields. This study analyzed the values of new data fields and attributes in the DT4000 form for crashes involving pedestrians and bicyclists, as known as vulnerable road user (VRU), using exploratory data analyses (EDA) and the Chi-square automatic interaction detector (CHAID). Specifically, we want to know if the new attributes added significant value to the VRU crash data. EDA produced the descriptive statistics for a selected list of data fields; and CHAID helped to select and rank variables by their prediction power on the VRU injury severity levels. The two forms produced different distributions and patterns of the same data. Results show that the new attributes and data fields offered a better opportunity to enable a more specific and comprehensive analysis, such as VRU locations, VRU's actions, and intersection-related roadway characteristics, involved parties' conditions, distracted driving involvement, and the action of a bicyclist immediately prior to a crash. Such information can provide examples of how better data collection and data quality can significantly improve safety analysis, especially for VRU.

Authors	Monik Gupta, Indian Institute of Technology, Bombay Nagendra Velaga, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-02913
Paper Title	**Modeling Traffic Violation Decisions of Motorized Two-Wheeler Drivers**
Abstract	Motorized Two-Wheeler (MTW) drivers contribute to the large share of road fatalities due to their vulnerability and higher severity of crashes. Traffic violations and human errors are the major contributing factors to road crashes. The data from 460 motorized two-wheeler drivers were collected through an online questionnaire exploring the traffic violation tendencies, latent psychological factors, and demographic attributes of the participants. The analysis was performed in the following three steps: (a) the Exploratory Factor Analysis (EFA) was performed to measure the latent psychological parameters from the questionnaire, (b) the decision tree was developed to classify the traffic violation choices based on demographic, and latent psychological parameters, thirteen interaction variables were obtained to explain the combined effect of demographic and psychological variables, (c) the binary logistic regression models were developed to quantify the traffic violation decisions based on demographic, latent psychological variables, and the interaction variables. The results showed that drivers were 1.3 times more likely to violate the traffic rules if they panicked and felt anxious while driving. Drivers having a vehicle of more than 150 CC (cubic cm) engine capacity had 1.8 times more odds of violating the traffic rules than the lower engine capacity vehicle drivers. Overall, this study quantified the impact of underlying psychological factors, demographic parameters, and their combined effect to assess the traffic violation tendencies among motorized two-wheeler drivers. These findings can help in evidence-based policymaking to restrict the traffic rules violations and therefore, can help in achieving the road safety goals.

Authors	Hao Chai Zheyong Bian, University of Houston Zhipeng Zhang, Shanghai Jiao Tong University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-02933
Paper Title	**Investigating Conflict Behaviors of Two-Wheel Vehicles at Non-Signalized Intersections Based on Trajectory Data**
Abstract	Unsafe acts occurred at intersections have become a primary contributor to traffic accidents and fatalities. A majority of studies have focused on signalized intersections in the past decade. Non-signalized intersections only raise limited concerns from previous researchers although they commonly exist on campus or suburban areas and have resulted in high-consequence accidents recently. Two-wheel vehicles (e.g., bicycles and e-bikes) are gaining popularity worldwide due to high mobility and low carbon emissions. Meanwhile, they are proven to be one of the most vulnerable transportation modes with high accident frequency and fatality rates. This study investigated the two-wheel vehicle-involved conflicts at non-signalized intersections based on trajectory data automatically collected from big video data. A practical framework was firstly proposed and employed to gather and process the microscopic trajectory data. To detect two-wheel vehicle-involved conflicts, this study employed a near-crash identification along with a post encroachment time (PET) indicator. These framework and methodology have been applied in a case study of one university campus in Shanghai. The traffic-related statistics and Chi-Square tests show that a higher proportion of conflicts occurred at the intersection entrances and yielding behaviors were not taken by a large proportion of the road users in conflicts. Ultimately, the analytical results can contribute to the development of intersection-specific countermeasures in traffic safety from the perspectives of education, engineering, and law enforcement. The vision-based methodology framework can also be adapted to other transportation scenarios to enhance safety management with accessible video data.

Authors	Yunfei Zhan, Southeast University School of Transportation Yulu Dai, Southeast University School of Transportation Sixuan Xu, Southeast University School of Transportation Xinbo Xie, Southeast University School of Transportation Huihuang Zhu, Southeast University School of Transportation
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-02948
Paper Title	**Quantifying Diverse Types of Pedestrian-Vehicle Conflicts at Actuated Signal Control Intersections with Lightgbm and SHAP**
Abstract	Signalized intersections are crash prone locations for pedestrians. Traditional crash modeling methods have limited capability, since they depend on historical crash data amount and quality. Traffic conflict are considered to be highly correlated with crash, with much higher frequency. Therefore, conflict-based safety modeling methods have been extensively used in recent years. In order to explore pedestrian risk at signalized intersections, three typical four-leg signalized intersections in Bellevue, Washington were selected in this study. Based on collected data, a Light Gradient Boosting Machine (LightGBM) was developed to identify the relationship between three types of pedestrian conflicts (i.e., left turn traffic, right turn traffic, and through traffic) with traffic volume, control type and roadway geometrics. A Shapley Additive explanation (SHAP) method was used to visualize and explain the impact of significant factors. Important findings include: (1) protected left turn phase may need to be considered, since higher left turn volume(>150 pcu/h) and pedestrian volume would cause higher risk with permitted left turn; two-stage pedestrian crossing and phase switch time adjustment could be considered to decrease risk between left turn traffic (>300 pcu/h) and pedestrians who have not cleared the intersection, for lag left turn protected control; (2) a certain level of traffic volume(600-800 pcu/h) may increase the risk of pedestrians who violate the pedestrian signal control; (3)when right turn traffic volume is high (>150 pcu/h), a long pedestrian red flashing time may increase jaywalking and risk. The research findings could provide valuable knowledge for pedestrian safety improvement at signalized intersections.

Authors	Nada Mahmoud, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai, Waymo Ou Zheng, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-03376
Paper Title	**An Integrated Approach to Identify Pedestrian and Bike Crash Hotspots Considering the Context Classification for Multi-lane Arterials**
Abstract	This research proposes an integrated approach to estimate vulnerable road users' exposure, develop safety performance functions, and identify the crash hotspots at intersections and along the roadway segments. The study utilized big data from multiple sources including Automated Traffic Signal Performance Measures (ATSPM) data, crowdsourced data (Strava), Closed Circuit Television (CCTV) surveillance camera videos, crash data, traffic information, roadway features, land use attributes, and socio-demographic characteristics. Statistical and machine learning models were developed and compared to estimate pedestrian and bike exposure. The results concluded that the Extreme Gradient Boosting outperformed other developed models in vulnerable road users' exposure estimation. The estimated exposure was utilized in developing the crash prediction models using Negative Binomial approach. The exposure variables (i.e., AADT, bike exposure, and the interaction between them) were found to have significant influences on vulnerable road users crashes at intersections and along roadway segments. Further, the context classification was significantly related to crash occurrence. C4-Urban General roadway segments were found to be significantly related to the increase of vulnerable road users' crashes at intersections and bike crashes along the segments. Afterwards, the crash hotspots were identified based on the calculated based on the Potential for Safety Improvements (PSI). Crashes were more likely to be located near the city of Orlando.

Authors	Runan Yang, University of South Florida Zhenyu Wang, University of South Florida Chanyoung Lee, Center for Urban Transportation Research at USF
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-03684
Paper Title	**Recursive Bivariate Probit Analysis of Fatalities and Improper Actions in Motorcycle- Vehicle Crashes on Horizontal Curves**
Abstract	A cause-effect chain, which describes the relationship between contributing factors, driver/rider improper pre-crash actions, and crash outcome (injury severity), exists in motorcycle-vehicle crashes on horizontal curves. Previous studies did not address the correlation between injury severity and improper actions in identifying risk factors. This study aimed to develop a recursive bivariate analysis to simultaneously investigate the effects of covariates on motorcyclist fatality and improper actions (for both riders and drivers) in curve-related motorcycle-vehicle crashes. Two recursive bivariate probit models were developed to identify significant factors that contribute to riders' or drivers' improper actions, factors that directly impact motorcyclist fatality only, and factors that influence motorcyclist fatality and riders' or drivers' improper actions simultaneously. The direct, indirect, and joint marginal effects of the identified contributing factors on motorcyclist fatality risk were addressed based on fitted models. The model results indicate that either riders' or drivers' improper actions in a motorcycle-vehicle crash significantly increase motorcyclist fatality risk. Riders' physical defects and alcohol/drug involvement are the most significant factors contributing to both riders' improper pre-crash actions and motorcyclist fatality. Curve design features were also found to have significant but diverse impacts on rider/driver improper actions and/or motorcyclist fatality risk. Other significant factors included roadway, rider, and driver characteristics. The recursive bivariate probit analysis approach produced fruitful results and provided useful information about concealed causal factors in injury severity analysis.

Authors	Qiang Zhang, Southeast University Xiaojian Hu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-03730
Paper Title	**Safety Analysis on Pedestrian-vehicle Exit Interactions at Non-signalized Intersections Based on YOLOv3-DeepSort**
Abstract	With the development of video surveillance technology, intelligent surveillance technology has been widely used in traffic safety. Traffic safety at non-signalized intersections has always been the focus of attention all over the world. Most researchers are dedicated to studying the interaction of traffic participants at the entrance of an intersection. However, the pedestrian-vehicle interaction at the exit of the intersection is also worthy of being studied. And this type of pedestrian-vehicle interaction is rarely studied. This paper takes pedestrians and vehicles as typical targets to study the interactive behavior at the exits of non-signalized intersections, and to study methods for extracting object trajectories in videos. For that purpose, we propose a processing framework for the analysis of pedestrian-vehicle interaction behaviors based on YOLOv3-DeepSort. The methodology is confirmed by practical case study in the stop-controlled intersections from someplace, China. Different measurements are used in the case: from the interaction analysis that determines pedestrian-vehicle interactions based on a Distance-Speed (DS) model, average crossing speeds and vehicle approaching behaviors in terms of speed. We obtain these measures from the trajectory data extracted by YOLOv3-DeepSort. Based on these measures, a comparative analysis is carried out between entrance and exit interactions. Results show that it is of great significance to the safety analysis of pedestrian-vehicle exit interactions at non-signalized intersections.

Authors	Jeff Gooch, VHB Ian Hamilton, VHB Bonnie Polin, Massachusetts Department of Transportation Riana Tanzen Tal Cohen
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-03819
Paper Title	**Systemic Safety Analysis of Mid-Block Pedestrian Crashes in Massachusetts**
Abstract	Pedestrians are vulnerable road users on Massachusetts roadways. To develop safety improvement projects to address pedestrian safety issues, MassDOT conducted a systemic safety analysis of severe mid-block pedestrian crashes. The analysis incorporated crash, roadway, transit, census, and equity data to identify roadway segments which were at the highest risk for a severe pedestrian crash. Based on overrepresentation, principal arterials, minor arterials, and major collectors were identified as focus facility types. Binomial logit regression was used to identify risk factors for each focus facility type. Risk factors included number of lanes, traffic volume, population density, commute behaviors, employment density, and measures of equity. The authors found consistent risk factors across the three focus facility types. Ultimately, MassDOT will use these results to prioritize sites for mid-block pedestrian safety systemic improvements.

Authors	William Agyemang, University of Alabama Emmanuel Adanu, University of Alabama Jun Liu, University of Alabama Steven Jones, The University of Alabama
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04196
Paper Title	**A Latent Class Analysis of Factors Associated with Injury Outcomes of Pedestrian Crashes on Inter-Urban Highways in Ghana.**
Abstract	Over the years, the uncontrolled interaction of human and vehicular activities of settlement areas along highways in Ghana has witnessed a rise in road traffic fatalities and injuries involving vulnerable road users, especially pedestrians. The increase in these pedestrian injury outcomes has been attributed to the problem of land planning usage and lack of pedestrian crossing facilities for safe crossing of the road. This study used Ghana as a case study to identify the factors associated with pedestrian injury outcomes. The multinomial logit latent class (MNL-LC) modeling method was employed to account for unobserved heterogeneity in the crash data used. Pedestrian-vehicle crash data from 2014 to 2018 on highways totaling 3037 was used for the modeling. The model estimation results show that speeding, hit and run and no shoulder was more likely to result in fatal injury while crashes involving pedestrians who were crossing the road had a 0.56% increase likelihood to result in hospitalized injury outcomes. Also, it was found that multiple-vehicle crashes increase the chance of minor injury outcomes and the road shoulder with over-grown weeds variable increased the probability of all the other injury outcomes except in fatal injury. The findings of the study provide bases for the development of appropriate countermeasures to reduce the number of pedestrian deaths and injuries in Ghana and other countries in the sub-region.

Authors	Dania Ammar, University of Michigan-Dearborn Aditi Misra, University of Michigan Shan Bao, University of Michigan, Dearborn
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04269
Paper Title	**Identify Factors related to Crash Injury Levels involving Bicyclists: A Crash Data Analysis**
Abstract	The safety of vulnerable road users has become an increasing society concern. The purpose of this paper is to provide a unique analysis of identifying significant factors that impact on bicyclists' crash injury levels through comparisons of several models. This paper describes the application of three standard multinomial logit models on the Crash Report Sampling System data from three consecutive years. Bicyclists' injuries were classified into three levels: Possible, Moderate, and Severe. The study found several significant factors were associated with the increasing likelihood of severe injuries on travel lanes including the time period between 2 am and 5:59 am, the year period between July and August , rural areas, crosswalks' availability, and unsignalized, uncontrolled and unleveled roadways . On the other hand, the occurrence of crashes during weekends and at non-trafficways or driveway access were the factors leading to lower probability of higher severities on non-travel lanes. Factors associated with higher likelihood of moderate and severe injuries at both locations were vehicles' high speed , straight moving direction compared to turning right , and crash with trucks , drivers' age being less than 30, and bicyclists' age being greater than 55 . Interestingly, bicyclists aged within 19-55 tend to be at a higher risk of developing severe injuries at other locations than those who are younger. Results of this study contributes to understanding crash scenarios and dictating the level of damage to the bicyclist allow the alteration of some circumstances characterizing these crashes, when possible, to reduce potential injuries.

Authors	Dania Ammar, University of Michigan-Dearborn Yueru Xu, Southeast University Bochen Jia Shan Bao, University of Michigan, Dearborn
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04321
Paper Title	**An Examination of Pedestrian Safety at Intersections through Crash Data Analysis**
Abstract	Pedestrians are the most vulnerable road users and are at risk of severe consequences when involved in traffic accidents. The purpose of this research is to determine the factors that have significant impacts on the increasing likelihood of pedestrians being seriously injured or killed when involved in a collision with a single vehicle at an intersection over past six years. Both 20132015 GES and 2016-2018 CRSS crash data from NHTSA were used in the analysis. The logistic regression models for the crash data showed that pedestrian age, light, vehicle type, and vehicle pre-motion are significant variables affecting pedestrians' injury severity levels. The pairwise comparison of the coefficients of the common factors in both models using the Wald chi-square statistic test shows similar results with few exceptions. Specifically, the GES data distinguished the weather, driver's age, pedestrian pre-crash movement, and speeding as further significant factors while CRSS data distinguished the year quarter and the number of lanes. The GES dataset factors imposing a higher threat on pedestrians were the drivers' belonging to the 19-25 age group, their speeding, pedestrians' roadway crossings compared to working or playing, and unexpectedly adverse weather conditions. On the other hand, the increasing number of lanes and crashes happening in the year period between July and August were the triggering factors for higher severities in the CRSS dataset. The variables indicating a higher likelihood of pedestrians' severe injuries in both datasets were pedestrians older than 26, dark lighting conditions, light trucks, and vehicles' right turning maneuvers.

Authors	Yige Tang, The Goodman Corporation T. Donna Chen (tdchen@virginia.edu), University of Virginia Linda Lim, University of Virginia
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04367
Paper Title	**Road Diet Safety Impact on Multimodal Transportation**
Abstract	A road diet's objective is to improve safety for all roadway users, while increasing livability by creating a bicycle and pedestrian friendly environment. This study analyzes safety impacts of 57 road diets completed in five states in the United States over the last 15 years for vehicle, pedestrian, and bicycle modes, using the Empirical Bayes (EB) method where traffic volume data was available and Naïve Before and After (Naïve) method where volume data was unavailable. EB analysis of 85 segments and 107 intersections (from 24 road diet projects) estimated segment crash modification factors (CMFs) of 0.66 for vehicle-only crashes, 0.89 for vehicle-pedestrian crashes, and 0.35 for vehicle-bike crashes; intersection CMFs were estimated to be 0.53 for vehicle-only crashes, 0.44 for vehicle-pedestrian crashes, and 0.41 for vehicle-bike crashes. The Naïve method analysis of all 57 road diet projects estimated CMFs of 0.85 for vehicle-only crashes, 1.12 for vehicle-pedestrian crashes, and 0.98 for vehicle-bike crashes. Results suggest that road diet safety impacts on pedestrians are not conclusive, especially given the rising numbers of pedestrian crashes in recent years. Furthermore, the lack of standard bicycle and pedestrian volume data across different states limits the ability to measure mode-specific safety impacts of road diets across larger samples of project locations, highlighting the need to increase data collection efforts on non-motorized modes.

Authors	Amrita Goswamy, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Nada Mahmoud, University of Central Florida Qing Cai, Waymo
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04393
Paper Title	**Safety Effectiveness of Rectangular Rapid Flashing Beacons (RRFB)**
Abstract	In 2017 about 5,977 pedestrians were killed in traffic crashes in the United States. Mid-block crossings of streets, particularly large busy arterials, can be unsafe as drivers may often fail to stop or yield to pedestrians in the uncontrolled marked crosswalks. The Rectangular Rapid Flashing Beacons (RRFB) is a pedestrian crosswalk countermeasure system that caution drivers by providing them with real-time warning about the presence of pedestrians in an upcoming crosswalk. This paper investigated the safety effectiveness of existing RRFBs installed in the state of Florida between 2013 to 2018 on state and county roadways with speed limit ranging from 25 to 55 mph. Data from all seven districts of Florida was incorporated. The study evaluated 154 treatment sites with RRFB installations and 158 control sites without RRFB with similar roadway and traffic characteristics. Safety performance functions were developed using negative binomial models and crash modification factors were calculated using the Empirical Bayes (EB) methodology for total pedestrian crashes, injury and non-injury pedestrian crashes. A Crash Modification Factor (CMF) of 0.31 for total pedestrian crashes was observed showing that RRFB have the potential to reduce 69% of total pedestrian involved crashes that included fatal, injury and property damage only crashes. The study also calculated the CMF for fatal and injury pedestrian crashes grouped together to be 0.30 and the CMF for injury pedestrian crashes was calculated to be 0.27. This showed that RRFBs have good potential to reduce injury crashes.

Authors	Cecilia Kadeha, Florida International University Angela Kitali, University of Washington Tacoma Jimoku Salum, Florida International University Priyanka Alluri, Florida International University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04437
Paper Title	**Safety Performance of Midblock Pedestrian Crossing Treatments**
Abstract	Pedestrian safety is a serious concern, especially at midblock locations. Crossing streets at uncontrolled midblock locations can pose a serious risk to pedestrians. Midblock crosswalks offer a safer, more visible, and more direct route for pedestrians to cross and encourage pedestrians to cross at designated locations. This study quantified the safety effectiveness of pedestrian safety treatments at midblock locations in Florida. A cross-sectional analysis using a Bayesian zeroinflated negative binomial regression model was used to evaluate the safety of midblock segments and develop crash modification factors (CMFs) for different geometric, traffic, land-use, and census variables. The analysis was based on five years (2012-2016) of midblock pedestrian crashes in Florida. The analysis results revealed that the following variables significantly increased (at a 90% Bayesian credible interval) the frequency of pedestrian crashes: natural logarithm of AADT; proportion of the low-income population; density of bus stops; density of bars and food establishments; and density of shopping centers. On the other hand, the rise in proportion of senior population (aged 65 or older) and logarithm of the total population reduced the frequency of pedestrian crashes. Although not significant at the 90% Bayesian credible interval, midblock segments with crosswalks had a CMF of 0.82, indicating an 18% reduction in pedestrian crashes. Moreover, the posterior probability distribution indicates 71% chance midblock pedestrian treatments will reduce pedestrian crashes. The results could help practitioners strategically install pedestrian crossing treatments that could improve pedestrian safety at midblock locations.

Authors	Ming-heng Wang, Taiwan Police College
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04613
Paper Title	**Investigating the Difference of Factors Contributing to Motorcyclist Fatality in Single Motorcycle and Multiple Vehicle Crashes**
Abstract	Motorcyclists account for more than sixty percent of traffic fatalities in Taiwan, and nearly thirty percent of them were in single-motorcycle crashes. Five years of motorcycle-involved crash data were divided into three subset data of single-motorcycle (SM), motorcycle-motorcycle (MM), and motorcycle-vehicle (MV) crashes. Three logistic regression models were conducted to identify the factors contributing to motorcyclist fatalities and to examine the relevant variables for determining the odds of motorcyclist fatality. The results showed the significant factors for all motorcycle-involved crashes include crash time, lighting condition, speed limit, gender, age, helmet use, engine size, and BAC values. Specific factors in SM crashes include hitting fixed objects, run-off-road, riding without a license, crashes on the curve, grade segments, and road median with barriers or traffic islands. In MM and MV crashes, the significant factors include head-on collisions, crashes on rural roads, good weather conditions, improper turns and violating the right of way. Collisions with big heavy motorcycles and all other motor vehicles, unlicensed, speeding, improper turning, violating the right of way, distracted, positive BAC motorcyclists or vehicle drivers are also factors for MM and MV crashes. Law enforcement should focus on unlicensed, impaired, speeding motorcyclists and drivers, and those who violate the right of way and have improper turns. Roadside objects and facilities such as utility poles, traffic devices, or traffic islands should be checked for the appropriate locations and equipped with reflective devices or injury protection facilities.

Authors	Rebecca Sanders, Safe Streets Research & Consulting Trisalyn Nelson
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1056
Session Title	Safety of Motorcyclists and Active Transportation Modes (36)
Paper Number	TRBAM-22-04849
Paper Title	**Near Misses, Crashes, and Falls while E-scooting, Walking, and Bicycling in a College Tow**
Abstract	Dockless e-scooters were used for 86 million trips in 2019, indicating great potential as a new transportation mode in cities and on university campuses. Yet, little is known about how escooters users interact with people walking, bicycling, and driving. While several studies have examined e-scooter injuries reported in hospital data, near misses are chronically understudied in general, and even more so for this newer mode of transportation. This paper presents the results of an online survey of 1256 university staff (22% response rate) in Tempe, AZ. Using this single population, we compare the prevalence of incidents and incident types, crashes, and injuries and injury types among those who use e-scooters, walk, and bicycle. Our results indicate key differences in how e-scooter users experience safety incidents compared to people walking and bicycling, with e-scooter users more likely to report issues related to pavement, equipment, or losing control, and people walking and bicycling more likely to report conflicts with other roadway users. Our findings suggest important areas for policy and infrastructure innovation, including prioritizing separate space for e-scooters to mitigate conflicts with pedestrians, and continuing to evolve rider training and speed governance to help keep e-scooter users safe. Other findings corroborate the underreporting of injuries among non-auto users and underscore the importance of measuring near misses to develop a comprehensive picture of transportation safety.

Lectern Session 1246

Doctoral Student Research in Transportation Safety

Tuesday, January 11 10:30 AM- 12:00 PM ET
Convention Center, Salon AB
Lectern

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

Authors	Meghna Chakraborty, Michigan State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20780
Paper Title	**Relationship between Horizontal Curve Characteristics and Single Vehicle Crashes on Rural Two-Lane Highways**
Abstract	Not Available.

Authors	Rebeka Yocum, Penn State: The Pennsylvania State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20781
Paper Title	**Socialization of Safety: An Investigation into the Impact Socioeconomic Factors Have on Crash Frequency, Severity, Risk, and Cost in Pennsylvania**
Abstract	Not Available.

Authors	Arash Bakhshi, University of Wyoming
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20782
Paper Title	**Safety Performance Assessment of the Wyoming Connected Vehicle Pilot Deployment Program**
Abstract	Not Available.

Authors	Aryan Hosseinzadeh, University of Louisville
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20783
Paper Title	**Linking Motor Vehicle Crashes with Emergency Medical Services Runs and Trauma Registry for Injury Outcome Assessment**
Abstract	Not Available.

Authors	Qing Chang, Auburn University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20784
Paper Title	**A Machine Learning Approach to Quantify Effects of Design Features on Wrong-Way Driving Incidents at Off-Ramp Terminals of Partial Cloverlead Interchanges**
Abstract	Not Available.

Authors	Qingyu Ma, Old Dominion University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20785
Paper Title	**E-Scooter Safety: Understanding the Impact of Wheel Size Using Mobile Sensing Data**
Abstract	Not Available.

Authors	Ashutosh Arun, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20786
Paper Title	**A Novel Road User Safety Field Theory to Estimate Crash Frequency-By-Severity: Application of Computer Vision Techniques for Automated Safety Assessment**
Abstract	Not Available.

Authors	Hananeh Alambeigi, Texas A&M University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20787
Paper Title	**Modeling Driver Behavior During Automated Vehicle Takeovers**
Abstract	Not Available.

Authors	Yu (Fred) Song, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20788
Paper Title	**Traffic Crash Patterns and Causations based on Sequence of Events: Preparing for a Transition into Automated Transportation**
Abstract	Not Available.

Authors	Tobias Panwinkler, TU Dortmund University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20789
Paper Title	**Accident of Pedelecs (Pedal Electric Bicycles) and Conventional Bicycles in Comparison: Structural and Spatial Analysis**
Abstract	Not Available.

Authors	Ganesh Pai, University of Massachusetts, Amherst
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lecturn Session 1246
Session Title	Doctoral Student Research in Transportation Safety
Paper Number	P22-20791
Paper Title	**Drivers' Hazard Avoidance During Vehicle Automation: Impact of Mental Models and Implications for Training**
Abstract	Not Available.

Poster Session 1268

TRB Minority Student Fellows Research Presentations

Tuesday, January 11 10:30 AM- 12:00 PM ET
Convention Center, Hall A

Poster

Sponsored by: Section - Executive Management Issues (AJE00)

Authors	Laura Camarena, University of Texas, El Paso
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	P22-20513
Paper Title	**Importance of Fine Aggregates in Achieving Adequate Skid Resistance in TxDOT Hot Mix Asphalt Mixtures**
Abstract	The three main performance-related issues that a pavement exhibits are excessive cracking and rutting, and a loss of skid resistance. The cracking- and rutting-related issues are minimized by the recently developed Balance Mixed Design (BMD) procedure. Poor skid resistance is one of the main reasons for accidents in different environmental conditions. A well-designed pavement would satisfy the friction demand of the road and reduce wet-pavement accidents. Many of the pavements that show adequate skid resistance shortly after construction, may experience rapid decay in their skid resistance due to excessive polishing of aggregates by vehicles. Despite many comprehensive studies related to frictional characteristics and performance of pavement surfaces, the results of such studies have not been consolidated into a comprehensive design guideline for addressing friction issues. This study aims to expand the possibility of using the laboratory polishing and frictional testing procedure in asphalt concrete mixtures as an assessment and quality acceptance test method. This study also evaluates the influence of fine aggregates and fines on the skid resistance of asphalt concrete. Thus, providing a guideline and procedure for transportation agencies on the design of high skid resistance fine mixes.

Authors	Esther Bia, University of New Mexico - Albuquerque: The University of New Mexico Nick Ferenchak, University of New Mexico
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	TRBAM-22-03517
Paper Title	**The Impact of Bus Rapid Transit on Traffic Safety: A Case Study from Albuquerque, New Mexico**
Abstract	Bus rapid transit (BRT) systems are becoming increasingly popular, yet their interaction with traffic safety has not been fully explored in the United States. How do BRT systems impact traffic safety, and specifically for vulnerable road users such as pedestrians? Albuquerque, New Mexico recently installed the Albuquerque Rapid Transit (ART) system, a BRT system running along Central Avenue, a main east/west corridor through the city. Using collision data and volume counts for three snapshots in time (before, during, and after construction of the BRT), we analyzed the safety outcomes (all collisions and fatal/serious injury collisions) for all road users and pedestrians. We compared outcomes from the ART corridor to outcomes on alternative routes, on control segments of Central Avenue (those that did not see ART construction), and across the city. Collision counts saw the strongest decreases from before to after on the ART corridor (8.2%). These benefits were more marked for fatal and serious injury collisions, with those collisions decreasing 64.9% on ART (compared to a 5.7% decrease on control segments). Although vehicle volumes decreased an average of 28.6% after construction on Central Avenue, per vehicle rates of fatal and serious collisions still decreased 57.1%. These results indicate that ART made the corridor safer overall (fewer total collisions), and while the risk to individual drivers increased, an individual's chance of being fatally or seriously injured decreased significantly (-57.1%). Findings suggest that BRT systems can play an important role in the pursuit of a safe, healthy, and efficient transportation system.

Authors	Joi Robinson, Tennessee State University Deo Chimba, Tennessee State University Hellen Shita, Tennessee State University
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	TRBAM-22-00844
Paper Title	**Freight Segment Crashes and Hazmat Evaluation**
Abstract	Freight Intermodal Connectors (FICs) which are also known as "first mile/last mile roadways" are connector facilities that link freight-intensive land uses to main freight routes. For the efficient and reliable freight movements, FICs must be in good operational and safety conditions. Intermodal freight logistic hubs attract significant amount of trucks which deliver and pick up goods, containers and services through public roadway segments, hence experience safety issues. This paper evaluated FICs in Tennessee to identify deficiencies related to safety needs. The connectors were ranked based on if critical crash rates exceed actual rates. The crash analysis along the connectors was conducted using the Negative Binomial (NB) regression with the Random Effect to address the issue of random variation due to unobserved factors as well as the heterogeneity due to variations in FIC segment types and characteristics. The NB model parameters were estimated using the Markov chain Monte Carlo (MCMC) simulations using the Bayesian Regression Models. Model results show traffic volume, land use characteristics, connector length, median type and access density are significantly influencing crash occurrences along these connectors.

Authors	Maya Mayes, Tennessee State University Suleman Swai, Tennessee State University Deo Chimba, Tennessee State University Hellen Shita, Tennessee State University
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	TRBAM-22-01011
Paper Title	**Safety Analysis of Near Intersections Parking**
Abstract	This study evaluated occurrence of crashes due to parked vehicles near intersections. The frequency and the severity of the crashes were assessed using crash data spanning 2007 to 2017. The study analyzed crashes that occurred within 100ft of the intersections throughout Tennessee. The analysis showed about 89% of these types of crashes were property damage only (PDO), 9% were minor injury, and 2% were severe injury or fatal crashes. The Zero Inflated Negative Binomial (ZINB) and Multinomial Probit (MNP) were used to assess the severity and crash frequency respectively. It was found that higher number of lanes, higher directional split, and higher AADT increases the likelihood of crashes involving parked vehicles near intersections. Injury severity modeling using Multinomial Probit (MNP) regression showed that the urban landuse, total number of vehicles involved in a crash, and presence of street lighting all have a significant influence to injury severities.

Authors	Norel Mcadoo, Tennessee State University Deo Chimba, Tennessee State University Hellen Shita, Tennessee State University
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	TRBAM-22-00845
Paper Title	**Correlation of Incident Duration to Highway Crashes**
Abstract	This paper introduces Hurdle Models (HM) which according to literature assumes two scenarios with respect to crash or incident occurrence; sections which never experience crash or incidents and sections that have experienced crashes or incidents at least once. The paper uses Hurdle Models (HM) to analyze scheduled and unscheduled roadwork related incidents and secondary crashes, and then compare the findings to those obtained through ZINB model. Two families of Hurdle models (NB-complementary log-log, and NB-logit) and ZINB were used to model incidents to evaluate the impact of different roadway, traffic, environmental and driver variables. The best model was evaluated in terms of model fitness and statistical significance of the variables. The results showed that ZINB model have the best fitness compared to NB-logit and NB-complementary log-log. However, NB-logit and NB-complementary log-log results were comparative to one another as they produced nearly equal weights of Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) though their fitness was significantly lower compared to those of ZINB. Weighting the hurdle models, NB-complementary log-log was found to be 0.3 times likely to minimize information loss compared to a NB-logit model.

Authors	Jose Portillo Deo Chimba, Tennessee State University Hellen Shita, Tennessee State University
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	TRBAM-22-00319
Paper Title	**Patterning Demographic and Socioeconomic Characteristics Affecting Pedestrian and Bicycle Crash Frequency**
Abstract	The objective of this study was to investigate factors influencing occurrence of pedestrian and bicycle crashes in Tennessee. Areas of interest were demographic, socio-economic, roadway geometry, traffic, and land use factors that could influence pedestrian and bicycle crash rates on specific infrastructure. Geographic Information System (GIS) and statistical modeling were applied to study the crash patterns with respect to these factors. GIS was used to geo-locate and collect the crash locations onto the roadway network joined with background data of the crash locations. Negative Binomial (NB) regression was used to model the relationship between contributing factors and the crashes in order to detect any positive or negative correlations with the crashes. The following factors were found to have significant correlation with pedestrian and bicycle crash occurrences: percentage distribution of population by race, age groups, mean household income, percentage in the labor force, poverty level, and vehicle ownership. Land use, number of lanes crossed by pedestrians or bicyclists, posted speed limit and the presence of special speed zones, were all found to influence the occurrence of these crashes significantly. The findings were used to identify patterns of demographic, socio-economic, variables (geographic or geometric) in pedestrian and bicycle high crash locations in Tennessee and using that pattern to flag other areas to indicate to TDOT they, also, are more likely to experience pedestrian and bicycle crashes.

Authors	Jesus Molina, Florida International University Angela Kitali, University of Washington Tacoma Priyanka Alluri, Florida International University
Sponsoring Committee	Section - Executive Management Issues (AJE00)
Session Number	Poster Session 1268
Session Title	TRB Minority Student Fellows Research Presentations
Paper Number	TRBAM-22-03735
Paper Title	**Is There a Relationship Between Daylight Saving Time and Traffic Crashes?**
Abstract	Daylight saving time (DST) begins each year at 2:00 am on the second Sunday of March (clock moves forward by one hour) and ends at 2:00 am on the first Sunday of November (clock moves back by one hour). The study was conducted using 37 years of crash data in Florida from 1983 to 2019. The analysis was based on crashes that occurred during the week before and the week following the time change. The paired Wilcoxon rank test implemented using a Bayesian approach was used to compare the difference in crash frequency following the clock shift due to DST. The analysis showed that the time shift has a significant effect on traffic crashes. More specifically, the beginning of DST in the spring was associated with a higher frequency of fatal and nighttime crashes. Shifting of clock following the end of DST in the fall resulted in a significant increase in all, no injury, morning peak hours, afternoon off-peak hours, two-vehicle, and multiple-vehicle crashes. Crashes during evening peak hours decreased in the immediate week following the time change. These findings were primarily significant the Sunday when the shift occurred and the following Monday and Tuesday. It may be inferred from these findings that the impact of DST on safety may be attributed to disruption of circadian rhythms and not only the one-hour loss in the spring and one-hour gain in the fall. The study findings can assist researchers and practitioners in understanding the impacts of DST on safety.

Poster Session 1304

Safety Performance and Strategies (52)

Tuesday, January 11 1:30 PM- 3:00 PM ET
Convention Center, Hall A
Poster

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

Authors	Asif Mahmud, Pennsylvania State University Vikash Gayah, Pennsylvania State University, University Park
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-00053
Paper Title	**Estimation of Crash Type Frequencies on Individual Collector Roadway Segments**
Abstract	Individual collision types have different underlying causes and thus the relationships between roadway/traffic characteristics and crash frequency are likely to differ across unique collision types. While developing separate statistical models for each collision type is the most straightforward approach, it can be very tedious and can produce unreliable estimates for rare collision types. Moreover, ignoring correlations between different collision types may result in biased and inefficient parameter estimation. To overcome these limitations, researchers have adopted a multivariate approach and a two-stage approach. In two-stage approach, a model which predicts total crash frequency is combined with proportion model to predict frequency of different collision types. More efficient one-stage joint models, in which both the frequency and proportion model are estimated simultaneously and predictions are provided more directly, have also been proposed for macro-level analysis. This study investigates the performance of joint model paradigm in analyzing unique collision type frequencies on individual road segments. For this, a joint negative binomial-multinomial fractional split (NB-MFS) model is used. Moreover, this study also proposes the use of a multinomial logit (MNL) model to estimate the proportion of different collision types. As total crash frequency NB model and MNL utilize different datasets, a two-stage estimation process is required, which leads to the two-stage NB-MNL model proposed here. The goodness of fit statistics show that the NB-MNL model performs better than collision-specific NB models, multivariate negative binomial (MVNB) model and joint NB-MFS model and is thus a promising approach in predicting crash frequency by collision type.

Authors	Xing Li, Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-00234
Paper Title	**Integrated Analysis of Contributing Factors to Traffic Violations and Crashes**
Abstract	This study investigates contributing factors to traffic infractions' seriousness. In this study, the traffic infractions are divided into four categories by seriousness (normal driving, minor violation, serious violation, and crash with violation). The ordered logit model with heterogeneity in means indicate that many factors potentially affect the likelihood of traffic violations by severity including individual, time, and socioeconomic factors. The key findings include (1) drivers are more likely to commit serious violations during the nighttime; (2) areas with a higher proportion of driving to work are less likely to have serious violations; (3) Hispanic drivers in the area with longer travel time to work are more likely to be associated with a more serious infraction. The results from this study are expected to be beneficial for policymakers to comprehend the factors increasing the probability of traffic violations and establish effective strategies to minimize the number and seriousness of traffic infractions. Keywords: Traffic Safety, Traffic Violation, Traffic Crash, Random Parameters with Heterogeneity in Means and Variances, Ordered Logit

Authors	Scott Himes, VHB James Bonneson, Kittelson & Associates, Inc. (KAI) Vikash Gayah, Pennsylvania State University, University Park Xiaoyue Cathy Liu, University of Utah
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-00658
Paper Title	**Safety Prediction Method for Freeway Facilities with High Occupancy Lanes**
Abstract	The objective of this paper is to describe the development of a safety prediction method for freeways with High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes, collectively referred to as HO lanes. This method has been developed and documented in a manner that is consistent with the safety evaluation methods in Part C of the Highway Safety Manual (HSM). Such a predictive methodology would assist State DOTs in explicitly considering safety performance impacts when planning, designing, and operating freeway facilities with HO lanes. Data were collected in California and Washington to support development of the predictive methodology. This method focuses on the evaluation of one freeway travel direction with each application. The paper summarizes key differences and similarities between this method and the current predictive method for freeways in Chapter 18 of the HSM Supplement. The method includes models for predicting total crash frequency and multiple-vehicle crash frequency. The method applies to freeway facilities with continuous HO lane access, buffer-separated HO lanes with intermittent access, and barrier/pylon-separate HO lanes with intermittent access between the HO lane(s) and the GP lanes. The method does not differentiate between HOV and HOT designation

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-00902
Paper Title	**Exploring Relationship between Credit Ratings and Crash Risk**
Abstract	The emergence of a data-rich world contributes to data-driven analyses across all engineering fields. This research examines the use of publicly available data to improve existing traffic crash prediction models. The research builds upon prior work that analyzed the relationship of census variables and crash performance models. This study seeks to explore whether other publicly available data could assist in explaining crash variability for use as a surrogate measure of risk. Credit scores by zip code in the state of California are publicly available and were used to interpolate credit scores throughout the state. These data were then examined to see whether there is any relationship to crash risk. The results showed both positive and negative trends between credit rating and crash frequency for levels of credit rating and annual average daily traffic. The research demonstrates that the use of public credit score data may have value in helping explain crash variability. Though the study served as a proof-of-concept in presenting the use of publicly available data sources, at this time, the results of the study are still inconclusive. Future studies should include investigation of more crash locations to control for confounders, and increase the granularity of the credit rating data to overcome study assumptions

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01064
Paper Title	**Safety Evaluation of Freeway Exit Ramps with Advisory Speed Reductions**
Abstract	Posted speed limits inform drivers of the maximum permissible safe speed on the highway under ideal roadway, traffic, and weather conditions. Various studies have investigated the safety impacts of speed limit changes, particularly on high-speed rural highways. One area of particular concern on such roadways is the approach to exit ramps that require substantive speed reductions, such as loop ramps. To date, there has been limited research examining the safety impact of the differential between the mainline speed limit and the lower exit ramp advisory speeds. This study aims to evaluate this relationship through the estimate of a series of safety performance functions. Random effects negative binomial regression models were estimated using data from 187 exit ramps where advisory speed signs are present throughout rural Michigan. The analyses were based on a five-year analysis period from 2014 to 2019. This includes a transition period where Michigan increased speed limits on more than 600 miles of limited access freeways in 2017. In addition to speed differentials, various roadway characteristics such as deceleration lane length and curve radius were also evaluated. Results indicate that lane departure crashes increased as the difference between mainline and ramp speed increased. The study also identified exit ramps with deceleration lane lengths less than the minimum recommendation as per the AASHTO Green Book. These sites were found to experience higher numbers of crashes compared to ramps with above-minimum deceleration lane lengths

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01097
Paper Title	**Safety and Operational Effectiveness of Protected Only Versus Protected/Permitted LeftTurn Signal Phase**
Abstract	Roadway intersections fatalities account for around 24% of total fatalities each year, with left-turning vehicles associated with most of these crashes. To manage the left-turning movements, various left-turn signal phases like protected only (PO), protected/permitted left-turn (PPLT), and flashing yellow arrow (FYA) are currently in use. However, their overall effectiveness has not been well established. The paper evaluated the safety and operational effectiveness of PO over PPLT left-turn signal phase using sample intersections from Louisiana

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01141
Paper Title	**Estimation of Freeway Segment Project Design-Level SPFs and Adjustment Factors using Ohio Data**
Abstract	Safety performance functions (SPFs), and associated adjustment factors (AFs), play a critical role in reliable crash prediction. SPFs are mathematical equations that predict average crash frequency for a facility based on traffic volume, segment length, and other roadway characteristics. Project design-level SPFs help to quantity and compare the safety performance of alternative geometric design and traffic operations characteristics. Agencies generally have two options for obtaining SPFs: 1) calibrating national SPFs or 2) developing jurisdiction-specific SPFs. The objective of this effort was to engage in developing project design-level SPFs to improve the prediction of safety performance for project design alternatives on freeway segments in Ohio. A further objective was to evaluate the predictive performance of the Ohio Department of Transportation's (ODOT's) calibrated version of the Highway Safety Manual (HSM) predictive model, a new bi-directional predictive method, and a new one-direction predictive method. The results indicated the one-direction predictive method provided reliable predictions for all crash types and severities when compared to the baseline of the calibrated version of the HSM predictive method. The one-direction method is easier to implement on complex alignments, provides a broad set of AFs, but does exclude some factors that may be relevant to practitioners. Additional external crash modification factors may be considered with the onedirection predictive method, as needed, to analyze the factors that are excluded from the onedirection predictive method

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01173
Paper Title	**Safety Performance of Unsignalized 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. MUT intersections (also known as "Michigan lefts", "boulevard turnarounds", or "Michigan loons") are one such design that accommodates all left-turn movements via directional U-turn crossovers within the median. Prior work has consistently shown that MUTs can provide superior safety performance when used in the appropriate conditions. However, research which is specific to unsignalized reduced left-turn conflict intersections continues to be limited to work conducted prior to the Highway Safety Manual or which includes RCUT intersections. This study included the evaluation of historical traffic crashes and volume data at 95 unsignalized intersections in the state of Michigan. This included the collection of data for 39 MUT sites and 56 reference group sites in order to estimate SPFs and CMFs which can be used when considering future conversions. Ultimately, CMFs for fatal and injury crashes of 0.438 and 0.686 are recommended when converting intersections with undivided two-lane two-way major approaches and four-lane divided boulevard major approaches, respectively. While there was no significant difference in PDO crashes associated with converting intersections with undivided two-lane two-way major approaches, a CMF of 1.325 is recommended for PDO crashes specific to conversions with four-lane divided boulevard major approaches

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01452
Paper Title	**Inferring causal effects of work zone configurations on crash risk**
Abstract	The increasing amount of crashes occurred in work zones has received considerable attention in recent years. Previous studies mainly focus on associations between work zone configurations and crashes occurrence. While identification of associational relations helps understand how work zones co-exist with crashes, it does not provide interventional guidelines necessary to improve safety of work zone operations. In this paper, a causal inference model based on Potential Outcome framework is proposed to infer the true causal effects of work zone configurations on crash risks. In the development of such model, three challenges have been identified and addressed: (1) Potential confounding bias due to unobserveable roadway characteristics; (2) Potential bias caused by unobserved variables in multi-source data; (3) Lack of the actually observed traffic data and weather information at the time when a crash occurs. The proposed methodology and the results are validated via a series of robustness tests. The results show that the causal effect of a work zone on crash occurrence is significantly positive, especially on roadways with high traffic volumes, long work zone distances and during day time. It appears conducting work zones during night time with the current deployment strategies in Pennsylvania does not necessarily increase crash risks

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01509
Paper Title	**Comprehensive Assessment of Road Section Risk Caused by Risky Driving Behavior**
Abstract	ABSTRACT In order to reduce the potential risk of risky driving behavior and improve road traffic safety, a comprehensive risk assessment model of road traffic risky driving behavior was proposed, which took road sections scenes as the basic modeling unit. Firstly, the vehicle operation parameters and road traffic environment data were extracted from video data collected by unmanned aerial vehicles. Next, the risk assessment index system was established based on scene elements selection and the weight of each index was determined by the modified entropy method. Then, a comprehensive risk assessment model of risky driving behavior was constructed based on Cloud-Fuzzy Comprehensive Evaluation and Grey Correlation Analysis, which could not only evaluate the risk level of a single scene, but also rank the risk levels of multiple scenarios by constructing the risk correlation order between different scenes. Finally, the application of the model was illustrated by three typical scenes in Jiading District of Shanghai. The model could be applied to road traffic systems with electronic monitoring devices, to realize dynamic evaluation about the risk and real-time warning of risky driving behavior. Keywords: Risk assessment of risky driving behavior, Cloud-Fuzzy Comprehensive Evaluation, Road section risk, Risk correlation order

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-01750
Paper Title	**Exploring relationships between urban crash-related factors and aberrant behaviors considering the spatial variability within the same country**
Abstract	Crash data analyses based on accident datasets often do not include human-related variables because they can be hardly reconstructed from crash data. However, records of crash circumstances can help for this purpose, since crashes are classified considering aberrant behaviors undertaken by the drivers. In this case, urban crash data from the 10 greatest Italian cities were used to develop four logistic regression models having as dependent variable the human-related crash circumstance (distracted or careless driving, illegal maneuvering, pedestrian hit and speeding) and the other crash-related factors as predictors (information about the users and the vehicles involved and about road geometry and conditions). Another model was built to account for injury severity. The spatial variability across the 10 different cities was considered through a multilevel approach, which however revealed the spatial variability only for distraction-related crashes. In the other models, the effect of the spatial variability was unsignificant instead, indicating quite homogeneous behavioral aspects related to crashes within the same country. Results showed several relationships between crash factors (driver, vehicle or road-related) and human-related crash circumstances and severity. The presence of crossings and unsignalized intersections was particularly related to crashes with illegal maneuvering as crash circumstance while the night period was clearly related to speeding crashes and to severe crashes, as well as vehicles different than cars, as expected. This study was conceived for exploring relationships between crash factors and human-related crash circumstances, but it also provides practical insights concerning safety measures in the urban environment, based on crash data analysis

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02066
Paper Title	**Understanding Patterns of Contributing Factors in Encroachment-Related Work Zone Crashes**
Abstract	Work zone safety is one of the critical goals of transportation agencies. Vehicles change the 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. Frequency of the roadway departures at work zones, higher risk of fatality, and little insights about encroachment types at work zones assert the need for a thorough study. This study aims 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 a unique data mining method known as Cluster Correspondence Analysis (CA). This method identified four clusters in 'non injury' and 'fatal and injury' crash data separately. Major factors contributing to vehicle encroachment were identified. Three dominating clusters are median related crashes on two lane divided high volume roadways, single vehicle overturning collisions on two-way divided roadways with unprotected median, and overturning crashes on two-lane undivided roadways in controlled traffic. The findings of this study will be useful for safety engineers to contribute reducing encroachment related work zone crashes

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02205
Paper Title	**Statistical Analysis of Inter-Crash Time Under The Impact of A Long-term Work Zone**
Abstract	Disrupted traffic in work zones introduces mobility and safety concerns for both road users and maintenance personnel. To assist long-term work zone traffic management to improve safety performance, it is critical to investigate the impact of work zone on traffic accidents in terms of crash frequency and severity. In this study, we present the survival analysis based inter-crash time modeling before and during a major rehabilitation project in New Jersey, and identify the influencing factors that may accelerate the occurrence rate of crashes with the presence of the longterm work zone. The regression model applied in the study could serve as a crash warning system with different crash risk indicators and prepare traffic operators with potential changes of crash risk under different situations in the work zone area

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02290
Paper Title	**Wrong-Way Driving Crash Propensity: Does Locality and Nonlocality Matter?**
Abstract	Extensive research has been conducted on Wrong-Way Driving (WWD) prone crash locations, crash contributing factors, and safety countermeasures. Still, the number of WWD crashes remains nearly constant over the past years, necessitating further investigation from different perspectives. Past studies identified various crash contributing factors that directly contributed to WWD crash frequency and severity. Prime factors include driver characteristics, environmental and temporal characteristics, and interchange layouts. However, the impact of locality and non-locality on WWD crash propensity is seldom investigated. Therefore, this study explores the major WWD crash contributing factors related to local and non-local drivers. A total of 1,048 WWD fatal crashes from 2015 to 2017 were collected from the Fatality Analysis Report System (FARS) database. Drivers' locality and non-locality were defined using the distance traveled from home to crash location using Geographic Information System. Descriptive statistics and a multinomial logit model were developed to analyze the significant contributing factors specific to driver groups. The results demonstrated that factors such as rural setting, unprotected median types, and dark but not lighted conditions significantly contributed to WWD fatal crashes when the driver was non-local. In contrast, local drivers are more prone to be involved in WWD crashes in urban areas and while driving under the influence of alcohol or drugs. Based on the results, different safety countermeasures related to WWD crashes were recommended targeting local and non-local drivers

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02308
Paper Title	**The Evolution of Parking Safety: Past, Present, and Future**
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 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. This research provides a comprehensive overview of parking lot crashes and an analysis of related crash statistics. Additionally, this research assessed the potential safety benefits that could have been achieved if self-driving and self-parking vehicles had been available. Researchers used the CRIS data available for the Texas crash database and estimated that self-driving and self-parking technologies could eliminate nearly 39,000 parking lot crashes, 3,100 injuries, 287 serious injuries and 30 fatalities per year. Results also estimated that cost savings associated with Texas parking lot crashes could average between $888 million and $946 million per year if self-driving and self-parking vehicles were available

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02324
Paper Title	**Effect of the "Peak and Plate" Vehicular Restriction on Accident Rates Colombia's Experience**
Abstract	This paper analyzes the influence of license plate number restriction ("peak and plate") on vehicular circulation (congestion) and accident rates in urban areas. To this effect, the authors conducted a statistical analysis of a grouping of records obtained by traffic authorities to study the correlation between the occurrence of accidents and the implementation of a traffic demand management measure, such as restriction based on the last license plate number, for periods of time before and after the measure is enforced. The proposed methodology was applied in Medellín and Bogotá, Colombia. The main findings indicate that more accidents occur in the hours before and after those in which the restriction applies

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02434
Paper Title	**Dynamic Updating Evaluation of Vehicle Collision Risks at the Upstream Toll Plaza Area**
Abstract	This study aims to estimate the real-time vehicle collision risk in diverging area of toll plaza. With the trajectory data extracted from unmanned aerial vehicle (UAV) videos, six different discrete sampling methods are employed to reduce calculation pressure. Using the extended time to collision (ETTC) as an indicator to measure vehicle collision risk, Bayesian dynamic logistic regression (LR) model is developed to estimate the vehicle collision risk and its contributing factors in diverging area with different sampling methods, and compared the prediction accuracy with Standard LR model by using Area under Receiver Operating Characteristics curve (AUC). Furthermore, the sensitivity analysis of forgetting parameter and AUC in Bayesian dynamic LR models of different sampling methods is tested. The results show that the AUC values of all Bayesian dynamic LR models and Standard LR models are more than 0.9, which indicates that they have good prediction performance. Due to the Bayesian dynamic LR model could significantly reduce estimation time of dynamic data, it has higher calculation efficiency and better performance of collision risk evaluation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02572
Paper Title	**Modeling Aggressive Driving Behavior Based on Graph Construction**
Abstract	The occurrence of aggressive driving behavior is a random process among time-varying transversion. Regression models, which are based on the normal data construction (mean and S.D.), are not advanced in characterizing the driving feature among a large set of time-series attributes. This paper models aggressive driving behavior based on graph construction. The raw data are used to extract the pieces of the graph. Each graph represents a specific driving trip that includes driver characteristics, environment, and driving behavior variables. The effect of graph construction was verified based on the Shanghai Naturalistic Driving Study data. 17 variables related to aggressive driving are extracted based on statistical analysis. The result shows that a 5-sec time window is suitable for aggressive driving behavior modeling. 11 variables (speed, longitudinal acceleration, lateral acceleration, lateral placement, gender, age, distracted, drowsy, weather, flat curve, time-to-collision) can be used for graph construction based on high significance features. Both normal data construction and graph construction are used for modeling. The models based on a mean plus S.D. and graph construction can achieve higher accuracy and smaller error than normal (mean only), and graph construction present the best model performance. This paper also extracted the weight of each variable in the model. The main factor associated with aggressive driving is TTC, and the main factor of driving behavior that influences aggressive driving is the duration of aggressive longitudinal acceleration. This method can be used in real-world applications for improving driving safety with the applications in the Advanced Driver Assistance Systems.

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02574
Paper Title	**Addressing Endogeneity in modeling Speed Enforcement, Crash Risk and Crash Severity Simultaneously**
Abstract	Speeding is one of the major causes of significant increase in crash risk and the associated injury severity outcomes. To combat such significant safety concern, increased speed limit enforcement system has been adopted widely all around the world. This study aims to present an econometric approach that estimate the casual effect of speed enforcement on safety, while also addressing the endogeneity issue by employing an instrumental variable approach in conjunction with a simulated maximum likelihood approach. In our study, safety enforcement is represented as number of speeding tickets issued from the speed camera systems, while safety profile is presented as two dimensions of interests including total crash risk and crashes by injury severity levels. The proposed econometric model takes the form of a correlated panel random effect model with speed enforcement endogeneity. The empirical analysis is demonstrated by employing roadway segment-level crash data and speeding tickets data from Queensland, Australia for the year 2010 through 2013. The outcome of the study will allow the decision makers to identify a robust resource allocation and speed camera deployment plan

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02762
Paper Title	**Predicting the lane-changing decision and execution risks: A pre-emptive approach for the whole lane-changing process**
Abstract	Lane-changing (LC) maneuver has significant impacts on traffic safety. Instead of focusing on a specific stage of the LC process and the posterior LC risk estimation, this study proposed a pre-emptive LC risk prediction approach to explore the complete process of the LC decision (LCD) and execution. The execution process includes either implementing the LC (LCI) or keeping the current lane (LK). The HighD dataset was employed and three kinds of datasets were further extracted, i.e., the LCD datasets, the LCI datasets, and the LK datasets. For each dataset, we extracted features from trajectory data in three different time periods and constructed three sub-datasets. Then, we applied four machine classifiers to predict the LCD and the risk of LCI and LK, including the Decision Tree (DT), the Random Forest (RF), the Support Vector Machine (SVM), and the eXtreme Gradient Boosting (XGBoost). The results indicate that the simplest classifier DT performs very well on the LC decision datasets. In addition, the XGBoost performs better than the rest three classifiers on the LCI and LK datasets. According to the predictive performances of the classifiers on the highest risk level, we provide suggestions about which time period of the trajectory data should be selected for feature selection. The proposed approach could have the potential of being integrated into the advanced driver assistance system and vehicle-to-vehicle communication in the near future.

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-02934
Paper Title	**Investigation of Spatial Transferability of Alternative Parameterizations for the Dispersion Function in Negative Binomial Models Predicting Crash Counts by Severity**
Abstract	Negative binomial (NB) regression is commonly preferred to Poisson regression for modeling crash counts since it employs a dispersion parameter to allow the variance to differ from the mean. Recent researchers have gone further, defining the dispersion parameter as a function varying with geometric and traffic features to better fit the data. This study evaluates five alternative dispersion functions (DF) (one fixed, two varying with segment length only, and two varying with both segment length and traffic volume) in negative binomial models for predicting five crash severity counts on five types of rural and urban roadway segments using data from the Highway Safety Information System (HSIS). Models are evaluated on fit as well as spatial transferability. Model fit using each DF is tested using log-likelihood and Bayesian Information Criteria (BIC) and predictive accuracy is tested using holdout sample prediction for multiple draws. Spatial transferability is tested by predicting for data from a different state. In most cases, models with two dispersion parameters fit the data better than models with fixed or one dispersion parameter. However, models with one dispersion parameter (fixed or varying with segment length or traffic volume) have better holdout prediction accuracy than models with two dispersion parameters. Including traffic volume with segment length in the DF significantly improved the prediction accuracy for freeways. Models with one-parameter DFs have better transferability accuracy than those with two parameters. The fixed DF and one-parameter DF with segment length and traffic volume are best for non-freeway and freeway facilities, respectively.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03136
Paper Title	**A Comparative Study to Evaluate the Application of Different Negative Binomial-Lindley Variations in Crash Data Modeling**
Abstract	It has been shown by many studies that the Negative Binomial Lindley (NB-L) distribution offers a better performance compared to the commonly used Negative Binomial (NB) distribution, especially when the dataset is highly dispersed or includes many zero observations. Consequently, different variations of the NB-L distribution have been introduced through mixing the NB distribution with different Lindley generalizations. However, little is known on how these models perform or compared in different data domains. In addition, there are also multiple Lindley distributions that have not yet been tried in mixture with the NB distribution. This study conducted a comparative analysis among different variations of the NB-L distribution to determine which variation performs the best. We considered several previously developed, as well as two newly proposed variations, negative binomial weighted Lindley (NB-WLindley) and negative binomial quasi Lindley distributions. Results confirmed that the proposed NB-WLindley performs better in majority of data domains used in the simulation analysis. This study also examined the application of the NB-WLindley in generalized linear modeling (GLM). We found that the NB-WLindley GLM performs better relative to the traditional NB as well as the NB-L GLM proposed in the past.

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03185
Paper Title	**Safety Evaluation of Changing Speed Limit from 55 mph to 60 mph on Two-Lane, Two-Way Road Segments**
Abstract	This paper describes the efforts to evaluate the safety impacts of increasing the speed limit from 55 mph to 60 mph on selected two-lane, two-way state highway road segments in Minnesota. An empirical Bayes (EB) before-after analysis was used to estimate Crash Modification Factors (CMFs) for both segments and intersections. The segment analysis showed a 7 percent increase in total crashes that was statistically significant, alongside insignificant increases/decreases in injury crashes. The intersection analysis was split into two groups (all traffic control types and thru stop control only). The aggregate CMFs for all intersections within these two groups show that most of the CMFs hovered close to 1. Disaggregate intersection analysis was also performed on four subgroups (3- and 4-leg, lighting/no lighting). The aggregate analysis conducted using all the segment and intersection data showed very minor increase/decrease in the total and injury crashes. This aggregate result along with before and after operating speed data from another Minnesota Department of Transportation (2019) study showing that the 85th percentile operating speed remained the same and that the mean operating speeds increased by 1 mph following the speed limit increase can lead to a conclusion that the speed limit increase from 55 mph to 60 mph had a minor effect on combined segment and intersection crashes or operating speeds.

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03214
Paper Title	**Location-Based and Driver Class-based Analysis for Reaction Time in CarFollowing Situations**
Abstract	This study aims at examining the differences in driver's reaction time while driving on horizontal curves and straight roadway segments and among different driver classes to better emulate human driver behavior in car-following situations. For this purpose, speed, gap, relative speed, and acceleration were extracted from naturalistic car-following trajectories to estimate the reaction time. The reaction time was estimated for two stimuli-response pairs; namely, speed-gap and relative speed-acceleration pairs using the cross-classification method. The reaction time was estimated separately for each driver and aggregated based on location (i.e., curves and segments) and based on driver class (i.e., cautious, normal, and aggressive). The results reveal that drivers' reaction time on curves is consistently higher than their reaction time on straight segments and this difference is statistically significant. Moreover, the comparison between normal drivers and aggressive drivers indicates that regardless of the location, aggressive drivers have significantly longer reaction time than normal drivers as aggressive drivers can accept closer gaps and higher relative speed. Also, cautious drivers have a longer reaction time when compared to normal drivers; however, the difference is not significant in most cases. Furthermore, cautious and normal drivers have a longer reaction time on curves when compared to their reaction time on straight segments. These findings can enhance driver behavior simulation in car-following modeling and improve the prediction of human driver reactions in mixed human-driven and autonomous vehicles environment. Also, this study highlights the importance of considering drivers' inter-and intra-heterogeneity in mixed human-driver and autonomous vehicle environments.

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Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03348
Paper Title	**Analysis of Collision Avoidance Maneuvers and Risk Assessment of Aggressive and NonAggressive Drivers at Intersections**
Abstract	Driver's Collision Avoidance Maneuver (CAM) decision has a greater correlation with crash probability and its severity. The present study aimed to investigate the extent to which the crash impending scenario influence the CAMs of aggressive, moderately aggressive, and non-aggressive drivers at unsignalized intersections. The complexity or criticality of a situation plays an important role in drivers' CAM behavior. Therefore, the study designed five challenging critical road events (an oncoming vehicle approaches the conflict with varying time gaps: 3 sec to 7 sec to increase the criticality of the event) using a driving simulator. A Generalized Linear Mixed model was used to study the effects of driving aggression and conflict approaching time headways on CAM (evasive maneuvers observed in the study are brake-only, speeding, and brake and acceleration). It was observed that approaching speed is a major influencing factor of CAMs for all driver categories. With a 1 m/s increment in approaching speed, the probability of a driver adopting 'speeding' and brake and acceleration increased by 34% and 16% to avoid collisions. For aggressive drivers, the probability of adopting speeding and brake and acceleration to avoid collision increased by 1.87 times and 1.23 times, respectively. Similarly, it was increased by 1.94 times and 1.72 times, respectively for the drivers who had crash history. 65% of the aggressive drivers, who attempted excessive speeding to avoiding collision, were eventually crashed into conflict vehicle. Among three CAMs, 'speeding' (61%) is majorly contributing to crash occurrence followed by 'brake and acceleration' (34%).

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03499
Paper Title	**Finite Mixture Negative Binomial-Lindley to Model Heterogeneous Crash Data with Many Zero Observations**
Abstract	Crash data are often highly dispersed; it may also include a large amount of zero observations or have a long tail. The typical Negative Binomial (NB) model cannot model these data properly. The Negative Binomial-Lindley (NB-L) model has been proposed as an alternative to the NB to analyze data with these characteristics. Research studies have shown that the NB-L model has a superior performance comparing to the NB when data includes numerous zero observations or have a long tail. In addition, crash data often are collected from sites with different spatial or temporal characteristics. Therefore, it is not unusual to assume that crash data are drawn from multiple subpopulations. Finite mixture models are powerful tools to account for underlying subpopulations and capture the population heterogeneity. This research documents the derivations and characteristics of the Finite mixture NB-L model (FMNB-L) to analyze data generated from heterogeneous subpopulations with many zero observations and a long tail. We demonstrated the application of the model to detect subpopulations with a simulation study. We then used the FMNB-L model to estimate statistical models for Texas 4-lane freeway crashes. These data have unique characteristics; it is highly dispersed, have many locations with very large number of crashes, as well as significant number of locations with zero crash. We used multiple goodness-of-fit metrics to compare the FMNB-L model with the NB, NB-L and the finite mixture NB models. The FMNB-L detected two subpopulations in datasets. The results show a significantly better fit comparing to other analyzed models.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03530
Paper Title	**Spatial Analysis of the Relationship between Intersection Crashes and the Urban Built Environment: A Case Study of Des Moines**
Abstract	This study makes a methodological contribution by exploring the relationship between urban intersection crashes and the built environment. The study focuses on specific neighborhoods within the city of Des Moines, Iowa, with contrasting socioeconomic characteristics to examine variation between the neighborhoods. Exploratory Spatial Data Analysis was used to identify crash clusters at intersections using 7-year crash data (2013-2019) obtained from the Iowa Department of Transportation. Google Street View was used as a tool to develop the built environment variables. Regression modeling was then employed to establish a relationship between intersection crash clusters and the built environment. Study results show that commercial/institutional land uses, bus stops, and signalized intersections are significant and positively impact intersection crash incidence. Additionally, crash incidences were higher in neighborhoods with high household poverty percentages. These findings potentially can enlighten policymakers to focus on appropriate safety treatments such as traffic calming measures. Design ideas to improve the built environment and a policy re-evaluation for bus stop locations can be developed that could reduce intersection crashes.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03644
Paper Title	**A Tabu-Search-Based Combinatorial Subset Selection Approach to Support Investigation of Built Environment and Traffic Safety Relationship**
Abstract	Traffic crashes are a leading cause of death globally, with an increasing rate in urban areas. Considering this increasing risk, this study focuses on the relationship between built environment and traffic safety, and built environment variables needed to construct this relationship model. The aim of this paper is to determine the best subset of built environment variables through a generalizable methodology. The built environment is operationalized through the D-classification (e.g., density, diversity, and design), and various datasets are collected from different agencies. Traffic safety is operationalized through vehicle- and vulnerable road user (VRU)-involved crash frequencies at the zonal level. A preliminary GIS-based process is conducted to associate the crash data at the census block group level, followed by examining the built environment-traffic safety relationships through a series of negative binomial models optimized for subset selection. The model generation is performed automatically by an embedded tabu-search procedure. Two case studies are presented: a single county case (Leon) and a tri-county case (Miami-Dade, Broward, and Palm Beach). Results show that some variables such as population, bus stops, employment entropy, and traffic volume have positive relationships with crash occurrences. In contrast, several factors show inconsistent effects by crash type or location. For example, “motorized mode” parameter has a negative effect on crash occurrences in the single-county case, whereas it is insignificant for the tri-county case. “Non-motorized mode” parameter, on the other hand, has a positive effect on crash occurrences in the tri-county case, while it is insignificant for the single county case.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03889
Paper Title	**Formalizing the Swiss Cheese Model and Heinrich's Triangle to Support Accelerated Safety Assessment**
Abstract	There is significant ongoing research to proactively evaluate the safety of new technologies, including autonomous vehicles, before enough crashes occur to directly measure their impact. This paper advances a new approach to understand the generation mechanism of crashes and uses it to formulate a previously unknown relationship characterizing the distribution of safety-critical driving incidents, including both crash and non-crash safety incidents. We analyze the distributional form of five diverse datasets that approximate motor vehicle safety incident severity, including one dataset of hard braking events that characterizes the severity of non-crash incidents. Our empirical analysis finds that all five datasets closely fit a lognormal distribution (Kolmogorov-Smirnov distance < 0.012; significance of loglikelihood ratio with other distributions < .00003). We explain these results by linking them to well-known but largely qualitative safety frameworks related to the generation mechanism of safety-critical incidents as well as the frequency and severity of such events. We provide a theoretical formalization of the Swiss Cheese Model (SCM) and show through analysis and simulations that the formalization leads to a lognormal distribution of the severity continuum of safety-critical incidents. This finding is consistent with the empirical data we examine as well as Heinrich's Triangle, another heretofore largely qualitative framework that hypothesizes that safety events of increasing severity have decreasing frequency. Our results support the use of more frequent, low-severity events to rapidly assess safety for any system consistent with our formalization of SCM. This includes any complex system designed for robustness to single-point failures, including autonomous vehicles.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03921
Paper Title	**Behavioral Safety Analysis Using Integrated Multidisciplinary Data and Countermeasure Development**
Abstract	Driver errors contribute to more than ninety percent of traffic crashes on roadways. Predicting driver behavior-related crashes precisely plays a dominant role in identifying the sites with the highest potential for safety improvement and implementing effective countermeasures in reducing driver errors to improve highway safety. This study employs integrated multidisciplinary data to estimate crash prediction models for driver behavior-related crashes, including crash data, roadway geometry and traffic information, crime and citation data, toxicology data, socioeconomic and demographic data, and business data. Crash prediction models are estimated using the negative binomial model at the town level for six types of driver behaviors, i.e. impaired driving related crashes, aggressive driving related crashes, young driver involved crashes, motorcycle involved crashes, pedestrian involved crashes and distracted driving related crashes. The principal component analysis is conducted to account for the multicollinearity issue in the data. Moreover, this study proposes a procedure of collecting and standardizing countermeasures related to driver behaviors from different resources which can be used by practitioners to mitigate driver behavior-related issues and improve highway safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-03926
Paper Title	**Roadway Crash Prediction Model Updating in Guangzhou, China**
Abstract	Roadways, significant carriers of urban traffic, are essential to city safety improvement. Crash prediction models assist traffic administrators in identifying risk factors and estimate crash frequency, which play an essential role in traffic safety management. With crash occurrence and influencing factors change over time, however, the crash prediction models might not be suitable for current circumstances and even provided the wrong estimation for crash prediction. In order to explore the change of risk factors and crash frequency, this study conducted a longitudinal safety comparison of the urban roadway in Guangzhou, China. Utilizing the Bayesian negative binomial model framework, the relationships of crashes and safety influencing factors, such as road geometric characteristics, traffic operation characteristics, and road isolation facilities, have been accurately captured. Additionally, a two-stage Bayesian updating method was adopted to update the crash prediction model for 2020, based on informative prior information obtained from 2015. Modeling results indicated that updating an existing model is better than establishing a new model. Moreover, safety influencing factors had significant differences towards crashes longitudinally. The findings could be applied to long-term risk factors and hot spots identification, and more effective and well-targeted improvement measures can be implemented.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-04188
Paper Title	**Evaluation of Struck Parked Vehicle Crashes**
Abstract	Struck parked vehicle (SPV) crashes account for 3% of fatal and injury crashes in New Jersey—the same as head-on crashes—but SPV crashes are vastly under-researched. Moreover, SPV crashes are the state's fifth-highest crash type, accounting for 11% of all New Jersey crashes and amounting to an estimated cost of $845,847,000 in property damage and injury related expenses in 2018 in the state of New Jersey. SPV crashes are even more common on local roadways, accounting for 26% of municipal crashes and more than 20% of some counties' crashes. Despite the frequency of SPV crashes, there are few countermeasures to deploy against such crashes. The research described in this paper included a review of existing research on SPV crashes as well as a statewide analysis of SPV crash trends in New Jersey. One of the identified countermeasures, to stripe a parking lane, was further researched as a case study in a New Jersey municipality that frequently employs edgelines. An analysis of the case study findings show that there were 14% SPV crashes per mile on sections where there was an edgeline, compared with 20% SPV crashes per mile on section were there was not an edgeline.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-04220
Paper Title	**The COVID-19 pandemic and its effects on road crashes and crash outcomes in Alabama**
Abstract	With the rising number of cases and deaths from the COVID-19 pandemic, nations and local governments, including many across the U.S., imposed travel restrictions on their citizens. This travel restriction order led to a significant reduction in traffic volumes and a generally lower exposure to crashes. However, recent preliminary statistics in the US suggest an increase in fatal crashes over the period of lockdown in comparison to the same period in previous years. This study sought to investigate how the pandemic affected road crashes and crash outcomes in Alabama. Daily vehicle miles traveled and crashes were obtained and explored. To understand the factors associated with crash outcomes, four crash-severity models for manner of collision and time of the year were developed using the first 28 weeks of crashes recorded in 2020. The findings reveal that although traffic volumes and vehicle miles traveled had significantly dropped during the lockdown, there was an increase in the total number of crashes and major injury crashes compared to the period prior to the lockdown order, with speeding, DUI, and weekends accounting for a significant proportion of these crashes. These observations provide useful lessons for road safety improvements during extreme events that may require statewide lockdown, as has been done with the COVID-19 pandemic. Traffic management around shopping areas and other areas that may experience increased traffic volumes provide opportunities for road safety stakeholders to reduce the occurrence of crashes in the weeks leading to an announcement of any future statewide or local lockdowns.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-04264
Paper Title	**Distracted Driving Crashes: A Review on Data Collection, Analysis, and Crash Prevention Methods**
Abstract	Distracted driving is one of the top three reasons for traffic fatality. Every year, thousands of people get injured or killed in motor vehicle crashes resulting from distracted driving. The recent technological advancement has increased the sources and frequency of distractions. This study aims to conduct a comprehensive literature review and prepare a summary of findings for identifying best practices to collect and analyze data on distracted driving and countermeasures to mitigate distracted driving. We identified the works of literature in the last 15 years that focus exclusively on distracted driving. The results found that the severity of crashes due to distracted driving depends mainly on driver's behavior and the geometric design of roadway and temporal variables. It was also found that several techniques to collect driver behavior data using dashcam cameras integrated into the dashboard of the cars. For the detection of distracted driving, deep learning techniques are used mainly by researchers. We also found that the integration of the four E's approach in countermeasures is needed to mitigate distracted driving. These findings would further help decision-makers comprehend the significant contributing factors associated with crash injury severity due to distracted driving and implement necessary data collection, data analysis, and practical treatments to reduce the crash severity. Based on the literature review findings, we have proposed future research recommendations to address distracted driving.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Safety Performance and Strategies (52)
Paper Number	TRBAM-22-04494
Paper Title	**HSM Calibration Sample Size based on Calibration Factor Statistical Properties**
Abstract	The Highway Safety Manual (HSM) provides guidance for the calibration of Safety Performance Functions (SPFs) to adjust their predictions to new jurisdictions. The HSM also provides guidance on minimum sample sizes for calibration of SPFs. However, related research literature suggests that more data than HSM recommended may be needed to achieve successful calibration. This paper revises the problem of determining the sample size for calibration from the statical properties of the estimator of C, calibration factor defined in the HSM. General results confirmed prior research suggesting that the uncertainty of the C estimator is proportional to the crash coefficient of variation. Furthermore, under assumptions of negative binomial (NB) distributions of crashes, this paper showed that the standard error of the C estimator depends on the following features: sample size, the crash average, and the NB dispersion parameter. The paper proposes a formulation for the minimal sample size for estimating C, based on the desired precision, level of confidence, and the three influential features listed above. The paper briefly presents an application of the proposed formulation on Texas highway segment data. Finally, the paper identifies future work and provide recommendations based on these results.

Poster Session 1340
Advancing New Methods and Data (55)
Tuesday, January 11 4:00 PM- 5:30 PM ET
Convention Center, Hall A
Poster

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

Authors	Ahmed Al-Kaisy, Montana State University Kazi Huda, Montana State University, Bozeman
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00222
Paper Title	**Empirical Bayes Application on Low-Volume Roads: Oregon Case Study**
Abstract	This paper presents an investigation into the application of the Empirical Bayes (EB) method and the Highway Safety Manual (HSM) predictive methodology on low-volume roads in Oregon. A study sample of around 870 miles of rural two-lane roadways with extensive crash, traffic and roadway information was used in this investigation. To better understand the effect of low traffic exposure in estimating the EB expected number of crashes, the contributions of both the observed and the HSM predicted number of crashes were examined and analyzed. The study found that, on low-volume roads, the predicted number of crashes is the major contributor in estimating the EB expected number of crashes. The study also found a large discrepancy between the observed and the predicted number of crashes using the HSM procedures calibrated for the state of Oregon, which could partly be attributed to the unique attributes of low-volume roads that are different from the rest of the network. However, the expected number of crashes for the study sample using the HSM EB method was reasonably close to the observed number of crashes over the ten-year study period. The study findings show that it can still be very effective to use network screening methods that rely primarily on risk factors for low-volume road networks. This is especially applicable in situations where accurate and reliable crash data is not available. Keywords: low-volume roads, Empirical Bayes, crash prediction, network screening

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00295
Paper Title	**Exploring Relationships between Months and Different Types of Traffic Accidents: An Accident Risk Analysis of Mountain Freeways Based on Data Modeling**
Abstract	As well known, the traffic accident risk of mountain roads is significantly higher than that of ordinary roads. This paper took a mountainous freeway located in China as an example, utilizing K-means and Apriori to initially extract the monthly distribution patterns of different types of accidents. We designed a method to quantify the output of K-means and Apriori to help assess the risk level. Then, the logistic regression model was constructed to analyze the gain effect of each month on accidents. Results suggested that the monthly distribution patterns of different types of accidents are inconsistent. That is, lower total accident risk will mask the high risk of certain types of accidents. Moreover, when identified as high-risk months by both K-means and Apriori for certain types of accidents, the tendency for such types of accidents to occur in these months will significantly increase several times. There is also a noteworthy finding that the months identified as high-risk by only one of K-means and Apriori are not significant in the model, which also indicates the necessity and efficiency of using both of them at the same time. The conclusions can help local relevant organizations to formulate strategies for preventing different types of traffic accidents, and provide a methodological reference for relevant studies in other regions.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00377
Paper Title	**Overfitting Prevention in Accident Prediction Models: Bayesian Regularization of Artificial Neural Networks**
Abstract	In the present paper, we implemented the Bayesian Regularization (BR) backpropagation algorithm for calibrating an Artificial Neural Network (ANN) as Accident Prediction Model (APM) to be used on Italian four-lane divided roads. We chose the BR-ANN since it efficiently allows dealing with limited data and avoiding overfitting issues by the addition of a regularization term in the objective function to be minimized during training. Moreover, BR-ANNs are sparsely employed in road safety analyses, and their peculiarities deserve to be emphasized. In our work, the BR-ANN aims to predict the number of Fatal and Injury (FI) crashes for both road segments and road intersections across 236 road elements, for a total length of 78 km. The input features are road element length, horizontal and vertical alignment, road section geometry, operative speed, traffic flow, free viewing distance, and road element type (road segment or road intersection). An amount of 3,413 FI crashes that occurred between 2015 and 2019 have been considered as output targets. Training and test phases of the BR-ANN have been evaluated by Determination Coefficient (R2), Root Mean Square Error (RMSE), scatterplots, residuals analysis, and by the same ANN architecture trained with the Gradient Descent backpropagation algorithm (GD-ANN). Results demonstrate that the BR-ANN markedly outperforms the GD-ANN, which suffers from severe overfitting issues. BR-ANN does not overfit data, reports a satisfactory R2 (0.726), and shows a Gaussian residual distribution with zero mean. Road authorities should consider regularized ANNs for performing appropriate safety analyses, especially in contexts of limited data.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00520
Paper Title	**Real-time Conflict Risk Analysis and Prediction Based on High-resolution Trajectory Data**
Abstract	The real-time conflict risk model is much less studied compared to the crash-based model. This study aims at exploring the association of conflicts and traffic flow characteristics with the consideration of heterogeneity and develop real-time prediction models to identify conflict-prone conditions. The high-resolution trajectory collected from the HighD dataset is used as empirical data. A novel method with the virtual detector approach for macroscopic traffic data extraction and a hybrid data analytic framework is proposed for the trajectory data analysis. The hybrid analytic framework consists of an exploratory study by random parameter logit model with heterogeneity in means and variances and a comparative study on machine learning methods, including eXtreme Gradient Boosting (Boosting), Random Forest (Bagging), Support Vector Machine (Single-classifier), and Multilayer-Perceptron (Deep neural network). Modeling results indicate that (1) traffic flow characteristics have significant impacts on conflict probability; (2) the statistical model considering mean heterogeneity outperforms the counterpart and lane differences variables are found to significantly impact the means of random parameters for both lane variables and lane differences variables; (3) eXtreme Gradient Boosting trained on an under-sampled dataset turns out to be the best model with the highest AUC of 0.871 and precision of 0.867. Re-sampling techniques have significant effects on model improvement. The proposed model seems to be sensitive to the conflict threshold. The sensitivity analysis on feature adoption further confirmed that the conflict risk prediction should consider both the subject lane features and lane difference features.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00572
Paper Title	**A Bayesian Approach to Examine the Impact of Pavement Friction on Intersection Safety**
Abstract	The safety of intersections has been the focus of many studies since intersections are considered hazardous zones of road networks. Identifying the main contributing factors of severe traffic crashes at intersections is crucial to implementing appropriate countermeasures. We investigated the major contributing factors to crash injury severity at intersections, particularly pavement surface friction. Intersection crash data of Wyoming, from 2007 to 2017 (excluding 2010 and 2011 since friction data were not available), were collected for this study. The random forest technique was employed to identify the critical variables influencing crash injury severity risk. Also, a Bayesian ordinal probit model was developed to explore the relationships between such risk and the crash contributing factors. As per the random forest model's results, pavement friction has a strong impact on crash injury severity risk. Other important variables identified were the use of safety restraints, intersection type, signalized or unsignalized, reckless driving and crash type. The results of the Bayesian model demonstrated that higher pavement surface friction levels and proper use of restraints reduced the likelihood of severe injury. On the other hand, speeding and reckless driving related crashes were found to raise injury severity risks. When it comes to crash type, it was inferred that rear-end and sideswipe crashes were less likely to be severe than head-on and fixed-object crashes. Based on these findings, several countermeasures may be proposed, such as those of pavement friction requirements, driver's education and traffic law enforcement to mitigate injury severity concerns at intersections.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00641
Paper Title	**Evaluating Safety Benefits of V2X Sensor Sharing on Rural Highways Using Microscopic Simulation Model**
Abstract	Safety is a critical aspect of transportation design and operations. Practioners utilize various references to ensure that roadways meet safety, operational, and sustainability requirements. Despite this, human error remains as a factor that contributes to unsafe driving behavior and potential crashes. Connected and autonomous vehicles (CAVs) are expected to improve traffic safety and operations. Although sensor perception ranges and capabilities may pose challenges, the sharing of information via Vehicle-to-Everything (V2X) communication provides drivers with an effective solution for overcoming sensor limitations. Sharing data obtained through a vehicle's sensors can allow a follower to understand what lies beyond its perception range and assist in making informed decisions pertaining to their future behavior. The objective of this study is to use microscopic traffic simulation to assess the safety impacts of using V2X for sharing sensor-obtained roadway information with a CAV. Several scenarios are tested in a simulated environment where drivers on a straight tangent must react to a sharp horizontal curve. Performance is evaluated using the measured values for longitudinal jerk, lateral jerk, and speed variance. The results of this study indicate that V2X sensor sharing (V2X-SS) can provide significant benefits to CAV performance. CAVs receiving sensor-obtained information were observed to behave in a manner more akin to their human-driven counterparts in comparison to those receiving BSMs. CAVs using sensor-obtained information maintain braking and lateral jerk values within safety thresholds. Additionally, speed variance was observed to be at its lowest when CAVs utilized V2X sensor information

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00855
Paper Title	**Short Duration Crash Prediction for Rural Two-lane Roadways: Applying Explainable Artificial Intelligence**
Abstract	Conventional traffic crash analysis methods often use highly aggregated data, making it difficult to understand the effects of time-varying factors on crash occurrence. In this study, the combined effect of roadway geometry, speed distribution, and weather conditions on crash occurrence and severity was investigated on short duration daily level crash data. This study collected data from four different sources on rural two-lane roadways in Texas. A machine learning method, XGBoost, was applied to train the data. To mitigate imbalanced data problem, synthetic minority over-sampling technique (SMOTE) method was applied. The XGBoost model was trained separately on all crash occurrences and severe crash occurrences. Finally, explainable artificial intelligence (AI) technique SHAP (SHapley Additive exPlanation) method was applied to investigate the contribution of all variables to the model's output. The results show that AADT has a significant impact on all crash occurrences and severe crash (fatal and incapacitating injury) occurrences on rural two-lane roadways. Moreover, weather condition factors including daily precipitation, average visibility, and standard deviation of visibility show association with high crash occurrences. The short duration crash prediction models of this study can provide more insights on the relationships between crash, geometric variables, traffic exposure, weather, and operating speed.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00911
Paper Title	**Optimizing control model parameters of connected automated vehicles using empirical trajectory data**
Abstract	This study proposed a new method to obtain more realistic trajectory data of connected automated vehicle (CAV) based on empirical trajectory data, and further improved the safety condition by optimizing the CAV model parameters. Firstly, the initial car-following pairs (I-CFP) were extracted. Secondly, we took the selected parameters as input of the simulation models (the autonomous Adaptive Cruise Control (ACC) and Cooperative ACC (CACC) vehicle model), to obtain the trajectory data of the simulated car-following pairs (S-CFP), where the CAV is the following vehicle. Thirdly, the optimized two parameters (k1 and k2) and the optimized three parameters (t , k1 and k2) were taken as input to obtain the optimized & simulated car-following pairs (O&S-CFP), respectively. Fourthly, we evaluated the safety condition of the I-CFP, S-CFP and O&S-CFP, and compared them from the perspective of the number of car-following pairs at risk (N-CFPR) and the aggregated Time Exposed Time to Collision (TET). It was found that the safety condition of S-CFP is better than that of I-CFP. And the safety condition of the O&S-CFP has been further improved. Finally, we used a situation as example to verify the car-following effect of the CAV, which denotes whether the speed change of the CAV is basically consistent with that of leading vehicle. It was found the CAV in the S-CFP and O&S-CFP have good car-following effects by comparing the speed trend graphs, and the effect in the O&S-CFP is better, which means the model optimization is valuable.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00919
Paper Title	**Modeling Conflict Risk with Real-time Traffic Data for Road Safety Assessment Using A Copula-based Joint Approach**
Abstract	This study proposes a conflict-based traffic safety assessment method by combining conflict frequency and severity with short-term traffic states. Instead of analyzing historical crash data, this study employs microscopic trajectory data to quantify the relationship between conflict risk and traffic characteristics. Time-to-collision (TTC) index is used to detect conflicts, then a severity index (SI) is proposed on the basis of Time-integrated-TTC (TIT) indicator. With SI, k-means algorithm is applied to classify and define the conflict severity within a specific time and space. Zero truncated poisson regression and ordered logit regression are employed to estimate the effect of short-term traffic states on conflict frequency and severity. Furhermore the copula-based joint modeling method is applied to explore the potential non-linear dependency of conflict risk attributes, and different risk levels are considered. The HighD dataset from German is utilized to examine the proposed method, and a total of 18 copula models are tested to select the best one. Results show that the correlations between traffic states and conflict risk (frequency and severity) are significant, and the dependency of conflict risk various among different risk levels. Findings indicate that the proposed method is practicable to assess real-time traffic safety within a specific region by using short-term (30-second time interval) traffic states, which also contribute to the design of proactive safety strategies under different risk levels. Keywords: Conflict frequency, Conflict severity, Safety assessment, Copula model.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-00933
Paper Title	**Development of New Performance Measures based on Data Mining Weights for Hotspot Identification**
Abstract	In this study, new performance measures are proposed for hotspot identification in urban intersections that reflect the severity factor weights based on data mining. To estimate the severity factor weights of crashes at urban intersections, the study utilizes tree-based Random Forest and Extreme Gradient Boosting. The importance of variables in the severity classification model is standardized and utilized for calculating the score of each crash, which is aggregated into intersections. The aggregated score is used as a dependent variable for Safety Performance Functions (SPFs) in network screening process. To illustrate the under-dispersed severity score aggregation data, SPFs that follow the COM-Poisson distribution as well as Negative binomial are developed. Independent variables in SPFs set up intersection geometry elements that can be collected from online GIS services. The final 4 performance measures are proposed, each reflecting the severity weights. A total of 42,513 intersection crashes from 2017 to 2018 in Korea were collected for crash injury severity analysis. Hotspot identification was performed on 81 intersections, and 3 tests were conducted for validation of 4 measures. Tests show that the RF-based weighted and have the best consistency. Since the severity factor weights of each crash are reflected, the intersection vulnerable to dangerous crashes can be analyzed in more detail. It is expected that effective safety improvement project plans can be established from the perspective of safety managers in the future.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-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.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01252
Paper Title	**Improving Spatio-temporal Transferability of Real-Time Crash Likelihood Prediction Models Using Transfer Learning Approaches**
Abstract	A real-time crash likelihood prediction model is an important component of the proactive traffic safety management system. Over the past decades, numerous models were proposed and achieved promising results on predicting real-time crash likelihood. However, most studies ignored the model transferability, especially for deep learning models. The transferability of a model could be referred to as applying the pretrained model to new data from other locations or periods. Transfer learning aims to improve the performance of the pretrained model on new data. The purpose of this study is to improve the spatial-temporal transferability of the deep learning crash likelihood prediction model. Trajectory and crash data from five arterials in Florida were collected. Different features were generated from the trajectory data for predicting crash likelihood, such as average speed, the standard deviation of speed, the number of hard accelerations, etc. A two-layer Long Short-term Memory (LSTM) model was used for predicting the crash likelihood. Two scenarios were created to investigate spatial and temporal transferability. Extensive experimental results suggested that the crash likelihood prediction model could be accurately transferred to new data by using the fine-tuning approach. The transferred models achieved higher predictive accuracy compared with models directly developed on new data. Moreover, spatial transfer learning outperformed temporal transfer learning in terms of sensitivity and false alarm rate. The results from this study could be applied to transfer pretrained crash likelihood prediction models to new locations when few crashes are available or trajectory data is limited.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01375
Paper Title	**Real-time Secondary Crash Likelihood Prediction Using A Hybrid Machine Learning Model**
Abstract	Secondary crashes usually occur within the spatio-temporal impact ranges of primary crashes, which could cause traffic disturbance and increase traffic safety problems. However, existing studies only focused on predicting the likelihood of crashes leading to secondary crashes without considering the likelihood of the occurrence of secondary crashes. In addition, previous studies did not consider the real-time implementation of secondary crash likelihood prediction models and included too many features that were not available in real-time. A real-time secondary crash likelihood prediction model aims to predict the likelihood of secondary crashes in a short period (e.g., 5-10 min) and update the results every minute. The main objective of this paper is to develop a machine learning model to predict real-time secondary crash likelihood. Two XGBoost models were developed for predicting the likelihood of crashes leading to secondary crashes and the likelihood of the occurrence of secondary crashes, respectively. A hybrid model was proposed to combine the results from the two developed models. Results indicated that the proposed hybrid model significantly improved the accuracy of secondary crash likelihood prediction. The proposed model has the potential to be applied in proactive traffic safety management systems and prevent the occurrence of secondary crashes. Moreover, experimental results suggested that several features related to real-time traffic flow conditions were crucial for predicting secondary crash likelihood, such as the average traffic volume and average occupancy.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01507
Paper Title	**Effects of Inclement Weather Events on Road Surface Conditions and Traffic Safety – An Event-based Empirical Analysis Framework**
Abstract	Pavement friction has been widely recognized as an important winter road maintenance performance indicator for objectively assessing the level of service required to maintain safe driving conditions during inclement weather events. Despite significant efforts being put forth by road agencies, prevailing road surface conditions during snowstorms can yield negative consequences that compromise the safety of the traveling public. Acknowledging the vast road network that needs to be monitored and the uncertainty associated with the randomness of hazardous road weather conditions, this paper presents a novel event-based framework aimed at investigating the magnitude of the effect of varying pavement friction levels in urban environments on traffic safety during snowstorms. Negative Binomial safety performance functions developed using hourly weather datasets and road surface conditions information found a strong statistically significant relationship between pavement friction and traffic safety. This meant that, with the accumulation of snow and ice during snowstorms, road surface conditions were found to deteriorate thereby increasing the likelihood of collision occurrence. The event-based models developed also suggested that the risks of driving during snowstorms varied dramatically depending on varying surface states represented by friction coefficients; collisions were expected to significantly decrease whenever pavement friction was above 0.6, while at conditions where pavement friction deteriorated to below 0.35, collisions were predicted to significantly increase. Additionally, arterial roads were shown to experience a significantly higher number of collisions than collectors further justifying why arterials should be prioritized in snow clearing policies which most cities adopt.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01545
Paper Title	**Application of Explainable Machine Learning for Real-time Safety Analysis Toward Connected Vehicles Environment**
Abstract	Due to the difficulty of obtaining traffic flow data and conflicts simultaneously, real-time safety evaluation by using macroscopic traffic features is much less studied. This study aims to analyze real-time safety by taking conflict analysis as a disaggregate study and apply explainable machine learning to provide insights into the impact of traffic features on conflict occurrence. A virtual fixed detectors approach is employed to capture the cross-sectional traffic data in the HighD dataset and the trajectory data of vehicles is also considered, assuming these data can be obtained under connected vehicles (CV) environment. Subsequently, the CV Market Penetration Rate (CV-MPR) is analyzed to reveal its influence on improving the safety evaluation. The results show that the Random Forest model outperforms eXtreme Gradient Boosting, Support Vector Machine and Adaptive Boosting and achieves the best performance with the highest AUC of 0.827. By the result of SHAP (SHapley Additive exPlanation) analysis, several traffic features are found to have a relatively more significant impact on the occurrence of conflict and their influences on conflict occurrence are then discussed. Additionally, the feature dependency analysis is conducted for three pairs of features. The result suggests that the impacts of traffic features are not always fixed and there may exist specific patterns of paired features affecting real-time safety. The findings help explain the complex conflict mechanism in traffic flow. Experimental result regarding CV-MPR demonstrates that the model performance will be gradually enhanced as the penetration rate increasing.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01746
Paper Title	**Towards Explainable Artificial Intelligence (XAI) for Early Anticipation of Traffic Accidents**
Abstract	Traffic accident anticipation is a vital function of Automated Driving Systems (ADSs) for providing a safety-guaranteed driving experience. An accident anticipation model aims to predict accidents promptly and accurately before they occur. Existing Artificial Intelligence (AI) models of accident anticipation lack a human-interpretable explanation of their decision-making. Although these models perform well, they remain a black-box to the ADS users, thus difficult to get their trust. To this end, this paper presents a Gated Recurrent Unit (GRU) network that learns spatio-temporal relational features for the early anticipation of traffic accidents from dashcam video data. A post-hoc attention mechanism named Grad-CAM is integrated into the network to generate saliency maps as the visual explanation of the accident anticipation decision. An eye tracker captures human eye fixation points for generating human attention maps. The explainability of network-generated saliency maps is evaluated in comparison to human attention maps. Qualitative and quantitative results on a public crash dataset confirm that the proposed explainable network can anticipate an accident on average 4.57 seconds before it occurs, with 94.02% average precision. In further, various post-hoc attention-based XAI methods are evaluated and compared. It confirms that the Grad-CAM chosen by this study can generate high-quality, human-interpretable saliency maps (with 1.42 Normalized Scanpath Saliency) for explaining the crash anticipation decision. Importantly, results confirm that the proposed AI model, with a human-inspired design, can outperform humans in the accident anticipation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01786
Paper Title	**Exploring Driving Styles Using Large-Scale GPS Trajectory Data: A Latent Dirichlet allocation Topic Approach**
Abstract	Driving style identification has become a highlight in recent years and of great significant in the field of traffic safety research. This study aims to identify and analyze driving styles using largescale GPS trajectory data taking different time periods, traffic and weather conditions into account. The k-means clustering algorithm and Latent Dirichlet allocation (LDA) topic model are employed to recognize and classify driving styles. Before driving style recognition, data is preprocessed and the optimal value of the number of clusters and the number of topics is explored. Results of the classification show that driving styles are composed of three driving states with different probability combinations. The driving style in the morning peak is much more cautious whereas the one in the evening rush hours is more changeable and the style in other period of the day depends more on the drivers themselves. Driving styles in a working day show more conservative following states than the ones in a non-working day. Moreover, the driving style is also affected by the weather and it is more cautious and conservative when it happens to be rainy. Findings of this study can be helpful for traffic management under driving context and contributes to the research on traffic safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01811
Paper Title	**Apply Explainable Machine Learning Techniques in Daily Crash Occurrence and Severity Modeling for Rural Interstates**
Abstract	Conventional traffic crash analysis methods often use highly aggregated data, making it difficult to understand the effects of many time-varying factors on crash occurrence. Although studies have used data with small aggregation intervals, they typically analyze the effect of a single factor on crash occurrence. In this study, the collaborative effect of roadway geometry, speed distribution, and weather conditions on crash occurrence and severity is investigated using explainable machine learning methods on daily level crash data. The data are collected from four different sources on rural interstate highways in Texas. Four machine learning methods: Random Forest, AdaBoost, XGBoost, and Deep Neural Network, are tested on the dataset. The model comparison results show that XGBoost performs the best on the imbalanced dataset. In the feature selection process, the Pearson correlation coefficient is applied to remove highly correlated variables. The study then uses the synthetic minority over-sampling technique (SMOTE) method to mitigate the data imbalance issue. The XGBoost model is trained twice on all crash occurrence and severe crash occurrence. Finally, the SHAP (SHapley Additive exPlanation) method is applied to investigate the contribution of all variables to the model's output. The results show that weather condition factors have a significant contribution to all crash occurrences. However, speed distribution factors have a stronger impact on severe crash occurrences. Precipitation has a positive impact on all crash occurrences, while for severe crash occurrences precipitation does not have an obvious impact. Instead, nighttime speed standard deviation becomes important for severe crash occurrence.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01878
Paper Title	**Automated Vehicle Crash Sequences: Patterns and Potential Uses in Safety Testing**
Abstract	With safety being one of the primary motivations for developing automated vehicles (AVs), extensive tests are being carried out to ensure AVs can operate safely on roadways. Since 2014, the California Department of Motor Vehicles (DMV) has been collecting AV collision and disengagement reports, which are valuable data sources for studying AV crash patterns. In this study, sequences of events extracted from California AV collision reports are used to investigate patterns and potential uses in developing AV test scenarios. A crash sequence of events describes the interactions between AVs and other road users throughout the pre-crash and crash process. Employing sequence analysis methods and clustering, this study evaluates 168 AV crashes (with the AV in automatic driving mode at the time of crash or automation disengaged just prior to crash) reported to the California DMV in 2015-2019. Analysis of subsequences shows that the most representative pattern in AV crashes is “crash following AV stop”. Analysis of event transition shows that disengagement, as in 24% of all studied AV crash sequences, has a transition probability of 68% to an immediate crash. Cluster analysis characterizes AV crash sequences into seven groups with distinctive crash dynamic features. Cross-tabulation analysis shows that sequence groups are significantly associated with variables measuring crash outcomes and describing environmental conditions. Crash sequences are useful for developing AV test scenarios. Based on the findings, a scenario-based AV safety testing framework is proposed with sequence of events embedded as a core component.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-01944
Paper Title	**VT-Grid: A Three-Step Gradient Boosting Approach for Crash Frequency Prediction Utilizing Geospatial, Roadway Geometry, and Pavement Condition Information**
Abstract	In this study, we propose a framework for crash frequency prediction utilizing Virtual Traffic Grids (VT-Grid). Our proposed framework utilizes a combination of crash data with traffic, roadway geometry, and pavement condition information for a selected geo-fenced area of interest, generating a geographic grid with cells of varying traffic, geometrical and pavement conditions, and historical crash frequencies. We optimize the size of the grid and hence the number and characteristics of the generated cells, which are used to train, validate, and test a Gradient Boosting Machine (GBM) model for predicting the crash frequencies. We compare the GBM model to multiple popular machine learning algorithms. The optimal GBM model was able to achieve an overall R2 of 73% for continuous crash frequency prediction, with an R2 of 94% for predicting crash frequencies that fall within the 90th percentile of the observed crashes rate, and an accuracy of 84% for crash frequency multi-class classification. The proposed framework and results of this exploratory study provide a highly reproducible and scalable blueprint for crash frequency prediction utilizing factors that transportation agencies can readily control or account for (namely, traffic, roadway geometry, and pavement condition). This will aid practitioners in assessing how different roadway maintenance and traffic demand management strategies may impact the expected number of car crashes within a certain geographical area where they can influence those factors.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02165
Paper Title	**Utilizing Reinforcement Learning Tree to Develop the Real-time Traffic Safety Management Framework on Urban Expressways**
Abstract	How to reduce the crash frequency and the loss caused by crashes on urban expressways is the main objective for traffic managers and researchers. Real-time crash risk prediction (RTCRP) is one of the most important techniques to identify crash precursors so as to take measures to smooth the traffic fluctuations; and automatic incident detection (AID) is another important technique to identify the occurrence of incidents timely so as to take measures to reduce the its negative impacts on traffic flow. Exploring better modelling methods is still the important research point in this field. In this paper, a state-of-the-art reinforcement learning tree (RLT) approach is proposed to develop RTCRP and AID models, and is further implemented to build a traffic safety management framework on urban expressways with real-time traffic data streaming. Historical crash data and corresponding traffic flow data were integrated and divided into a training dataset and a test dataset to develop and test RTCRP models and AID models. In addition, the prediction results were compared with those given by other frequently used classification algorithms, including random forest and support vector machine (SVM). The results prove that RLT slightly outperforms random forests and RLT can improve 3.6% and 1.8% compared with the SVM in RTCRP and AID. At the cost of 10.0% false-alarm rates, 79.8% and 92.9% of crash cases can be identified and detected correctly by the RLT model. RLT has the potential to predict and detect the crash occurrence in the traffic safety management.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02211
Paper Title	**A Comparison of Logistic Regression and Long Short-Term Memory for Vehicular Crash Hotspot Prediction in Chattanooga, Tennessee**
Abstract	To address the ever present issue of vehicular crashes which claims lives and degrades the quality of life in urban areas, preventative measures need to be taken. Predicting crash hotspots is one viable way to enable implementation of countermeasure and minimize or prevent crash occurrence. In this work, we comparatively evaluate two methods (a Logistic Regression (LR) model and a Long Short-Term Memory (LSTM) model) for vehicular crash hotspots prediction on a given day in the city of Chattanooga, TN. These models analyze crashes and their associated weather and roadway geometric characteristics to understand factors contributing to crash occurrence, and are used to produce hotspot predictions for dates not covered by the dataset used for the model creation. Several variants of each model (both LR and LSTM) were created to thoroughly explore the prediction capabilities of each model. Based on the confusion matrix values (True Positive, False Positive, True Negative, and False Negative), the Logistic Regression model was deemed more successful at correctly identifying crash prediction hotspots, noted by LR's lower number of False Positive predictions when compared to the LSTM. However, with LSTM as the base, we can expand the model to adapt to ConvLSTM and other state-of-of-art techniques.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02716
Paper Title	**Crashes and Near Crashes Causation Analysis Using Naturalistic Driving Data**
Abstract	Determining crash causation has always been a focus and a difficulty in the field of traffic safety. Previous research has had to rely on insufficient crash data and crash causation analysis methods limited to a single crash, and has not taken advantage of the application value of pre-crash scenarios in causation analysis. This study therefore proposed a two-stage crash causation analysis method based on pre-crash scenarios, and analyzed crashes and near crashes (CNCs) using naturalistic driving data. From the Shanghai Naturalistic Driving Study (SH-NDS), 572 CNCs were extracted, and 25 pre-crash scenarios were identified using the Pre-Crash Scenario Typology. In-depth investigations of CNCs in the same scenario were analyzed to determine the causes of crashes using the proposed systematic crash causation derivation framework, which summarizes the causation patterns in each scenario based on the interaction of humans, vehicles, infrastructure, and environment subsystems. The differences between the causation patterns of three common pre-crash scenarios (rear-end, lane change and pedalcyclist collisions) were determined through statistical analysis. Following too closely and non-driving-related distraction were important causes of rear-end scenarios. Distraction, as well as willful behavior and violation of traffic laws was a common pattern (61.2%) in lane change pre-crash scenarios. Pedalcyclist scenarios leading to CNCs were particularly impacted by pedalcyclists violating traffic regulations, visual obstructions, and inadequate lanes for non-motorized vehicles. Based on causation patterns, this study suggests countermeasures for the three scenario types. These findings provide support for safety improvement projects and the development of advanced driver assistance systems.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02721
Paper Title	**Modeling Reliability and Unreliability of Safety in the Network Equilibrium Model: An α-Reliable Mean-Excess Approach**
Abstract	In this study, a network equilibrium model accounting for both the traveler's safety concern and travel time concern is proposed. Since the travelers might not only worry about the average safety condition of their routes, but also the reliability and unreliability aspects of safety (e.g., crash risk). Thus, reliability and unreliability aspects of safety are modeled using the concept of α-reliable mean-excess traffic equilibrium model (METE). Crash risk cost (CRC) distribution is adopted, and the travelers are assumed to have gained the knowledge of CRC distribution based on their traveling experience, which they incorporate into their long-term habitual user equilibrium (UE) flow pattern. The proposed model ensures the reliability aspect of safe arrival at a specified confidence level α and also accounts for the unreliability aspect of encountering the worst safety condition beyond the acceptable effective CRC in the distribution tail of 1-α. The variational inequality formulation is being reformulated as an unconstrained smooth gap function. Using a numerical example, the proposed model is compared with the Mean CRC (MCRC) and Effective CRC (ECRC) user equilibrium models to elaborate the differences in properties of the models and also highlight the realism of using the mean-excess CRC user equilibrium (MECRC-UE) model. It is argued that the proposed model captures a more realistic behavior of road users.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02777
Paper Title	**A cross-country comparison and risk analysis of lane-changing behaviors using vehicular trajectory data**
Abstract	Improper lane-changing leads to deaths, injuries, and property damages. Although many studies have employed the vehicular trajectory data to conduct lane-changing safety analyses, most of them only utilized one single dataset, which is collected from one country with limited traffic conditions. The differences in lane-changing behavior in different countries are rarely investigated. This study aims to compare the lane-changing behaviors in different countries and to investigate the contributing factors of lane-changing collision risks. We employed three different datasets collected from three different countries to extract the lane-changing behaviors. 11 key features of the lane-changing behaviors are selected and compared. The lanechanging risk index (LCRI) is calculated to quantify the collision risk of lane-changing vehicle groups. We further divided the LCRI into different levels by the k-means algorithm. To investigate the contributing factors of lane-changing collision risks, we established a random parameter ordered logit (RPOL) model for each dataset. The main results suggest that (1) the lane-changing behaviors are quite different in different traffic conditions and different countries. In congested conditions, the drivers usually change the lane in a shorter distance with larger steering angles; (2) even with similar traffic conditions, the drivers in Germany are more aggressive than the drivers in the Netherlands. (3) the number and the effects of variables are different in different RPOL models, and a possible reason might be the differences in traffic conditions and driving habits. This study points out the portability issues of the researches based on a single trajectory dataset.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02833
Paper Title	**Safety Analytics at a Granular Level Using a Gaussian Process Modulated Renewal Model: A Case Study of the COVID-19 Pandemic**
Abstract	With the advance of intelligent transportation system technologies, contributing factors to crashes can be obtained in real time. Analyzing these factors can be critical in improving traffic safety. Despite many crash models have been successfully developed for safety analytics, most models associate crash observations and contributing factors at the aggregate level, resulting in potential information loss. This study proposes an efficient Gaussian process modulated renewal process model for safety analytics that does not suffer from the information loss due to data aggregations. The proposed model can infer crash intensities in continuous time dimension so that they can be better associated with contributing factors that change over time. Moreover, the model can infer non-homogeneous intensities by relaxing the independent and identically distributed (i.i.d.) assumption of the crash occurrence process. To demonstrate the validity and advantages of this proposed model, an empirical study examining the impacts of the COVID-19 pandemic on traffic safety at six interstate highway sections is performed. The accuracy of our proposed renewal model is verified by comparing the areas under the curve (AUC) of the inferred crash intensity function and the actual crash counts. Counterfactual crash intensities are then predicted conditioned on exogenous variables at the crash time. Time-varying safety impacts such as bimodal, unimodal, and parabolic patterns are observed at the selected highways. The case study shows the proposed model enables safety analytics at a granular level and provides a more detailed insight into the time-varying safety risk in a changing environment.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02958
Paper Title	**Crash Data Augmentation Using Variational Autoencoder**
Abstract	In this paper, we present a data augmentation technique to reproduce crash data. The dataset comprising crash and non-crash events are extremely imbalanced. For instance, the dataset used in this paper consists of only 625 crash events for over 6.5 million non-crash events. Thus, learning algorithms tend to perform poorly on these datasets. We have used variational autoencoder to encode all the events into a latent space. After training, the model could successfully separate crash and non-crash events. To generate data, we sampled from the latent space containing crash data. The generated data was compared with the real data from different statistical aspects. T-test, Levene-test and Kolmogrove Smirnov test showed that the generated data was statistically similar to the real data. It was also compared to some of the minority oversampling techniques like SMOTE and ADASYN as well as the GAN framework for generating data. Crash prediction models based on Logistic Regression (LR), Support Vector Machine (SVM) and Artificial Neural Network (ANN) were used to compare the generated data from the different oversampling techniques. Overall, variational autoencoder (VAE) showed excellent results compared to the other data augmentation methods. Specificity is improved by 8% and 4% for VAE-LR and VAE-SVM respectively when compared to SMOTE while the sensitivity is improved by 6% and 5% when compared to ADASYN. Moreover, VAE generated data also helps to overcome the overfitting problem in SMOTE and ADASYN since there is flexibility in choosing the decision boundary.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-02993
Paper Title	**Utilizing Imbalanced Classification Algorithm for Real-Time Safety Analysis Using Floating Car Data on Expressway**
Abstract	Real-time crash risk analyses play a vital role in Active Traffic Management Systems (ATMS) by identifying the hazardous traffic conditions that potentially precede crash occurrences within a very short time. Currently, the recent advancements in traffic sensing and detection technologies have had a tremendous impact on real-time crash risk safety analysis. However, there is a lack of prior studies that attempted to examine the relationships between crash occurrence and real-time traffic data collected from floating cars on expressways. Moreover, several researchers mostly developed real-time crash prediction models with resampled balanced datasets which may be inadequate to the large continuous real-time traffic data environment. Therefore, in this study, a comprehensive imbalanced classification algorithm, Adaptive Boosting Algorithm for Convolutional Neural Networks (AdaBoost-CNN), has been first time introduced to build a practical real-time crash prediction model. This study primarily aims to: (1) investigate the feasibility of using Floating Car Data (FCD) to predict the real-time crash risk on expressways; and (2) explore the efficiency of AdaBoost-CNN algorithm to solve the imbalanced data classification problem. Two models are compared to the proposed AdaBoost-CNN. First, AdaBoost with CNN base classifiers is compared to the proposed model to investigate the influence of transfer learning on prediction accuracy. Second, One-Dimensional Conventional Neural Network is designed with balanced data to examine the capability of AdaBoost-CNN to handle the imbalanced data issue. Experiments demonstrate the high accuracy of AdaBoost-CNN in predicting crash and non-crash cases in the context of sensitivity, false alarm rate, and Area under Curve scores.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03105
Paper Title	**Automated Vehicle Data Pipeline for Accident Reconstruction: New Insights from LiDAR, Camera, and Radar Data**
Abstract	As automated vehicles are deployed across the world, it has become critically important to understand how these vehicles interact with each other, as well as with other conventional vehicles on the road. One such method to achieve a deeper understanding of the safety-implications for Automated Vehicles (AVs) is to analyze instances where AVs were involved in crashes. Unfortunately, this poses a steep challenge to crash-scene investigators. It is virtually impossible to fully understand the factors that contributed to an AV involved crash without taking into account the vehicle's perception and decision making. Furthermore, there is a tremendous amount of data that could provide insight into these crashes that is currently unused, as it also requires a deep understanding of the sensors and data management of the vehicle. To alleviate these problems, we propose a data pipeline that takes raw data from all on-board AV sensors such as LiDAR, radar, cameras, IMU's, and GPS's. We process this data into visual results that can be analyzed by crash scene investigators with no underlying knowledge of the vehicle's perception system. To demonstrate the utility of this pipeline, we first analyze the latest information on AV crashes that have occurred in California and then select two crash scenarios that are analyzed in-depth using high-fidelity synthetic data generated from the automated vehicle simulator CARLA . The visualization and data analysis from these scenarios clearly demonstrate the vast improvement in crash investigations that can be obtained from utilizing state-of-the-art sensing and perception systems used on Avs.

Authors	Matthew Bell, Western Transportation Institute (WTI) Yiyi Wang, San Francisco State University Robert Ament, Western Transportation Institute (WTI)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03151
Paper Title	**Risk Mapping of Wildlife-Vehicle Collisions across the State of Montana, USA: A Statistical Learning Approach for Imbalanced Data**
Abstract	Wildlife-vehicle collisions (WVCs) cost the United States an annual sum of $8,388 million in property damage, human injury/death, economic loss of animal life, and road maintenance. Imbalanced data is frequently encountered in the study of WVC risk, where a limited number of collisions scatter over a large geographic area, reducing prediction accuracy and coefficient estimates of statistical learning models. This research study demonstrates how to use synthetic minority over-sampling technique (SMOTE) to handle imbalanced WVC data and a combination of statistical and machine learning models to infer seasonal WVC risk across a mesh grid of 18,684 analysis units. An array of regularized variables describing landscape, road, and traffic was used to develop negative binomial (NB) and random forest (RF) models to infer WVC risk. Models are evaluated via out-of-sample prediction and goodness-of-fit. SMOTE-augmented data are found to improve accuracy of predicting crash risk while retaining the characteristics of the original dataset. SMOTE works particularly well with random forest models in the prediction of seasonal WVC risk. High-risk segments match locations that have large numbers of reported WVCs and coincide with other published work that identify locations of WVC hotspots in Montana. This research provides the first application of SMOTE on WVC prediction and can be used to address under-reporting of WVCs. The results can be used to support detection of high-risk segments and siting of WVC countermeasures.

Authors	Lauren Hoover, University of Central Florida Tanmoy Bhowmik, University of Central Florida Shamsunnahar Yasmin, Queensland University of Technology Naveen Eluru, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03304
Paper Title	**Understanding Crash Risk using a Multi-Level Random Parameter Binary Logit Model: Application to Naturalistic Driving Study Data**
Abstract	This study presents a framework to employ naturalistic driving study (NDS) data to understand and predict crash risk at a disaggregate trip level accommodating for the influence of trip characteristics (such as trip distance, trip proportion by speed limit, trip proportion on urban/rural facilities) in addition to the traditional crash factors. Recognizing the rarity of crash occurrence in NDS data, the research employs a matched case-control approach for preparing the estimation sample. The study also conducts an extensive comparison of different case to control ratios including 1:4, 1:9, 1:14, 1:19, and 1:29. The model parameters estimated with these control ratios are reasonably similar (except for the constant). Employing the 1:9 sample, a multi-level random parameters binary logit model was estimated where multiple forms of unobserved variables were tested including (a) common unobserved effects for each case-control panel, (b) common unobserved factors affecting the error margin in the trip distance variable, and (c) random effects for all independent variables. The estimated model was calibrated by modifying the constant parameter to generate a population conforming crash risk model. The calibrated model was employed to predict crash risk of trips not considered in model estimation. This study is a proof of concept that NDS data can be used to predict trip level crash risk and can be used by future researchers to develop crash risk models.

Authors	Yangsong Gu, University of Tennessee, Knoxville Diyi Liu, University of Tennessee, Knoxville Ramin Arvin, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville Lee Han, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03540
Paper Title	**Predicting Intersection Crash Frequency Using Connected Vehicle Data: Application of Geographical Random Forest**
Abstract	Accurate crash frequency prediction is critical for proactive safety management. The emerging connected vehicles technology provides us with a wealth of vehicular motion data, which enables a better connection between crash frequency and driving behaviors. However, appropriately dealing with the spatial dependence of crash frequency and multitudinous driving features has been a difficult but critical challenge in the prediction process. To this end, this study aims to investigate a new Artificial Intelligence technique called Geographical Random Forest (GRF) that can address spatial heterogeneity and retain all potential predictors. By harnessing more than 2.2 billion high-resolution connected vehicle Basic Safety Message (BSM) observations from Safety Pilot Model Deployment in Ann Arbor, MI, 30 indicators of driving volatility are extracted, including speed, longitudinal and lateral acceleration, and yaw rate. The developed GRF was implemented to predict rear-end crash frequency at intersections. The results show that: 1) rear-end crashes are more likely to happen at intersections connecting minor roads compared to major roads; 2) a higher number of hard acceleration and deceleration events beyond two standard deviations in the longitudinal direction is a leading indicator of rear-end crashes; 3) the optimal GRF significantly outperforms Global Random Forest, with a 9% lower test error and a substantially better fit; and 4) geographical visualization of variable importance highlights the presence of spatial non-stationarity. The proposed framework can proactively identify at-risk intersections and alert drivers when leading indicators of driving volatility tend to worsen.

Authors	Xuesong Wang, Tongji University Qi Zhang Xiaohan Yang, Tongji University Yingying Pei Jinghui Yuan, Oak Ridge National Laboratory Chao Wang Juntao Wang
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03672
Paper Title	**Traffic Safety Analysis and Model Updating for Freeway Using Bayesian Method**
Abstract	Crash frequency and the influencing factors relating to freeways are changing over time, which means that crash prediction models developed in the past may not be suitable for current traffic conditions. In order to make sure that the implemented safety models fit the current traffic condition, this study proposed a comparative analysis on the basis of freeway datasets in 2017 and 2020 collected from Suzhou, China. Considering the spatial correlation among analysis units and the hierarchical data structure involved, a Bayesian conditional autoregressive negative binomial (CAR-NB) model and a Bayesian hierarchical CAR-NB model were used to explore the varied effects on safety of various influencing factors. The results showed that 1) the HCAR-NB model outperformed the CAR-NB model in prediction accuracy and 2) the number of crashes was significantly correlated with the average speed, speed variance, segment length, and several geometric design features. In addition, Bayesian inference with informative priors was used to update the HCAR-NB model to improve its goodness-fit and efficiency. Based on the modeling results, the potential for safety improvement (PSI) method was used to identify hotspots for the two years. The results confirmed that the hotspots spatiotemporally shift among the freeways. The proposed crash prediction model and model updating method are expected to help local traffic police develop a better understanding of the changes in contributing factors and therefore make informed decisions about safety countermeasures.

Authors	Yang Cheng, University of Wisconsin, Madison Keshu Wu, University of Wisconsin, Madison Hanchu Li, University of Wisconsin, Madison Steven Parker, University of Wisconsin, Madison Bin Ran, University of Wisconsin, Madison David Noyce, University of Wisconsin-Madison
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03731
Paper Title	**Work Zone Crash Occurrence Prediction based on Planning Stage Work Zone Configurations Using an Artificial Neural Network**
Abstract	Work zones are essential to maintain and improve the nation's road infrastructure. However, work zones affect traffic safety, and crashes and fatalities associated with work zones in the U.S. have increased substantially. Most existing work zone crash studies are not able to support the improvement of work zone planning and configuration, despite providing insights about individual crash level attributes. This study proposes an artificial neural network (ANN) based approach to predict the crash occurrence in work zones only using work zone configurations and design parameters. The goal is to explore whether using simple work zone configuration features available at the planning stage as the input can achieve satisfying work zone crash prediction. The performance of the proposed model is satisfying and comparable with existing studies using more comprehensive features. The proposed approach, early at the work zone design and planning stage, can provide designers and decision-makers with quick work zone safety evaluation for design alternatives and suggest extra resources and attention needed.

Authors	Mingjie Feng, Tongji University Xuesong Wang, Tongji University Bowen Cai, Tongji University Ahmad Yehia Minghui Zhong
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-03923
Paper Title	**Hourly Traffic Crash Prediction Using Environmental and Electric Vehicle Big Data**
Abstract	Robust crash prediction is critical for deploying traffic law enforcement and emergency rescue resources in advance. So far, real-time crash prediction works are mostly at 5-minute intervals, and their results are oriented toward proactive traffic safety management of intelligent transportation systems but are too pressing for manual traffic safety management. Therefore, this study attempts to conduct the hourly traffic crash prediction to give relevant departments enough time to take measures in advance. A freeway portion in Shanghai was chosen and separated into homogenous segments, with meteorological data, traffic operation data, and crash data collected for each hour, resulting in an imbalanced dataset of crash and non-crash. To deal with the large imbalanced dataset and produce high crash prediction accuracy, an AdaBoost-CNN model, which is an integration of Adaptive Boosting and Convolutional Neural Network, was employed. The Extreme Gradient Boosting (XGBoost) and Random Forest models were also trained based on resampled datasets by Synthetic Minority Over-sampling Technique (SMOTE) and compared with the AdaBoost-CNN model. The XGBoost and Random Forest models turned out to have a poor performance on hourly crash prediction even though their training datasets were resampled by SMOTE. In addition, comparing with previous papers, the classic SMOTE method is not enough to deal with the extremely imbalanced issue. The AdaBoost-CNN model that trained through the dataset resampled by SMOTE, however, outperformed the other models in the present study and the models in similar previous research, indicating that the AdaBoost-CNN method has the potential to deal with imbalanced crash data.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-04468
Paper Title	**Divergent Effects of Factors on Crashes under Autonomous and Conventional Driving Modes Using A Hierarchical Bayesian Approach**
Abstract	Influencing factors on crashes involved with autonomous vehicles (AVs) have been paid increasing attention. However, there is a lack of comparative analyses between influencing factors on crashes of AVs and human-driven vehicles. To fill this research gap, the study aims to explore the divergent effects of factors on crashes under autonomous and conventional driving modes. This study obtained 154 publicly available autonomous vehicle crash data (70 for the autonomous driving mode and 84 for the conventional driving mode), and 36 explanatory variables were extracted from three categories, including environment, roads, and vehicles. Then, a hierarchical Bayesian approach was applied to analyze the impacting factors on crash type and severity under both driving modes with considering unobserved heterogeneities. The results showed that some factors affected both driving modes, but their degrees were different. For example, daily visitors' flowrate had a greater impact on the crash severity under the conventional driving mode, while the presence of turning movement led to a larger decrease in the likelihood of rear-end crashes under the autonomous driving mode. More influencing factors only had a significant impact on one of the driving modes. For example, in the autonomous driving mode, two sidewalks decreased the severity of crashes, and on-street parking was positively associated with rear-end crashes, but they were not significant in the conventional driving mode. This study could contribute to the understanding and development of autonomous driving systems and the better coordination and complementarity between autonomous driving and conventional driving.

Authors	Irfan Ahmed, HDR Mohamed Ahmed, University of Wyoming
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-04681
Paper Title	**Investigating the Safety Effectiveness of Wildlife-Vehicle Crash Countermeasures using a Bayesian Approach: A Comparison between Carcass Removal Data and Traditional Crash Data**
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. Two types of WVC data are used in this study: carcass removal data and traditional crash data. A randomintercept 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. The results suggest that the treatment of implementing wildlife warning signs on hotspots of high WVC has been ineffective. This can be attributed to the noncompliance to the signs, perhaps due to the stationary nature of the information provided. The crossing structures are found to be effective with an estimated CMF of 0.65 and 0.54 using the carcass data and crash data, respectively. Recommendations could be made to implement more active information dissemination via dynamic message signs where crossing structures may not be feasible. The findings from this study indicate that the carcass removal data is more comprehensive than the crash data, despite the underreporting issue existing in both datasets. Therefore, a unique identifier should be added in both datasets to enable merging the data and obtain more complete results from the analyses.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-04756
Paper Title	**Safety Evaluation of Ride-Hailing Drivers and Improvement Strategies Based on Vehicle Trajectory Big Data**
Abstract	Online ride-hailing service has been popular since the 2010s because of its several advantages over conventional modes of transportation. Nevertheless, most drivers of the ride-hailing service are not professional drivers, and their driving behavior and safety should be thoroughly evaluated. Although there have been many studies for the ride-hailing service in the aspect of mode choice, OD estimation, equity, etc., no study has suggested a framework assessing microscopic driving behavior. Thus, the study aims at identifying dangerous microscopic behaviors of the ride-hailing drivers using trajectory Big Data from the largest ride-hailing service company in China along with other additional data (e.g., weather). The study also suggests effective strategies to improve driving behaviors based on 450 self-reported questionnaires collected from ride-hailing drivers. The developed framework is capable of identifying risky behaviors based on over-speeding, sudden acceleration/deceleration, and relative risky driving. Furthermore, contributing factors associated with the risky behaviors were revealed. Generally, nighttime, fog, residential street, a particular district, and bridge areas are associated with risky behavior. It is interesting that over-speeding is less observed in tunnels while sudden acceleration/deceleration and relative risky driving are more observed. The results from the questionnaire survey indicate that driving experience, at-fault crash involvement, risk awareness towards over-speeding, and sudden acceleration/deceleration have associations with drivers' willingness to improve the behavior. The methods and findings from this study will be useful for ride-hailing service companies to enhance their drivers' behavior and traffic safety.

Authors	Suvin Padinjare Venthuruthiyil, Indian Institute of Technology, Guwahati Mallikarjuna Chunchu, Indian Institute of Technology, Guwahati
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 1304
Session Title	Advancing New Methods and Data (55)
Paper Number	TRBAM-22-04784
Paper Title	**Proactive Safety Assessment of 3D Road Geometries Using Naturalistic Driving Data**
Abstract	Road traffic crashes are increasing rapidly in the low and middle income countries. According to reports, most crashes occur on highways with complex geometries, such as horizontal curves superimposed with vertical curves. The existing safety assessment practice for complex road geometries uses geometric design consistency measures based on operating/design speed, or historical crash data. Such practices have several limitations as reported by other studies. The present study proposes a proactive safety assessment method that can effectively capture the crash risk at complex road geometries without relying on historical crash data. A novel surrogate safety indicator called Anticipated Collision Time (ACT) was used to quantify the crash risk. ACT can capture the crash risk corresponding to different crash types, which allows the designers to develop crash-type-specific mitigation strategies. A comparison of actual and estimated crash frequencies shows that the proposed method can replicate the field scenario. For a given road geometry, a correlation analysis of crash exposure and severity with distinct crash types reveals a contrasting correlation between crash types. Evidently, geometric redesign to alleviate a particular crash type may lead to the occurrence of other crash types. Therefore, the geometric design practice should consider optimal trade-off of the occurrences of all the crash types. As the improvement of geometric elements is not always the only strategy to ensure safety, it would be more appropriate to add adequate protective measures (e.g., crash barriers) or installing warning systems to minimize the crashes or their severity.

ASC10 Sessions

Lectern Session 1049

Emergency Responder Safety and Next-Generation Traffic Incident Management

Monday, January 10 8:00 AM- 9:30 AM ET
Convention Center, 143
Lectern

Sponsored by: Section - Transportation Systems Resilience (AMR00)

Authors	Alexandria Noble, Battelle
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Lectern Session 1049
Session Title	Emergency Responder Safety and Next-Generation Traffic Incident Management
Paper Number	P22-20099
Paper Title	**Move Over Law Efficacy Research**
Abstract	Every state in the nation has a Move Over law in effect to reduce injuries and fatalities among roadside workers and incident responders, but evidential assessments reveal that the majority of the motoring public is not obeying these laws. This joint FHWA and NHTSA research project is exploring technologies employed, legislation, and current policies and practices as they relate to the Move Over law compliance issue. Hear how the research is assessing the efficacy of the laws (and the impact on curbing secondary crashes), exploring practices and tools employed, and newer technologies, to determine what has potential to increase compliance to the laws. Research is also objectively assessing compliance through observational data collection using an Object Detection and Tracking (ODT) machine learning algorithm developed by University of Maryland CATT Lab.

Authors	James Witherspoon, Battelle
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Lectern Session 1049
Session Title	Emergency Responder Safety and Next-Generation Traffic Incident Management
Paper Number	P22-20102
Paper Title	**Next Generation TIM**
Abstract	**TIM Tech Lessons.** New emergency responder training lessons (supplement the National TIM Responder Training curriculum) address advanced technologies as they apply to TIM in the areas of CAD, UAS, TMCs, Crowdsourcing TIM Data, and CAVs. **NextGen TIM**. As part of FHWA's EDC initiative, hear how NextGen TIM is focused on integrating good practices for TIM on arterial roadways and up to date results from engaging with and learning from nearly 2/3rs of the state DOTs who perform arterial TIM on a daily basis.

Authors	Kelley Pecheux, Applied Engineering Management Corporation Grady Carrick, Enforcement Engineering, Inc.
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Lectern Session 1049
Session Title	Emergency Responder Safety and Next-Generation Traffic Incident Management
Paper Number	P22-20101
Paper Title	**Secondary Crashes and Responder Struck by Research**
Abstract	It is important to understand the number and causes of secondary crashes related to TIM the extent and severity of the issue is unknown. Since the early 2000s, the FHWA TIM Program has been using three core performance measures: roadway clearance time (RCT), incident clearance time (ICT), and secondary crashes. Throughout the decades several efforts have been tackled to increase the quantity of data available, improve the quality of the data, and to increase the use of data for TIM performance measurement and analysis. Learn about this research into the number of secondary crashes (by roadway type and causation) and take a deeper look into causation and potential counter measures that may reduce secondary crashes. This initiative also is exploring identification of states that may be collecting responder struck by incidents, that data, and potential counter measures.

Authors	Martha Morecock Eddy, Battelle Memorial Institute
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Lectern Session 1049
Session Title	Emergency Responder Safety and Next-Generation Traffic Incident Management
Paper Number	P22-20100
Paper Title	**TIM for Rural Environments**
Abstract	TIM for Rural Environments is the crossover project in that both research and training materials are under development. To date the National TIM Responder Training program included materials on TIM for rural (and arterial) environments, but there is so much more to the topic of Rural TIM. Through the assistance of an expert panel of TIM responders and administrators, hear how this effort is researching unique challenges, good practices, and opportunities. This effort is producing a Rural TIM State of the Practice document and outreach materials – and will be developing and conducting a Rural TIM training course and pilot, which will serve as a stand-alone supplement to the National TIM Responder Training materials.

Lectern Session 1073

The Role of Speed in a Safe System

Monday, January 10 10:30 AM- 12:00 PM ET
Convention Center, Salon AB
Lectern

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

Authors	Nada Mahmoud, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai, Waymo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 1073
Session Title	The Role of Speed in a Safe System
Paper Number	TRBAM-22-02362
Paper Title	**Analyzing the Difference Between Operating Speed and Target Speed Using Mixed-Effect Ordered Logit Model**
Abstract	Desired operating speed (target speed) plays an important role in enhancing traffic operations and providing safe mobility to road users. Understanding the difference between vehicles' operating speed and target speed on arterial roads is important for achieving safer speed that is consistent with the activity generated in the context classified roadways. Hence, a mixedeffect ordered logit model was proposed to examine the significant exogenous factors that affect the difference between the two speeds. To the best of the authors' knowledge, no existing research has adopted the concept of target speed. Three years of INRIX speed data and exogenous variables including traffic and roadway characteristics, land use attributes, and socio-demographic information were utilized in the models. The data included information for around 1600 roadway segments in Central Florida. The results concluded that 16 variables were significantly associated with the difference between target speed and operating speed including speed limit, volume exposure, shoulder width information, sidewalk and shared path proportions, block length, number of signals, pavement conditions, residential and mixed land use, population density, and percentage of poverty. The results also indicated the effect of different time periods on the response variable. Hence, it recommended different posted speed limits based on the time of day. Further, the study suggested the roadway measures that should be followed in order to achieve the desired target speed.

Authors	Md Amdad Hossen, West Virginia University Kakan Dey, West Virginia University Md Tanvir Ashraf, West Virginia University Bhaven Naik, Ohio University Alex Phares
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 1073
Session Title	The Role of Speed in a Safe System
Paper Number	TRBAM-22-04109
Paper Title	**Effectiveness of Vision Zero Initiatives on Cyclists' Safety in New York City**
Abstract	In New York City (NYC), safety initiatives under the Vision Zero (VZ) action plan have successfully reduced pedestrian and motorist-involved crashes. However, cyclist-involved crashes have increased since the beginning of VZ initiatives in 2014. This study investigated the significant factors affecting cyclist-involved crash severity in NYC, including VZ initiatives by developing a Ordered Logistic Regression (OLR) model. Model results showed that crash locations, time of day, time of the year/season, driver-related factors, roadway factors, cyclist's error, and five VZ initiatives (i.e., bike priority area, priority corridor, priority zone or area, safe street for seniors, and signal retiming) were significantly associated with cyclist injury severity. Locations within or near a bike priority area and along a signal retimed corridor increased cyclist injury severity by 2.1% and 1.85%, respectively, compared to cyclist crashes in locations without these VZ initiatives. Cyclist crashes within 150 ft of a priority corridor, priority zone, and safe street for seniors decreased cyclist injury severity by 1.73%, 2.35%, and 2.6%, respectively, compared to cyclist crashes in locations without these VZ initiatives. In addition to safety improvement projects, safe streets for seniors and educational outreach to senior centers initiatices effectively reduced cyclist crash severity. Based on the findings of this study, NYC VZ program could emphasize implementation of priority corridor, priority zone or area, and safe street for seniors which wer found to be effective in improving cyclist safety.

Authors	Leah Mbugua, The World Bank Sudeshna Mitra, The World Bank Kazuyuki Neki, The World Bank R. F. Job, Global Road Safety Solutions William Wambulwa
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 1073
Session Title	The Role of Speed in a Safe System
Paper Number	TRBAM-22-02957
Paper Title	**Potential Reductions in Road Fatalities and Injuries from Reducing Speed Limits to Recommended Safe System Speed Limits in Low- and Middle-Income Countries**
Abstract	Guidelines for setting speed limits can be derived from the safe system principles which aim to eliminate deaths and serious injuries. This paper analyzes the potential road safety benefits of reducing current unsafe speed limits in low- and middle- income countries (LMICs) to recommended safe system speeds (i.e. 30kph for urban roads, 70kph for rural roads and 90kph for motorways) based on Nilsson's power model and estimates the economic benefits of reduced fatalities and serious injuries based on the iRAP methodology. The results indicate significantly high reductions in all road trauma with fatal crashes reducing by 4% to 44% depending on the road environment and region. Urban roads have the highest benefits owing to the greatest proportional drop in speed limits. A regional analysis indicates that South Asia region has the greatest potential reductions for all types of crashes and injuries on rural and urban roads, while Europe and Central Asia region has the greatest potential reductions on motorways. A total of US$ 91 billion or 0.37% of GDP in LMICs is estimated to be saved from the reduction in fatalities and serious injuries, with Africa region having the highest economic benefit relative to its GDP (0.47% of GDP). In practice, it is recommended that the reduction in speed limits be accompanied by effective sustainable speed management measures including suitable engineering treatments, automated speed enforcement, police enforcement and vehicle technologies such as speed limiters to ensure drivers' compliance and achieve profound road safety benefits.

Lectern Session 1162

Translating Safety Research to Real-World Solutions

Monday, January 10 4:00 PM- 5:30 PM ET
Convention Center, 150
Lectern

Sponsored by: Standing Committee on Research Innovation Implementation Management (AJE35)

Authors	Ge Shi, University of Connecticut Vannesa Methoxha, Howard/Stein-Hudson Associates, Inc. Carol Atkinson-Palombo, University of Connecticut Norman Garrick, University of Connecticut School of Engineering
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35)
Session Number	Lectern Session 1162
Session Title	Translating Safety Research to Real-World Solutions
Paper Number	TRBAM-22-04229
Paper Title	**Moving Beyond the Vision Zero Slogan: The Principles of Safe System for Traffic Safety**
Abstract	Safe system is a holistic way of managing traffic safety based on the underlying philosophy that road users'behavior is more dependent on the integral road system, rather than on individual ability and choice. The goal is to achieve zero road death by ensuring that the road environment is designed for prioritizing the physical tolerance of human body over the need for efficient movement of vehicles. Safe system was pioneered in the Netherlands and in Sweden in the 1990s and after 20 years, started to influence traffic safety management in other countries, including the U.S. However, there is need for a broader dissemination, understanding, and eventually, adoption of the underlying principles of sustainable safety. Our research shows that since the adoption of safe safety in the Netherlands and in Sweden, the risk of fatality has decreased at a rate far outpaced that in the U.S. The improvements have been particularly impressive when it comes to pedestrian and bicyclists who now has fatality risks that is as low as that of people in cars. In contrast, in U.S., the chance of a traffic fatality for a pedestrian is more than twice that for a person in a car. Given the spike in pedestrian fatality in the U.S. over the last decade there is a need to refocus on improving safety for pedestrians. Our paper outlines details of the Dutch and Swedish approach to safe system that is associated with their tremendous success in reducing traffic fatality – particularly for pedestrians and bicyclists.

Authors	Jason Anderson, Portland State University Sirisha Kothuri, Portland State University Christopher Monsere, Portland State University David Hurwitz, Oregon State University
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35)
Session Number	Lectern Session 1162
Session Title	Translating Safety Research to Real-World Solutions
Paper Number	TRBAM-22-01227
Paper Title	**Systemic Opportunities to Improve Older Pedestrian Safety: Merging Crash Data Analysis and a Stakeholder Workshop**
Abstract	This paper presents a framework for improving older pedestrian safety in regards to serious (fatal and incapacitating) crashes, using Oregon as a case study. Upon review of state and federal practices pertaining to older pedestrian safety, four years of crash data identified 112 older (≥ 65 years) pedestrian serious injury crashes. These data were explored for factors that might be addressed systemically using two methods. First, raw frequencies in the crash data were assessed to determine trends and crash-related factors that are overrepresented. Second, a random forest analysis is conducted to determine important variables for predicting older pedestrian serious injury crashes. Using these crash-related factors, a workshop was held with 18 local stakeholders and experts. As part of the workshop, key crash trends, potential causations, and potential countermeasures by priority of implementation were determined based on perspectives from workshop participants. Three key systemic solutions were identified to improve older pedestrian safety, including improving pedestrian visibility and illumination, implementing treatments for left-turns, and shortening pedestrian crossing distances across the state. The framework presented in the current study can be adopted by other agencies to systemically address a wide variety of safety concerns.

Authors	Miguel Figliozzi, Portland State University Jaclyn Schaefer, Portland State University Avinash Unnikrishnan, Portland State University
Sponsoring Committee	Standing Committee on Research Innovation Implementation Management (AJE35)
Session Number	Lectern Session 1162
Session Title	Translating Safety Research to Real-World Solutions
Paper Number	TRBAM-22-01087
Paper Title	**Evaluation of Posted Speed Limits Reductions on Urban Roads with a High Percentage of Cyclists**
Abstract	This paper presents a before and after analysis of the impact of posted speed limit (PSL) changes on passenger car (FHWA class two vehicles) speeds in Portland, OR. The study focuses on urban roads, comparing sites that underwent a PSL 5-mph reduction (treatment sites) and sites where the PSL did not change (control sites). Sites with a high percentage of and priority for cyclists (neighborhood greenways) and sites with a more standard traffic composition were compared. Differences in speed characteristics such as mean and 85 th percentile speeds, the speed variance, and the proportion of vehicles exceeding a speed threshold (relative to the posted speed limit) were evaluated on aggregate and individual scales. A series of statistical hypothesis tests were employed to assess changes in the speed characteristics among individual dataset pairs. The results suggest distinct differences between the treatment and control groups and neighborhood greenway and non-neighborhood greenway sites. Although there is a high degree of variability, the treatment group experienced more decreases in the speed characteristics, and by a greater amount than the control group, on average. Within the treatment group, sites with a priority for cyclists were even more likely to experience a larger reduction in operating speeds.

Poster Session 1219

Safety Management Systems Poster Session

Tuesday, January 11 8:00 AM- 9:30 AM ET
Convention Center, Hall A
Poster

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

Authors	Steven Matheny Ryan Love Kirolos Haleem, Western Kentucky University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-00085
Paper Title	**The Impact of COVID-19 Pandemic on Traffic Safety and Traffic Flow Patterns: A Case Study in the City of Bowling Green, Kentucky**
Abstract	COVID-19 pandemic is a cutting-edge topic nowadays; however, to the authors' knowledge, there exist limited studies revolving around this topic, specifically ones that are "citywide". The study objectives are: (1) perform safety investigation of COVID-19 pandemic in the city of Bowling Green, Kentucky, (2) perform operational investigation of COVID-19 pandemic in the city in terms of annual average daily traffic (AADT) changes, and (3) propose recommendations for improving safety during future pandemics. The post-pandemic period covers the core shutdown time (i.e., March 6, 2020 through July 31, 2020). This period was compared to the previous five-year (2015-2019) average during the same period (March 6 through July 31). Operation-wise, AADT was reduced by 37% across the city's major corridors. Traffic flow drops were most prevalent in areas near the university and downtown, while less prevalent near larger commercial areas. Safety-wise, the overall injury crash rate across the city's 22 major corridors has increased by 66.17% during the pandemic (or absolute injury crash rate increase of 0.73 crashes per million vehicle miles traveled). Single-vehicle crashes experienced the highest crash type involvement post-pandemic (at 28.12%, as opposed to 17.95% pre-pandemic), due to aggressive driving and increased anxiety levels. "Traffic Control Disregard" and "Drug Involvement" were the main crash causes that saw significant increases in crash involvement during the pandemic. It is recommended to increase law enforcement presence on roadways and conduct driver education campaigns during the shutdown to help reduce reckless driving and driving under the influence of drugs and alcohol.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-00545
Paper Title	**Systemic Safety Improvement Plan for Roadway Departure Crashes on Two-Lane Rural Roads in Virginia**
Abstract	This study developed a systemic safety improvement plan for roadway departure crashes on two-lane rural roads using low-cost countermeasures. Segments that have the potential for safety improvement were selected using Virginia-specific roadway departure safety performance functions. Decision tree analysis was applied to perform a systemic classification of roadway characteristics that are correlated with roadway departure problems. A list of countermeasures to deploy to target specific segments and patterns was developed based on the literature and input from field staff. The countermeasures were intended to warn of curves ahead, delineate curves, and warn of lane/road departure. Before deployment, a study of the section by field district traffic engineering staff is planned in order to finalize the safety improvement plan. The output of the study will be a safety improvement plan to deploy treatments systemically to two-lane rural roads as part of Virginia Highway Safety Improvement Program.

Authors	Farrukh Baig, Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-00929
Paper Title	**Trends of Traffic Safety Studies between 2010 and Early 2021: A Scientometric Analysis**
Abstract	Scientometric studies are important to identify and understand the research trends and developments in a specific research domain. In support of the World Health Organization's proclaimed decade of action for road safety (2010-2020), this study aims to explore road safety research between 2010 and early 2021. Using a bibliometric analytical method with VOSviewer software, this study highlights the overall research status of road safety from the perspectives of country/region, institution, article co-citation, and keywords co-occurrence. Findings indicate a continuous increase in road safety research articles in recent years. By co-citation analysis, the leading authors and their peer network visualization were also included in this study. The most contributing institutes, countries, academic journals were highlighted for future studies on the relevant research domain. This study also included keywords co-occurrence analysis highlighting the most used methods and research trends relevant to traffic safety research in the past decade. Logistic regression, psychological models, emergency health services, intelligent transportation systems (ITS), public policy, safety management systems, various transportation modes, and socioeconomic factors were the most important keywords used in the past decade for traffic safety-related research. The study's findings are expected to be useful for road safety researchers to understand the research trends in the area

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-01072
Paper Title	**Profile of Countries with Increases versus Decreases in Road Crash Fatality Population Rates in Low and Middle-Income Countries Focusing on Motorcycle Safety**
Abstract	Road crash fatalities have increased significantly in Low- and Middle- Income Countries (LMICs) between 2006 and 2016. This study presents how road safety characteristics have changed in LMICs by comparing data over time and relationships between the road crash fatality increase and a wide range of data from 125 LMICs. Parametric and nonparametric methods are used to test significance. There were 7 countries including Latin America and Caribbean region, Sub-Saharan Africa region, and South Asia region where the population rate of road crash fatalities consistently increased as per country reports, World Health Organization estimates, and Global Burden of Disease estimates. In these countries, the proportion of motorcycles, including powered two or three wheelers, to registered vehicles and GDP per capita approximately doubled over the same time (statistically significant). In these countries, the helmet-wearing rate was at only 42% for drivers and 27% for passengers. These patterns were not observed in LMICs with decreasing population fatality rates. Motorcycle helmet usage rates showed a strong relationship with decreasing fatality rates per 10,000 motorcycles in low and low-middle income countries. Effective interventions (including increasing helmet usage) are urgently needed for motorcycle crash trauma in LMICs, especially where the economy and motorization rapidly grow. National strategies for motorcycle safety, conforming to the Safe System principles, are recommended. For evidence-based policy formulation, there is a need to continue to strengthen the collection, sharing, and use of data.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-01341
Paper Title	**Estimating the Average Annual Cost of Crashes on Wyoming Downgrades using Time Series Analysis and Forecasting**
Abstract	The proportion of government funding allocated to state transportation budgets has significantly declined as a result of US policies trying to address the coronavirus pandemic. This has necessitated a more disciplined and efficient allocation of funds for various infrastructure development and rehabilitation projects. Economic assessments which include annual crash costs are usually estimated at the national level to inform resource allocation. These resources can then be used to implement measures to mitigate these crashes and the associated costs as well as to develop new technologies for continued improvement of road safety. This study employs time series analysis and forecasting techniques to make 10-year predictions of the number of injuries, fatalities and property damages occurring on US-16 highway based on historical data extracted from the Wyoming Department of Transportation database. The study determined that the estimated average annual cost of crashes with respect to the above-mentioned predictors is approximately $100,000,000.This result can be used to inform the Wyoming Department of Transportation on approximately how many dollars will be lost annually on US-16 with regards to these major crash outcomes to enable better planning and management of its infrastructure development funds.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-01484
Paper Title	**Improving Traffic Safety near Schools in Outskirts Areas through Internet of Thing (IoT): a Case Study in Iran**
Abstract	Speeding is one of the most significant contributing factors to road crashes in the outskirt areas. However, there are not enough studies on pedestrian safety on roads in outskirt areas. The purpose of this study is to examine four different signs near school zones in a high-risk outskirt area of Babol County in Iran to determine how effective they are at improving children's safety. Therefore, this study was conducted near primary schools on the main road in outskirt areas. IoT technology was used to develop an experimental system that records and collects the speed of vehicles. Collecting data was performed in two different steps. In the first step, the effectiveness of four signs was investigated in a 30-day study. As a result, all the signs reduced the speed of drivers. However, two signs were significantly effective compared to the other signs. In the next step, two signs with a higher impact were reinstalled for six months with a 3-month interval at two school zones. The results demonstrated that sign #4 improved safety with a 95% confidence; however, sign #2 was not always effective. The impact of sign #2 reduced over time. In addition, during the experiment, the vehicles' speed did not change in a control section upstream, which shows signs impacted reducing the speed. In addition, drivers reduced the speed when they approached the signs and then increased in zones located away from the signs. The two signs with the most significant influence provided more information to drivers.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-01905
Paper Title	**Safety and Economic Evaluation of the Highway Safety Improvement Program (HSIP): Is There a Return on Investment?**
Abstract	The Highway Safety Improvement Program (HSIP) is a Federal-aid program aimed at achieving a significant reduction in traffic fatalities and serious injuries on all public roads. Projects are selected based on the potential reduction of severe crashes and the greatest return on investment. In this paper, a step-by-step process and methodology were developed to evaluate Wisconsin HSIP projects implemented between 2013 and 2019. Safety effectiveness evaluation and economic assessment were conducted at the site specific and project level using the Empirical Bayes (EB) method. Crash cost benefit of implemented projects was quantified to find the benefit-cost (B/C) for a horizon of 10 years and observed period of analysis. With data available from project evaluations, Crash Modification Factors (CMF) for common treatments were developed. A total of 64 HSIP projects were evaluated. B/C ratios greater than one were observed in 43 projects. For a 10-year horizon, the aggregated B/C ratio was 2.71. Alternatively, using the observed data during the study period of each project, the observed overall crash cost benefit was equal to $72 million which corresponds to a B/C ratio of 1.10 (benefit already surpassed project costs at three to five years). Approximately 536 crashes were prevented which translates to seven lives saved, 379 injuries prevented, and avoided 1,067 property damage losses.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-01906
Paper Title	**Contributing Factors to Crashes on Kansas Freeways**
Abstract	Roadside safety treatments are financial investments intended to provide the greatest safety benefit for the cost of the treatment. The Kansas Department of Transportation (KDOT) funded a three-phase research study to investigate the in-service performance of its cable barriers, determine warrants for additional barrier installation, and evaluate factors contributing to right-side (roadside) departures. This paper discusses the roadside departure database. Contributing factors were tabulated and their relationship with environmental conditions, traffic volumes, roadway geometry, and driver influences were examined. A total of 4,665 roadside departures were identified from 2014 to 2018, including 695 crashes (14.9 percent) which also entered the median. Approximately 4.8 percent of roadside departures involved either a fatality or debilitating injury; driver impairment and rear-end collisions were associated with increased crash severity. Rear-end collisions negatively correlated with increasing traffic volume while every other contributing factor positively correlated. Implementing a Safe Systems approach, which encompasses both crash mitigation and prevention, could lead to more safety benefits than solely shielding potential hazards. Fixed-object crashes were reviewed, and bridge pier impacts were disproportionately severe. Nine out of 49 bridge pier crashes involved at least one fatality (18.4 percent) compared to 24 fatalities in 3,199 impacts with other fixed objects (0.8 percent). Lateral offsets were measured for each bridge pier using photogrammetric techniques, and ten of the eleven bridge piers involved in severe crashes were estimated to be within the clear zone. As a result, the benefit-to-cost for bridge pier shielding should be considered in accordance with proximity to the roadway.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-02261
Paper Title	**Evaluation of Crash Contributing Factors**
Abstract	Understanding of crash contributing factors is essential in safety management and improvement. These factors drive decisions on investments, policy, regulations, and other safety improvement activities. This paper provides an analysis of factors that contribute to crash occurrence based on two national datasets in the US (CISS and NASS-CDS) the years 2017-2019 and 2010-2015, respectively. Three taxonomies were applied in order t2o provide enhanced understanding of the various factors. These taxonomies were developed based on previous research and practice (e.g., human factors, vehicle factors, and roadway and environmental factors). Statistics for groupings of factor types are provided. Additionally, statistics for specific factors are provided.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-02476
Paper Title	**Using UAVs for vehicle tracking and collision risk assessment at intersections**
Abstract	Assessing collision risk is a critical challenge to effective traffic safety management. The deployment of unmanned aerial vehicles (UAVs) to address this issue has shown much promise, given their wide visual field and movement flexibility. This research demonstrates the application of UAVs and V2X connectivity to track the movement of road users and assess potential collisions at intersections. The study uses videos captured by UAVs. The proposed method combines deep-learning based tracking algorithms and time-to-collision tasks. The results not only provide beneficial information for vehicle's recognition of potential crashes and motion planning but also provided a valuable tool for urban road agencies and safety management engineers.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-02510
Paper Title	**The Role of High-speed Roads and Vehicle Ownership on Traffic Fatalities in India**
Abstract	The development of higher quality road infrastructure in developing countries improves ride quality but also enables greater driving speeds. Similarly, a growing middle class allows more people to afford personal vehicles but increases the number of drivers on the road. The improved mobility has historically been associated with economic growth, and its impact on traffic safety has been explored in high-income countries. However, the behavior of road users and vehicle ownership characteristics in middle-income countries are substantively different than those in high-income countries. This study explores the relationship between mobility and traffic safety at a region-wide level in India, a middle-income country. The results show that increasing lengths of National Highways are associated with an improvement in traffic safety while increasing lengths of all other types of roads and total number of motor vehicles are both associated with a deterioration in traffic safety. This study shows that safe roadway infrastructure has a huge role in enhancing overall safety even in countries with high vehicle heterogeneity, lack of driver education, and weak enforcement. This study's contribution should guide decision-makers in other middle-income countries to invest in traffic safety measures alongside any investments in higherquality road infrastructure.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-02558
Paper Title	**Macro-level Safety Model Updating: Application of Boosting Techniques**
Abstract	With the rapid changes in city traffic safety, there is a need to update macro safety models to predict crashes accurately at various times. Two main challenges: the homogeneous datasets and effective data collection for timely updating, have hindered researchers' ability to update the models, however. This study applied boosting techniques, which are well adapted to the conditions of data heterogeneity and small sample size, to macro safety model updating. To this end, crashes and regional characteristics were collected in 2009 and 2016 for Shanghai, China, as the source and target data domains, respectively. Four boosting-based updating models, AdaBoost.R2, two-stage TrAdaBoost.R2, Gradient Boosting, and CatBoost (an abbreviation for categorical boosting), along with a traditional two-stage Bayesian updating model, were established to evaluate and compare crash-prediction performance by Root Mean Square Error. The results showed that the CatBoost algorithm, with its ability to cope with heterogeneous datasets and categorical features, outperformed all the other methods. A further investigation into the optimal target sample size analysis was conducted. The three advanced boosting algorithms tended to have similar results around the proportion of 40% of target data (105 TAZs) in the training dataset. The two-stage TrAdaBoost.R2 and CatBoost tended to outperform other methods in the near-full sample size and small target sample size, respectively. Thus, the CatBoost algorithm model with 40% target data is recommended for macro safety model updating. These findings can be applied to the practice of long-term timely traffic safety monitoring and data collection optimization.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-02875
Paper Title	**Regional Traffic Safety Assessment Considering Crashes and Violations: Safety Risk Level and Influencing Factors**
Abstract	Regional traffic safety poses a public concern for many metropolitan areas, making it urgent to adopt safety assessment and analysis methods that can effectively coordinate the different needs of a city's districts. For example, safety performance in urban and suburban areas shows great disparity, making it unreasonable to assess the safety risk level of the two areas under the same criteria. Existing studies mainly use crash frequency or crash rate as indicators, but overlook that traffic violations can also measure regional traffic safety. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, for investigation. Socio-economic, roadway, land use, and police enforcement information of 115 districts in Suzhou were collected as independent variables. A composite assessment indicator was proposed considering crash rate, injury severity, violation rate, and area type. The 53 urban and 62 suburban districts were separately classified into three risk levels. Two random-effects two-level logit models (high-risk vs. moderate/low-risk, and moderate-risk vs. low-risk) were developed to capture the common influences of area types and various districts' individual characteristics on regional risk level. Results showed that (1) population density and GDP per capita play important roles in distinguishing high-risk and moderate/low-risk towns; (2) higher road and intersection density, and higher percentage of collector roads, were associated with higher risk levels. It was also demonstrated that the number of traffic police and patrol time in moderate-risk districts can be reasonably reduced to avoid wasting police resources. The proposed method shows promise for regional risk identification and improvement.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-03030
Paper Title	**Traffic Fatality Trends of Seven Developed Countries since 1970 – Assessment, Analysis, and Forecast**
Abstract	In February 2020, the "Stockholm Declaration" was announced, urging states toward 50% reduction in deaths and injuries over the next decade, leading to Vision Zero by 2050. The aim of this research is to understand how road traffic fatality patterns vary across selected developed countries and to see if they are on track to achieve the United Nation's 2030 target. After identifying potential reasons behind the patterns, time - series model was used to identify the effect of exposure variables on traffic fatalities. To assess the likelihood of meeting the U.N. target, an ARIMA model was used for obtaining trustworthy forecasts of road traffic fatalities using data from the last five decades from seven high-income countries. Total number of fatalities, vehicle-km travelled, vehicle ownership, GDP, GDP per capita, urbanization, population density and population were used to develop the ARIMA model using R-software. The forecasted performance of the models was validated for each country, which and was found to be within the 95% confidence interval. Estimated forecasts in all seven countries appear to be realistic, but, except for Japan and the U.S., fall short to achieve the U.N.'s 2030 target. Considering these results, countries may review the effects of safety interventions or other socioeconomic influences. Further interventions may be added to the existing model and to ascertain their effect of predicted fatality numbers. Keywords: Road Safety Planning; Accident Forecasting; ARIMA; Road Safety Improvements; International Comparison

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-02915
Paper Title	**Impact of COVID-19 travel-restriction policies on road traffic accident patterns with emphasis on cyclists: A case study of New York City**
Abstract	Since the first COVID-19 outbreak, travel-restriction policies widely adopted by cities across the world played a profound role in reshaping urban travel patterns. One important aspect of this shift is road traffic accidents. In this paper, by analysing the accidents data in the New York City and estimating three fixed effects logit models on whether types of accidents happen in a zip code in a certain time interval, we derived the following findings. First, while the overall number of road traffic accidents plummeted in the NYC after the stay-at-home policy was implemented, the average severity increased. The average number of cyclists killed or injured per accidents more than tripled relative to levels in similar times in previous years. Second, the declaration of the New York state stay-at-home order was significantly associated with a higher risk of accidents resulting in casualties. The number of Citi Bike trips in the area at the time overwhelmingly predicted severe risk for cyclists. Last, we applied the models to detect hot zones for cyclists' severe accidents. We found that these hot zones tend to be spatially and temporally concentrated, making it possible to target safety measures. This paper reveals higher risk for cyclists as an unintended consequence of travel-restriction policies, and provides a tool for evaluating impact on road safety should future travel restrictions be considered.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-03145
Paper Title	**Identifying the Impacts of COVID-19 Pandemic on Crashes in Texas Based on a Convolutional Neural Network Algorithm**
Abstract	The unprecedented COVID-19 pandemic has become one of the most challenging global problems. This unforeseen pandemic has created a new culture of online or web-based solutions, though the world still logistically and largely relies on the movement of vehicles. Crashes are still causing severe injuries during the pandemic, and the correlation between the COVID-19 cases and crashes is significantly higher. This paper presents an innovative way to explore the impact of COVID-19 pandemic on the basis of crashes that happened during the tenure. To determine the relativity and impacts of COVID-19 cases over the number of crashes, the convolutional neural network (CNN) algorithm is identified, which has been widely considered as one of the complex problem-solving algorithms in many research domains such as image processing, natural language processing, and data science. The pandemic data as well as the traffic related data are aligned to fed into the CNN model, while the outputs are the severity levels of crashes, namely suspected serious injury (SSI), suspected minor injury (SMI), possible injury (PI), fatal injury (FI), not injured (NI), and unknown (Un). The training and validation losses of the CNN model are quite low, and a set of traditional performance metrics are employed to evaluate the identified model, such as recall, precision, F-score, accuracy, and root mean square error (RMSE). Besides, the correlations between the attributes of the model as well as the confusion matrix are presented, which illustrates a satisfied prediction of crash severity levels.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-03367
Paper Title	**Safety and Equity Impacts of Automated Vehicles: A Quantification Framework and Empirical Analysis**
Abstract	Automated Vehicles (AVs) have the potential to improve traffic safety by preventing crashes, but the extent of the impact is unknown, given the limitations in AV road test. Moreover, the safety implications of AVs can vary across communities with different socioeconomic and demographic characteristics. In this study, we proposed a framework to quantify the potential safety implications of AVs in terms of preventable crashes and fatalities, accounting for some of the safety challenges of AV operation, including AV technologies' safety effectiveness, system failure risk, and the risk of disengagement from the automated system to manual driving. We further defined an empirical study to examine the proposed framework and investigate inequity in AV potential safety implications. The empirical analysis was conducted using 2017 crash data from the Dallas-Fort Worth, Texas, United States area. The results showed that AVs could potentially prevent up to 50%, 46%, 23%, 6%, and 5% of crashes for automation Levels 5 to 1, respectively. Among advanced driver assistance systems, pedestrian detection, electronic stability control, and lane departure warning showed more significant potential in reducing fatal crashes. We found a U-shaped relationship between the AV-preventable fatalities and household median income and ethnically diverse communities. The findings of this study suggest that low-income and ethnically diverse communities can benefit from AV implementation. The policy recommendations of this research suggest that city and state planning and transportation agencies may consider implementing policies and strategies for making AVs available to low-income and ethnically diverse communities at a lower cost.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-03406
Paper Title	**Examining Hot Spots of Crashes Involving Vulnerable Aging Road Users and their Spatial Relationship with the Built Environment**
Abstract	Traffic safety is a serious concern, especially among the aging population. When involved in traffic crashes, aging pedestrians and bicyclists tend to be more vulnerable compared to other age groups. This study examines crashes involving aging non-motorists in urban and rural counties in Florida at a macroscopic level. An optimized hot spot analysis was conducted to identify the clusters with a high concentration of crashes involving aging non-motorists. Further, the spatial relationship between crashes involving aging non-motorists and the built environment was investigated using geographically weighted regression (GWR). The results indicated that hot spots of crashes involving aging non-motorists were clustered in areas with a higher total population density and a higher proportion of the aging population. Spatial analysis results showed that clusters with more crashes involving aging non-motorists were associated with a higher population density, a higher proportion of the aging population, and a higher density of bus stops. Findings from this study provide essential guidance for transportation agencies in implementing aging-focused crash mitigation strategies, including education and outreach efforts that focus on improving the safety and mobility of the aging population.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-03769
Paper Title	**How did Transportation Fatalities, Total Crashes, and Crash Harm change during the COVID-19 pandemic? Evidence of Traffic Safety from Tennessee**
Abstract	Major concerns have been raised about road safety during the COVID-19 pandemic in the US, as the crash fatalities have increased, despite the substantial reduction in traffic. However, a comprehensive analysis of safety-critical events on roadways based on a broader set of traffic safety metrics and their correlates is needed. In addition to fatalities, this study uses changes in total crashes and total monetary harm as additional measures of safety. A comprehensive and unique time-series database of crashes and socio-economic variables is created at the county level in Tennessee. Results show that while fatal crashes increase by 8.2%, total crashes decrease by 13% and the total harm cost is lower by about $1.38 billion during COVID-19 (2020) compared with pre-COVID-19 conditions (2019). Time-series Feasible Generalized Linear Models using first differences are estimated to rigorously quantify correlates of fatalities, crashes, and crash harm. The results indicate that compared to the pre-COVID-19 periods, fatal crashes that occur during the pandemic involved more speeding and more reckless behaviors. Fatal crashes are more likely to happen on interstates and dark-not-lighted roads and involve commercial trucks. These same factors largely contribute to crash harm. As expected, a greater number of trips per person not staying home during COVID-19 is associated with higher crashes, fatalities, and crash harm at the county level. These results can inform policymaking to strengthen traffic law enforcement through appropriate countermeasures, such as the placement of warning signs and the reduction of the speed limit in hotspots.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-03847
Paper Title	**COVID-19 Policies and Road Safety: The Case of Nairobi**
Abstract	We examine how policies implemented to control the spread of COVID-19--such as curfews and other mobility restrictions--affect road traffic crashes and their severity. We combine unique data on emergency response and severity of crash injuries from Flare, a first response dispatcher and aggregator in Kenya, with crowdsourced data on road traffic crashes from Twitter and mobility data (traffic, congestion and speed) from Google and Waze for the city of Nairobi. Preliminary results indicate that (1) the total number of crashes decreased in the weeks after the closing of schools and bars and the introduction of other policies in line with decreases in mobility, though the percent decrease in crashes is smaller than the decrease in mobility; (2) after a curfew was implemented, crashes and injuries are redistributed around the curfew's starting time; (3) the decrease in crashes is short-lived, with crashes reverting to the pre-policy levels after several weeks. The concentration of crashes around certain times and locations following the introduction of the COVID-19 policies indicates potential policy levers to decrease adverse externalities of these policies on road safety when such policies need to be implemented in the future.

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Session Number	Poster Session 1219
Session Title	Safety Management Systems Poster Session
Paper Number	TRBAM-22-04687
Paper Title	**An Investigation into the Impact of Speeding on Traffic Safety Outcomes during COVID-19 Pandemic Unexpected Trends in Large U.S. Cities**
Abstract	As many governments around the world imposed mobility restrictions in order to reduce the spread of COVID pandemic and prevent potential deaths, a considerable reduction in daily traffic also resulted in reduced roadway crashes on roads in all around the world compared to previous years. However, the statistics show that this was not the case in the U.S. and in particular in large urban areas and when measured as fatalities with regards to the total miles driven. This paper aims to investigate the impacts of travel restrictions on traffic safety in selected ten large U.S. cities. We investigated fatalities, injuries and crash severity trends in 2020 and made a comparison with 2018 and 2019. The results show that the fatality number increased in most areas of study. While the national traffic death toll increased by 17% in 2020 compared to 2019, our findings illustrated that the trend was not identical across different areas, and cities showed dramatically different outcomes in terms of traffic safety measures. The highest fatality increases were observed in Philadelphia (69%) and in Chicago (40%). In addition, our results illustrate that the injury numbers were reduced in all studied cities. However, the severity index rose between 23%-71% in the study areas. The study also found that the severity index for pedestrians reached its highest level compared to the other types of users. Our findings suggest that speeding was a significant contributing factor in the increased traffic fatality numbers amid the Pandemic.

Poster Session 1376

Safety Studies on Low-Volume Roads

Wednesday, January 12 8:00 AM- 9:30 AM ET
Convention Center, Hall A

Sponsored by: Standing Committee on Low-Volume Roads (AKD30)

Authors	Jay Grossman, Valparaiso University Charles McKenzie, Elkhart County Highway Department Ignacio Veloz, Valparaiso University
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30)
Session Number	Poster Session 1376
Session Title	Safety Studies on Low-Volume Roads
Paper Number	TRBAM-22-04028
Paper Title	**Intersection Sight Distance Adjustments for Horse-Drawn Vehicles**
Abstract	Horse-drawn vehicles are present in significant numbers in some rural areas, and adjustments of intersection sight distance design parameters may be needed to improve their safety at intersections. This study examined the intersection sight distance case for a stop on a minor road. The eye height of a horse-drawn vehicle driver was found to be noticeably higher than the standard value used for passenger cars, but less than that used for trucks. The stopping position of the horse-drawn vehicle driver is further from the edge of travelled way of the major road than for motorized traffic. Analysis of accepted and rejected gaps for left turns and crossing maneuvers suggests that the critical gaps for horse-drawn vehicles are noticeably longer than for either passenger cars or trucks.

Authors	Md Shakir Mahmud, Michigan State University Anshu Bamney, Michigan State University Megat Usamah Megat Johari, Michigan State University Hisham Jashami, Michigan State University Timothy Gates, Michigan State University Peter Savolainen, Michigan State University
Sponsoring Committee	Standing Committee on Low-Volume Roads (AKD30)
Session Number	Poster Session 1376
Session Title	Safety Studies on Low-Volume Roads
Paper Number	TRBAM-22-03589
Paper Title	**Evaluating Driver Response to a Dynamic Speed Feedback Sign on Rural Highways Curves**
Abstract	Research was performed to evaluate the effectiveness of a dynamic speed feedback sign (DSFS) as a speed reduction strategy at horizontal curves on high-speed rural highways. A field evaluation was performed at five different horizontal curves located along two-lane rural highways in northern Michigan. All five locations were on rural highways with 65 mph speed limits and possessed curve advisory speeds varying between 25 and 65 mph. The DSFS were installed and evaluated at two different locations at each curve: 1.) at the curve advance warning/advisory speed sign and 2.) at the curve PC. Data were collected during each period using handheld LIDAR guns to track the speeds of vehicles while approaching and entering the horizontal curve. The results of this evaluation suggest that the DSFS had a significant effect on vehicle speeds while approaching and entering the curve. The DSFS was generally more effective at reducing motorists speeds when positioned upstream of the curve (e.g., at the curve warning/advisory speed sign). Furthermore, the DSFS was more effective at locations with sharper curvature (i.e., lower curve advisory speeds). Continued use of DSFS in this context is recommended, especially at locations with a significant differential (e.g., at least 25 mph) between the upstream speed limit and the curve advisory speed. In terms of sign placement, the DSFS should be positioned near the advance curve warning/advisory speed sign in order to provide adequate time for drivers to react and decelerate prior to reaching the curve.

Poster Session 1384

Emergency Response, Responder Safety, and Traffic Incident Management Research

Wednesday, January 12 8:00 AM- 9:30 AM ET
Convention Center, Hall A

Sponsored by: Section - Transportation Systems Resilience (AMR00)

Authors	Grady Carrick, Enforcement Engineering, Inc. Dr. Sivaramakrishnan Srinivasan, University of Florida
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 1384
Session Title	Emergency Response, Responder Safety, and Traffic Incident Management Research
Paper Number	TRBAM-22-03793
Paper Title	**Characterizing Incident Responder Crashes Involving Move Over Law Violations**
Abstract	This research seeks to understand secondary crashes involving incident responders where there was a citation issued to a party involved in the crash for violation of Florida's Move Over Law. From 2011-2020, there were 519 crashes involving a Move Over Law citation, where the circumstances of the crashes would require a driver to slow or change lanes because of a stopped responder vehicle. Analysis found that the majority of these crashes occurred during times other than daylight, and driver distraction and alcohol were notably present in the data. Law enforcement traffic stops were the most common precipitating activity, followed by previous crashes and vehicle disablements. More than 2/3 of crashes involved a law enforcement vehicle, with other responder vehicle types making up the remainder. A distribution of posted speed limits shows that more than half (58%) of Move Over violation crashes occur on roadways with a posted speed of 45 mile per hour or less. In 41 crashes, a pedestrian was struck, including 32 involving incident responders. In responder struck by crashes, law enforcement officers were by far the type of responder involved, making up more than 2/3 of struck by crashes. A lack of highvisibility safety apparel and operating on the traffic side of incident scenes were noted, along with a lack of traffic control device use. Local roadways made up a significant number of the struck by crashes, but higher speed roadways were more dangerous for towing operators and had a higher incidence of serious injuries.

Authors	Fatma Lestari, University of Indonesia: Universitas Indonesia Karl Kim, University of Hawaii Andrio Adiwibowo, Universitas Indonesia Devie Octaviani, Universitas Indonesia Micah Fisher, University of Hawai'i at Manoa Eric Yamashita, University of Hawai'i at Manoa
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 1384
Session Title	Emergency Response, Responder Safety, and Traffic Incident Management Research
Paper Number	TRBAM-22-02133
Paper Title	**Improving Service Coverage for Three-Wheeled Mobile Fire Units in Pari Island, Indonesia**
Abstract	Service area coverage by mobile fire response units is key to successful fire suppression and risk reduction. In this paper, the challenges of fire suppression in remote island communities are investigated. Small islands face not just having limited firefighting equipment and resources but also significant transportation problems. This study examines Pari, an island in the Pulau Seribu archipelago in Indonesia to understand the planning and management of mobile fire units (MFUs) for improving effective response and suppression. Like other communities in developing countries, the MFU in Pari Island uses a small three-wheeled vehicles designed for responding to emergencies in densely populated settlements with narrow roads and limited access. The purpose of this research is to review environmental, roadway, vehicle, and operating characteristics to support planning, management and operations of MFUs. Using Geographic Information Systems to investigate factors such as hose length and constraints based on the transportation infrastructure and exposure to fire hazards, service area coverages were estimated. Based on existing conditions, increasing hose length to 20 meters would increase the coverage of the MFU service area over existing service by two times. The use of a 30-meter hose, moreover, could provide coverage to over 96% of residential structures in Pari Island. In addition to description of analytical tools including coverage zones, Receiver Operating Characteristics (ROC) and Area Under the Curve (AUC) metrics to support MFU planning and operations, other initiatives to support increased resilience against fires and other hazards threatening small island communities are described.

Authors	Zubayer Islam, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Yina Wu, University of Central Florida
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 1384
Session Title	Emergency Response, Responder Safety, and Traffic Incident Management Research
Paper Number	TRBAM-22-00783
Paper Title	**Real-time Emergency Vehicle Event Detection Using Audio Data**
Abstract	In this work, we focus on detecting emergency vehicles using only audio data. Improved and quick detection can help in faster preemption of these vehicles at signalized intersections thereby reducing overall response time in case of emergencies. Important audio features were extracted from raw data and passed into extreme learning machines (ELM) for training. ELMs have been used in this work because of its simplicity and shorter run-time which can therefore be used for online learning. Recently, there have been many studies that focus on sound classification but most of the methods used are complex to train and implement. The results from this paper show that ELM can achieve similar performance with exceptionally shorter training times. The accuracy reported for ELM is about 97% for emergency vehicle detection (EVD).

3 Network Screening

Raghavan Srinivasan
University of North Carolina, Chapel Hill

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

The subcommittee identified **thirteen papers** related to network screening. Some papers in this category provide a case study of an application in a specific context. Other studies discuss methods with suggestions on the possibility of using these methods for network screening. This year, few papers proposed using surrogate measures data, and data from connected vehicles for pro-active network screening.

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

- Empirical bayes methods (Al-Kaisy and Huda; paper 22-00222)
- Artificial intelligence technique called Geographical Random Forest (GRF) to address spatial heterogeneity using connected vehicle data to proactively identify at-risk intersections (Gu et al.; paper 22-03540)
- Pattern-based surrogate safety measure (PSSM) using individual vehicle trajectory data to evaluate safety performance (Park et al.; paper 22-01040)
- Tree-based Random Forest and Extreme Gradient Boosting to reflect severity factor weights (Son et al.; 22-00933)
- A Logistic Regression (LR) model and a Long Short-Term Memory (LSTM) model (Phan et al.; paper 22-02211)
- Hierarchical Bayesian conditional autoregressive negative binomial model (Wang et al.; paper 22-03672)
- Traditional safety performance function redevelopment method (Zarei et al.; paper 22-00795)
- Random-effects two-level logit models to develop a composite assessment indicator including cash rate, injury severity, violation rate, and area type (Pei et al.; paper 22-02875)
- Geographically weighted regression (Kodi et al.; 22-03406)
- Combination of empirical Bayes and excess expected crashes (Tanzen et al.; paper 22-04476)

- Binomial logit regression (Gooch et al.; paper 22-03819)
- Spatio-temporal analytic tool and the Association Rule Mining (Tamakloe et al.; paper 22-01365)
- Extreme gradient boosting methods (Mahmoud et al.; paper 22-3376)

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

- Low-volume two-lane roads in Oregon (Al-Kaisy and Huda; paper 22-00222)
- Connected vehicle data from Ann Arbor, MI, to pro-actively identify high-risk intersections (Gu et al.; paper 22-03540)
- Individual vehicle trajectory data from four cities in Korea (Park et al.; paper 22-01040)
- Intersections in Korea (Son et al.; 22-00933)
- Urban crashes from Chattanooga, TN (Phan et al.; paper 22-02211)
- Freeways from Suzhou, China (Wang et al.; paper 22-03672)
- Three geographical regions in South-Western Ontario (Zarei et al.; paper 22-00795)
- 53 urban and 62 suburban districts in Suzhou, China (Pei et al.; paper 22-02875)
- Aging pedestrians and bicyclists (Kodi et al.; 22-03406)
- Pedestrian crashes in Massachusetts (Gooch et al.; paper 22-03819)
- Powered two-wheeler crashes in South Korea (Tamakloe et al.; paper 22-01365)
- Pedestrian and bicycle crashes in Florida (Mahmoud et al.; paper 22-3376)

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

Authors	Ahmed Al-Kaisy, Montana State University Kazi Huda, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00222
Paper Title	**Empirical Bayes Application on Low-Volume Roads: Oregon Case Study**
Abstract	This paper presents an investigation into the application of the Empirical Bayes (EB) method and the Highway Safety Manual (HSM) predictive methodology on low-volume roads in Oregon. A study sample of around 870 miles of rural two-lane roadways with extensive crash, traffic and roadway information was used in this investigation. To better understand the effect of low traffic exposure in estimating the EB expected number of crashes, the contributions of both the observed and the HSM predicted number of crashes were examined and analyzed. The study found that, on low-volume roads, the predicted number of crashes is the major contributor in estimating the EB expected number of crashes. The study also found a large discrepancy between the observed and the predicted number of crashes using the HSM procedures calibrated for the state of Oregon, which could partly be attributed to the unique attributes of low-volume roads that are different from the rest of the network. However, the expected number of crashes for the study sample using the HSM EB method was reasonably close to the observed number of crashes over the ten-year study period. The study findings show that it can still be very effective to use network screening methods that rely primarily on risk factors for low-volume road networks. This is especially applicable in situations where accurate and reliable crash data is not available.

Authors	Yangsong Gu, University of Tennessee, Knoxville Diyi Liu, University of Tennessee, Knoxville Ramin Arvin, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville Lee Han, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-03540
Paper Title	**Predicting Intersection Crash Frequency Using Connected Vehicle Data: Application of Geographical Random Forest**
Abstract	Accurate crash frequency prediction is critical for proactive safety management. The emerging connected vehicles technology provides us with a wealth of vehicular motion data, which enables a better connection between crash frequency and driving behaviors. However, appropriately dealing with the spatial dependence of crash frequency and multitudinous driving features has been a difficult but critical challenge in the prediction process. To this end, this study aims to investigate a new Artificial Intelligence technique called Geographical Random Forest (GRF) that can address spatial heterogeneity and retain all potential predictors. By harnessing more than 2.2 billion high-resolution connected vehicle Basic Safety Message (BSM) observations from Safety Pilot Model Deployment in Ann Arbor, MI, 30 indicators of driving volatility are extracted, including speed, longitudinal and lateral acceleration, and yaw rate. The developed GRF was implemented to predict rear-end crash frequency at intersections. The results show that: 1) rear-end crashes are more likely to happen at intersections connecting minor roads compared to major roads; 2) a higher number of hard acceleration and deceleration events beyond two standard deviations in the longitudinal direction is a leading indicator of rear-end crashes; 3) the optimal GRF significantly outperforms Global Random Forest, with a 9% lower test error and a substantially better fit; and 4) geographical visualization of variable importance highlights the presence of spatial non-stationarity. The proposed framework can proactively identify at-risk intersections and alert drivers when leading indicators of driving volatility tend to worsen.

Authors	Ahmed Al-Kaisy, Montana State University Kazi Huda, University of North Carolina, Charlotte
Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00222
Paper Title	**Empirical Bayes Application on Low-Volume Roads: Oregon Case Study**
Abstract	This paper presents an investigation into the application of the Empirical Bayes (EB) method and the Highway Safety Manual (HSM) predictive methodology on low-volume roads in Oregon. A study sample of around 870 miles of rural two-lane roadways with extensive crash, traffic and roadway information was used in this investigation. To better understand the effect of low traffic exposure in estimating the EB expected number of crashes, the contributions of both the observed and the HSM predicted number of crashes were examined and analyzed. The study found that, on low-volume roads, the predicted number of crashes is the major contributor in estimating the EB expected number of crashes. The study also found a large discrepancy between the observed and the predicted number of crashes using the HSM procedures calibrated for the state of Oregon, which could partly be attributed to the unique attributes of low-volume roads that are different from the rest of the network. However, the expected number of crashes for the study sample using the HSM EB method was reasonably close to the observed number of crashes over the ten-year study period. The study findings show that it can still be very effective to use network screening methods that rely primarily on risk factors for low-volume road networks. This is especially applicable in situations where accurate and reliable crash data is not available. Keywords: low-volume roads, Empirical Bayes, crash prediction, network screening

Authors	Yangsong Gu, University of Tennessee, Knoxville Diyi Liu, University of Tennessee, Knoxville Ramin Arvin, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville Lee Han, University of Tennessee, Knoxville
Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
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Paper Title	**Predicting Intersection Crash Frequency Using Connected Vehicle Data: Application of Geographical Random Forest**
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Authors	Seongmin Park, Hanyang University Seung-oh Son, Hanyang University Kawon Kang, Hanyang University, Ansan Hyeonseo Kim, Hanyang University, Ansan Juneyoung Park (jypark121@gmail.com), Hanyang University
Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01040
Paper Title	**Development of Pattern-based Surrogate Safety Measure using Individual Vehicle Data**
Abstract	In order to evaluate safety performance of specific roadway sections, a sufficient crash data is needed. To overcome this issue, many studies have tried to use the surrogate safety measures (SSM) estimated from the microscopic traffic simulations. However, it is difficult to adopt these developed SSM to reflect real world traffic conditions when the developed network in the simulation is not calibrated and validated accordingly. This article proposed a method to develop the pattern-based surrogate safety measure (PSSM) using individual vehicle trajectory data. The PSSM can be estimated based on nine different types of hazardous driving behavior (HDB) patterns. Using Digital Tacho Graph (DTG) data collected from the commercial vehicles such as buses, taxis, and trucks in 4 cities in Korea, HDB patterns were obtained. Various PSSMs were developed and validated with the observed crash data using random forest. Then, the surrogate safety performance function (SSPF) was estimated based on the frequency of HDB. To enhance model performance, machine learning and data mining techniques were applied. The results show that sudden deceleration, sudden lane change, sudden overtaking and sudden U-turn are related to traffic crashes during HDB. The results also show that high potential for safety improvement (PSI) was identified in the road section linking the urban and suburban areas. The findings from this study can provide new approach to adopt real-time individual vehicle trajectory data to evaluate safety performance of network levels.

Authors	Seung-oh Son, Hanyang University Juneyoung Park (jypark121@gmail.com), Hanyang University Gunwoo Lee Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00933
Paper Title	**Development of New Performance Measures based on Data Mining Weights for Hotspot Identification**
Abstract	In this study, new performance measures are proposed for hotspot identification in urban intersections that reflect the severity factor weights based on data mining. To estimate the severity factor weights of crashes at urban intersections, the study utilizes tree-based Random Forest and Extreme Gradient Boosting. The importance of variables in the severity classification model is standardized and utilized for calculating the score of each crash, which is aggregated into intersections. The aggregated score is used as a dependent variable for Safety Performance Functions (SPFs) in network screening process. To illustrate the under-dispersed severity score aggregation data, SPFs that follow the COM-Poisson distribution as well as Negative binomial are developed. Independent variables in SPFs set up intersection geometry elements that can be collected from online GIS services. The final 4 performance measures are proposed, each reflecting the severity weights. A total of 42,513 intersection crashes from 2017 to 2018 in Korea were collected for crash injury severity analysis. Hotspot identification was performed on 81 intersections, and 3 tests were conducted for validation of 4 measures. Tests show that the RF-based weighted and have the best consistency. Since the severity factor weights of each crash are reflected, the intersection vulnerable to dangerous crashes can be analyzed in more detail. It is expected that effective safety improvement project plans can be established from the perspective of safety managers in the future.

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Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-02211
Paper Title	**A Comparison of Logistic Regression and Long Short-Term Memory for Vehicular Crash Hotspot Prediction in Chattanooga, Tennessee**
Abstract	To address the ever present issue of vehicular crashes which claims lives and degrades the quality of life in urban areas, preventative measures need to be taken. Predicting crash hotspots is one viable way to enable implementation of countermeasure and minimize or prevent crash occurrence. In this work, we comparatively evaluate two methods (a Logistic Regression (LR) model and a Long Short-Term Memory (LSTM) model) for vehicular crash hotspots prediction on a given day in the city of Chattanooga, TN. These models analyze crashes and their associated weather and roadway geometric characteristics to understand factors contributing to crash occurrence, and are used to produce hotspot predictions for dates not covered by the dataset used for the model creation. Several variants of each model (both LR and LSTM) were created to thoroughly explore the prediction capabilities of each model. Based on the confusion matrix values (True Positive, False Positive, True Negative, and False Negative), the Logistic Regression model was deemed more successful at correctly identifying crash prediction hotspots, noted by LR's lower number of False Positive predictions when compared to the LSTM. However, with LSTM as the base, we can expand the model to adapt to ConvLSTM and other state-of-of-art techniques.

Authors	Xuesong Wang, Tongji University Qi Zhang Xiaohan Yang, Tongji University Yingying Pei Jinghui Yuan, Oak Ridge National Laboratory Chao Wang Juntao Wang
Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-03672
Paper Title	**Traffic Safety Analysis and Model Updating for Freeway Using Bayesian Method**
Abstract	Crash frequency and the influencing factors relating to freeways are changing over time, which means that crash prediction models developed in the past may not be suitable for current traffic conditions. In order to make sure that the implemented safety models fit the current traffic condition, this study proposed a comparative analysis on the basis of freeway datasets in 2017 and 2020 collected from Suzhou, China. Considering the spatial correlation among analysis units and the hierarchical data structure involved, a Bayesian conditional autoregressive negative binomial (CAR-NB) model and a Bayesian hierarchical CAR-NB model were used to explore the varied effects on safety of various influencing factors. The results showed that 1) the HCAR-NB model outperformed the CAR-NB model in prediction accuracy and 2) the number of crashes was significantly correlated with the average speed, speed variance, segment length, and several geometric design features. In addition, Bayesian inference with informative priors was used to update the HCAR-NB model to improve its goodness-fit and efficiency. Based on the modeling results, the potential for safety improvement (PSI) method was used to identify hotspots for the two years. The results confirmed that the hotspots spatiotemporally shift among the freeways. The proposed crash prediction model and model updating method are expected to help local traffic police develop a better understanding of the changes in contributing factors and therefore make informed decisions about safety countermeasures.

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Sponsoring Committee	Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00795
Paper Title	**A Quantitative Method to Determine When Safety Performance Functions Used for Network Screening Should be Redeveloped**
Abstract	The development of Safety Performance Functions for network screening process requires considerable effort for data collection and cleaning as well as specialized expertise in statistical modeling. Jurisdictions are therefore faced with the decision of whether they should redevelop SPFs and incur the associated costs, or just use an existing but outdated SPF and accept the less accurate NS results. However, at this time there are no quantitative methods by which jurisdictions can determine the magnitude of the errors associated with using an outdated SPF and therefore when SPF redevelopment is justified. In this paper, we propose a method by which jurisdictions can develop models to estimate the inaccuracy of applying outdated or recalibrated SPFs using a metric that is based on aggregated network level crash frequency and traffic flow data that are readily available to jurisdictions. The method is examined using historical crash and traffic flow data from three different geographical regions in south western Ontario, Canada as an example data set.

Authors	Yingying Pei, Tongji University Xuesong Wang, Tongji University Tianxiang Fan Zhongyang Qie, Traffic Police Department of Suzhou City Fang Liu, Traffic Police Department of Suzhou City
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	**Safety Management Systems**
Paper Number	22-02875
Paper Title	**Regional Traffic Safety Assessment Considering Crashes and Violations: Safety Risk Level and Influencing Factors**
Abstract	Regional traffic safety poses a public concern for many metropolitan areas, making it urgent to adopt safety assessment and analysis methods that can effectively coordinate the different needs of a city's districts. For example, safety performance in urban and suburban areas shows great disparity, making it unreasonable to assess the safety risk level of the two areas under the same criteria. Existing studies mainly use crash frequency or crash rate as indicators but overlook that traffic violations can also measure regional traffic safety. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, for investigation. Socio-economic, roadway, land use, and police enforcement information of 115 districts in Suzhou were collected as independent variables. A composite assessment indicator was proposed considering crash rate, injury severity, violation rate, and area type. The 53 urban and 62 suburban districts were separately classified into three risk levels. Two random-effects two-level logit models (high-risk vs. moderate/low-risk, and moderate-risk vs. low-risk) were developed to capture the common influences of area types and various districts' individual characteristics on regional risk level. Results showed that (1) population density and GDP per capita play important roles in distinguishing high-risk and moderate/low-risk towns; (2) higher road and intersection density, and higher percentage of collector roads, were associated with higher risk levels. It was also demonstrated that the number of traffic police and patrol time in moderate-risk districts can be reasonably reduced to avoid wasting police resources. The proposed method shows promise for regional risk identification and improvement

Authors	John Kodi, Florida International University Priyanka Alluri, Florida International University Gail Holley, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	**Safety Management Systems**
Paper Number	22-03406
Paper Title	**Examining Hot Spots of Crashes Involving Vulnerable Aging Road Users and their Spatial Relationship with the Built Environment**
Abstract	Traffic safety is a serious concern, especially among the aging population. When involved in traffic crashes, aging pedestrians and bicyclists tend to be more vulnerable compared to other age groups. This study examines crashes involving aging non-motorists in urban and rural counties in Florida at a macroscopic level. An optimized hot spot analysis was conducted to identify the clusters with a high concentration of crashes involving aging non-motorists. Further, the spatial relationship between crashes involving aging non-motorists and the built environment was investigated using geographically weighted regression (GWR). The results indicated that hot spots of crashes involving aging non-motorists were clustered in areas with a higher total population density and a higher proportion of the aging population. Spatial analysis results showed that clusters with more crashes involving aging non-motorists were associated with a higher population density, a higher proportion of the aging population, and a higher density of bus stops. Findings from this study provide essential guidance for transportation agencies in implementing aging-focused crash mitigation strategies, including education and outreach efforts that focus on improving the safety and mobility of the aging population.

Authors	Riana Tanzen, Kentucky Transportation Cabinet Reginald Souleyrette, Kentucky Transportation Cabinet Teng Wang, Kentucky Transportation Cabinet
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	**Safety Management Systems**
Paper Number	22-04476
Paper Title	**Incorporating Crash Severity to Improve Highway Safety Project Prioritization**
Abstract	Released in 2010, the Highway Safety Manual (HSM) provides procedures for evaluating highway safety improvements and prioritizing potential projects. Adopting the HSM guidelines, several states in the US use Excess Expected Crashes (EEC), a parameter dependent on Safety Performance Functions to rank safety projects. However, this method is limited by several methodological disadvantages (e.g., the severity of the observed crashes and the magnitude of the projected crashes by Empirical Bayes method are not considered). This paper describes a new safety scoring method developed for the Kentucky Transportation Cabinet (KYTC) for use in it's Strategic Highway Investment Formula for Tomorrow (SHIFT) project prioritization process. The method addresses crash severity and uses both EB estimates and the EEC metric. Additionally, it introduces a "goal-driven" EEC which represents the potential for reaching targets specified in the State's Strategic Highway Safety Plan and which may be customized for state's use. To demonstrate the use of the methodology, the analysis was performed on KYTC's list of potential projects for the 2020 SHIFT cycle.

Authors	Jeff Gooch, VHB Ian Hamilton, VHB Bonnie Polin, Massachusetts Department of Transportation Riana Tanzen Tal Cohen
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-03819
Paper Title	**Systemic Safety Analysis of Mid-Block Pedestrian Crashes in Massachusetts**
Abstract	Pedestrians are vulnerable road users on Massachusetts roadways. To develop safety improvement projects to address pedestrian safety issues, MassDOT conducted a systemic safety analysis of severe mid-block pedestrian crashes. The analysis incorporated crash, roadway, transit, census, and equity data to identify roadway segments which were at the highest risk for a severe pedestrian crash. Based on overrepresentation, principal arterials, minor arterials, and major collectors were identified as focus facility types. Binomial logit regression was used to identify risk factors for each focus facility type. Risk factors included number of lanes, traffic volume, population density, commute behaviors, employment density, and measures of equity. The authors found consistent risk factors across the three focus facility types. Ultimately, MassDOT will use these results to prioritize sites for mid-block pedestrian safety systemic improvements.

Authors	Reuben Tamakloe, University of Seoul Jungyeol Hong Dongjoo Park, University of Seoul
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-01365
Paper Title	**Investigating Chains of Risk Factors Influencing Fatal Powered Two-Wheeler Crashes at Spatio-Temporal Hotspot Locations in South Korea**
Abstract	Although researchers have explored factors influencing the safety of PTW's, no study comprehensively investigates the risk factors influencing their safety at crash hotspot locations considering the fault status of the rider and the geographical extent or area associated with frequent PTW crashes. As research suggests that spatial and temporal dependencies among crashes exist and that the factors influencing crashes are likely to differ based on the fault status of the road user, it is imperative to conduct a study that explores the contributory factors of fatal PTW crashes considering the riders fault status and the location of the crash. This study employs a spatio-temporal analytic tool and the Association Rule Mining (ARM) technique to discover hidden associations between crash-risk factors that lead to fatal PTW crashes based on the fault status of the rider at statistically significant PTW crash hotspots in South Korea from 2012 to 2017. The study results indicate the emergence of consecutive fatal PTW crash hotspots primarily concentrated around the central business district of South Korea's capital, Seoul. Interestingly, while reckless riding was the main traffic violation leading to PTW rider at-fault crashes at hotspots, violations such as improper safety distance and red-light running were strongly associated with PTW rider not-at-fault crashes at hotspots. Besides, while PTW rider at-fault crashes are likely to occur during summer, PTW rider not-at-fault crashes mostly occurred during spring. Engineering, enforcement, and education-related countermeasures targeted at both PTW's, and other vehicles are suggested to help improve traffic safety at the hotspot locations.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-03376
Paper Title	**An Integrated Approach to Identify Pedestrian and Bike Crash Hotspots Considering the Context Classification for Multi-lane Arterials**
Abstract	This research proposes an integrated approach to estimate vulnerable road users' exposure, develop safety performance functions, and identify the crash hotspots at intersections and along the roadway segments. The study utilized big data from multiple sources including Automated Traffic Signal Performance Measures (ATSPM) data, crowdsourced data (Strava), Closed Circuit Television (CCTV) surveillance camera videos, crash data, traffic information, roadway features, land use attributes, and socio-demographic characteristics. Statistical and machine learning models were developed and compared to estimate pedestrian and bike exposure. The results concluded that the Extreme Gradient Boosting outperformed other developed models in vulnerable road users' exposure estimation. The estimated exposure was utilized in developing the crash prediction models using Negative Binomial approach. The exposure variables (i.e., AADT, bike exposure, and the interaction between them) were found to have significant influences on vulnerable road users crashes at intersections and along roadway segments. Further, the context classification was significantly related to crash occurrence. C4-Urban General roadway segments were found to be significantly related to the increase of vulnerable road users' crashes at intersections and bike crashes along the segments. Afterwards, the crash hotspots were identified based on the calculated based on the Potential for Safety Improvements (PSI). Crashes were more likely to be located near the city of Orlando.

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 **forty-one 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 (22-03987, 22-02161, 22-03540, 22-01173, 22-03733, and 22-04860). The analysis included signalized intersections (22-03987, and 22-02161) and unsignalized intersections (22-01173, 22-03733, and 22-04860). On the other hand, many papers focused on developing SPFs for rural roadways (22-00222, 22-00855, 22-02703, and 22-01064) and freeways (22-01064, 22-00658, 22-01141, 22-01138, 22-02306, 22-02314, 22-03499, and 22-03923).

In addition, two papers developed macro level SPFs that could predict crashes for a geographic area rather than at a specific segment or intersection site (22-01286) or for highlighting cities or towns which may evidently need safety interventions (22-01754). Furthermore, three papers focused on more specific roadway facilities such as interchange (22-00230), and work zone (22-02066, 22-02205, and 22-03731). Multiple papers conducted safety performance analysis considering operated active traffic management (ATM) systems such as High Occupancy Toll lanes (HOT) and high-occupancy vehicle lanes (HOV) (22-00658, 22-02306, and 22-01138), Ramp Metering (22-01057), Variable/Advisory Speed Limit (VSL/VAS) (22-02314).

SPFs regarding **different crash types and severities** have also been widely conducted (22-00053, 22-01141, and 22-00139). Further, Paper 22-02211 developed a set of SPFs for different crash severities and conducted network screening to select the top one percent of hotspots within each facility type by injury severity level. In addition, SPFs for pedestrian and cyclist crashes were developed in Paper 22-03921. Several papers adopted developing SPFs for roadway segments at different aggregation levels (hourly, and peak period aggregation levels) (22-01138, 22-02314, 22-01507, and 22-03923).

Multiple papers insisted on the importance of **local calibration** and presented SPFs for the specific circumstance. For instance, Paper 22-00139 focused on estimating the local calibration factor when a database of adequate size cannot be assembled. Further, the problem of determining the sample size for calibration from the statical properties of the estimator of C, calibration factor defined in the HSM was revised in paper 22-04494. On another hand, paper 22-04133 compared two calibration strategies (using calibration factor

and a scalar factor). The results indicated that calibration factor is better than a scalar factor when Calibrating Safety Performance Functions.

Some studies introduced **distinct data sources** into the development of SPFs. Papers 22-03540 and 22-03923 predict intersection crash frequency using connected vehicle data, and environmental and electric vehicle big data, respectively. The divergent effects of factors on crashes under autonomous and conventional driving modes were explored in paper 22-04468. The COVID-19 pandemic and its effects on road crashes was studied in paper 22-04220.

Finally, multiple methodologies were proposed to develop SPFs such as Negative Binomial (22-01754), Bayesian Negative Binomial Models (22-02161 and 22-03926), Heterogenous Negative Binomial (HTNB) (22-00230), joint Negative Binomial-Multinomial Fractional Split (NB-MFS) model (22-00053), Finite mixture NB-L model (FMNB-L) (22-03499), and Poisson Log-Normal model (22-01138 and 22-02314). In addition, machine learning techniques were adopted in the safety performance analysis including Gradient Boosting model (22-01944), XGBoost (22-00855), Long-Short Term Memory (LSTM) (22-02211), Artificial Neural Networks (ANN) (22-03731), AdaBoost-CNN model (22-03923), and a new Artificial Intelligence technique called Geographical Random Forest (GRF) that can address spatial heterogeneity and retain all potential predictors (22-03540).

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

Authors	Ahmed Al-Kaisy, Montana State University Kazi Huda, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00222
Paper Title	**Empirical Bayes Application on Low-Volume Roads: Oregon Case Study**
Abstract	This paper presents an investigation into the application of the Empirical Bayes (EB) method and the Highway Safety Manual (HSM) predictive methodology on low-volume roads in Oregon. A study sample of around 870 miles of rural two-lane roadways with extensive crash, traffic and roadway information was used in this investigation. To better understand the effect of low traffic exposure in estimating the EB expected number of crashes, the contributions of both the observed and the HSM predicted number of crashes were examined and analyzed. The study found that, on low-volume roads, the predicted number of crashes is the major contributor in estimating the EB expected number of crashes. The study also found a large discrepancy between the observed and the predicted number of crashes using the HSM procedures calibrated for the state of Oregon, which could partly be attributed to the unique attributes of low-volume roads that are different from the rest of the network. However, the expected number of crashes for the study sample using the HSM EB method was reasonably close to the observed number of crashes over the ten-year study period. The study findings show that it can still be very effective to use network screening methods that rely primarily on risk factors for low-volume road networks. This is especially applicable in situations where accurate and reliable crash data is not available. Keywords: low-volume roads, Empirical Bayes, crash prediction, network screening

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00855
Paper Title	**Short Duration Crash Prediction for Rural Two-lane Roadways: Applying Explainable Artificial Intelligence**
Abstract	Conventional traffic crash analysis methods often use highly aggregated data, making it difficult to understand the effects of time-varying factors on crash occurrence. In this study, the combined effect of roadway geometry, speed distribution, and weather conditions on crash occurrence and severity was investigated on short duration daily level crash data. This study collected data from four different sources on rural two-lane roadways in Texas. A machine learning method, XGBoost, was applied to train the data. To mitigate imbalanced data problem, synthetic minority over-sampling technique (SMOTE) method was applied. The XGBoost model was trained separately on all crash occurrences and severe crash occurrences. Finally, explainable artificial intelligence (AI) technique SHAP (SHapley Additive exPlanation) method was applied to investigate the contribution of all variables to the model's output. The results show that AADT has a significant impact on all crash occurrences and severe crash (fatal and incapacitating injury) occurrences on rural two-lane roadways. Moreover, weather condition factors including daily precipitation, average visibility, and standard deviation of visibility show association with high crash occurrences. The short duration crash prediction models of this study can provide more insights on the relationships between crash, geometric variables, traffic exposure, weather, and operating speed.

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Sponsoring Committee	Standing Committee on Transportation of Hazardous Materials (AT040)
Session Number	1407
Session Title	**Hazardous Materials Transportation Risk and Performance**
Paper Number	22-02703
Paper Title	**Developing a Statewide Safety Performance Functions for Commercial Trucks Transporting Hazardous Materials on Interstate Rural Roads in Wyoming**
Abstract	Truck crashes in Wyoming are considered a major issue. Nearly 26% of crashes on rural interstate roads are Hazardous Materials (HAZMAT) truck related crashes. Wyoming encounters high energy- related activities, as it is considered among the top energy producing states in the US, in which it mainly relies on trucking industry for transportation. A crash involving a HAZMAT shipment might have a catastrophic impact due to the nature of the HAZMAT shipment. Therefore, it is crucial to identify traffic safety performance of HAZMAT trucks, so suitable countermeasures could be identified to reduce the frequency and/or severity of these crashes. This study aims to develop Safety Performance Functions (SPFs) for crashes involving HAZMAT utilizing traditional Negative Binomial (NB) models, as well as variations of the NB model, namely, NB-1 and NB-P. The results indicate that HAZMAT truck crashes are associated with vehicle miles traveled, truck percentage, horizontal and vertical characteristics, pavement type, and speed limits. The findings from this study showed that the NB-P models outperformed the traditional NB models based on likelihood ratio tests, information criteria, and prediction measures. Relevant insights regarding traditional countermeasures such as road geometry, warning signs, slippery road surface warnings, and climbing lanes, as well as non-traditional countermeasures including updating VSL algorithms, adding VMS, and integrating roadway geometry information into Connected Vehicle applications in Wyoming could be considered to assist stakeholders and emergency management agencies in better decision making toward a safer operations of HAZMAT trucks.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01064
Paper Title	**Safety Evaluation of Freeway Exit Ramps with Advisory Speed Reductions**
Abstract	Posted speed limits inform drivers of the maximum permissible safe speed on the highway under ideal roadway, traffic, and weather conditions. Various studies have investigated the safety impacts of speed limit changes, particularly on high-speed rural highways. One area of particular concern on such roadways is the approach to exit ramps that require substantive speed reductions, such as loop ramps. To date, there has been limited research examining the safety impact of the differential between the mainline speed limit and the lower exit ramp advisory speeds. This study aims to evaluate this relationship through the estimate of a series of safety performance functions. Random effects negative binomial regression models were estimated using data from 187 exit ramps where advisory speed signs are present throughout rural Michigan. The analyses were based on a five-year analysis period from 2014 to 2019. This includes a transition period where Michigan increased speed limits on more than 600 miles of limited access freeways in 2017. In addition to speed differentials, various roadway characteristics such as deceleration lane length and curve radius were also evaluated. Results indicate that lane departure crashes increased as the difference between mainline and ramp speed increased. The study also identified exit ramps with deceleration lane lengths less than the minimum recommendation as per the AASHTO Green Book. These sites were found to experience higher numbers of crashes compared to ramps with above-minimum deceleration lane lengths.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03987
Paper Title	**A Validation Study on Conflict-Based Crash Prediction Considering Crash Severity for Signalized Intersections**
Abstract	Traffic conflicts are the most widely used surrogate safety measures to harness data on critical safety events. However, the main body of the road safety literature has mainly focused on the relationship between traffic conflicts and total crashes, with very limited, if any, consideration of crash severity. The main goal of this study is to contribute to filling this gap by providing a validation study, using a rich dataset from 14 signalized intersections in the City of Bellevue, with over 3 million road users and 200,000 conflicts. Conflict data, measured by time to collision (TTC) and post-encroachment time (PET), was obtained using TrafxSAFE, a video analytics software, for one week of data. Crash data was obtained for a 6-year period. The modelling framework is based on a two-stage approach. First, the number of crashes is estimated using a count-data model that utilizes traffic conflicts. Then, assuming a crash has happened, the probability of the crash being in a certain injury level is computed using a Multinomial Logit (MNL) model. The results show that traffic conflicts are highly correlated with crash counts, highlighting that the safety analysis at signalized intersections, which are currently mainly based on traffic volume, could significantly benefit if conflicts were included in the models. Also, the results of MNL model provide the probabilities of each injury level given a crash has happened. The combination of the results of these two stages provides the expected number of crashes for each severity level, given different scenarios of crashes.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-02161
Paper Title	**Incorporating Driving Volatility Measures in Safety Performance Functions Improving Safety at Signalized Intersections**
Abstract	Every year, about 40 percent of the crashes in the US are related to intersections. To deal with such crashes, Safety Performance Functions (SPFs) are vital elements of the predictive methods in the Highway Safety Manual. The predictions of crash frequencies and potential reductions due to countermeasures are based on exposure and geometric variables. However, the role of driving behavior factors, e.g., hard accelerations and declerations, which can lead to crashes, are not explicitly specified in SPFs. One way to capture driving behavior is to harness connected vehicle data and quantify performance at intersections in terms of driving volatility measures. Studies have found driving volatility to be associated with risk and safety-critical events. Therefore, volatility can serve as a surrogate for driving behavior. This study incorporates driving volatility measures in the development of SPFs for four-leg signalized intersections. The Safety Pilot Model Deployment (SPMD) data containing over 125 million Basic Safety Messages generated by over 2,800 connected vehicles are harnessed and linked with crash, traffic, and geometric data belonging to 102 signalized intersections in Ann Arbor, Michigan. The results show that incorporating driving volatility measures in the intersection SPFs substantially improves the goodness-of-fit and predictive performance of the models. Also, the best results were obtained by applying Bayesian hierarchical Negative Binomial Models in which the spatial correlation between the signalized intersections are taken into account. The results of this study can have implications for practitioners and transportation agencies.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-03540
Paper Title	**Predicting Intersection Crash Frequency Using Connected Vehicle Data: Application of Geographical Random Forest**
Abstract	Accurate crash frequency prediction is critical for proactive safety management. The emerging connected vehicles technology provides us with a wealth of vehicular motion data, which enables a better connection between crash frequency and driving behaviors. However, appropriately dealing with the spatial dependence of crash frequency and multitudinous driving features has been a difficult but critical challenge in the prediction process. To this end, this study aims to investigate a new Artificial Intelligence technique called Geographical Random Forest (GRF) that can address spatial heterogeneity and retain all potential predictors. By harnessing more than 2.2 billion high-resolution connected vehicle Basic Safety Message (BSM) observations from Safety Pilot Model Deployment in Ann Arbor, MI, 30 indicators of driving volatility are extracted, including speed, longitudinal and lateral acceleration, and yaw rate. The developed GRF was implemented to predict rear-end crash frequency at intersections. The results show that: 1) rear-end crashes are more likely to happen at intersections connecting minor roads compared to major roads; 2) a higher number of hard acceleration and deceleration events beyond two standard deviations in the longitudinal direction is a leading indicator of rear-end crashes; 3) the optimal GRF significantly outperforms Global Random Forest, with a 9% lower test error and a substantially better fit; and 4) geographical visualization of variable importance highlights the presence of spatial non-stationarity. The proposed framework can proactively identify at-risk intersections and alert drivers when leading indicators of driving volatility tend to worsen.

Authors	Jonathan Kay, Michigan State University Timothy Gates, Michigan State University Peter Savolainen, Michigan State University Md Shakir Mahmud, Michigan State University
Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01173
Paper Title	**Safety Performance of Unsignalized 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. MUT intersections (also known as “Michigan lefts”, “boulevard turnarounds”, or “Michigan loons”) are one such design that accommodates all left-turn movements via directional U-turn crossovers within the median. Prior work has consistently shown that MUTs can provide superior safety performance when used in the appropriate conditions. However, research which is specific to unsignalized reduced left-turn conflict intersections continues to be limited to work conducted prior to the Highway Safety Manual or which includes RCUT intersections. This study included the evaluation of historical traffic crashes and volume data at 95 unsignalized intersections in the state of Michigan. This included the collection of data for 39 MUT sites and 56 reference group sites in order to estimate SPFs and CMFs which can be used when considering future conversions. Ultimately, CMFs for fatal and injury crashes of 0.438 and 0.686 are recommended when converting intersections with undivided two-lane two-way major approaches and four-lane divided boulevard major approaches, respectively. While there was no significant difference in PDO crashes associated with converting intersections with undivided two-lane two-way major approaches, a CMF of 1.325 is recommended for PDO crashes specific to conversions with four-lane divided boulevard major approaches.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03733
Paper Title	**Development and Evaluation of Calibration Factors of Safety Performance Functions for Unsignalized Intersections on Rural Multilane Divided Highways in Alabama**
Abstract	The crash prediction models in the Highway Safety Manual (HSM) were developed using data from various states; however, Alabama not being one of those states. Therefore the predictive models should be calibrated to adjust for local factors such as weather, roadway features, and driver characteristics. The objective of this paper is to develop local calibration factors (LCFs) for SPFs in the HSM 1 st Edition for unsignalized intersections on rural multilane-divided highways in Alabama and to evaluate theirs predictive performance. A total of nine years of crash data (2012 to 2020) were collected at 47 three-leg intersections and 65 four-leg intersections in Alabama from the Critical Analysis Reporting Environment (CARE) database. The LCFs were developed for both 3-leg intersections (3ST) and 4-leg intersections (4ST). The results show that HSM prediction models overestimate the crash frequency at these two types of intersections in Alabama. Additionally, to verify the calibrated SPFs, the total study sites were randomly separated into two groups: 70% of the study intersections to estimate the LCF, and the rest 30% intersections for verification. The mean absolute percentage error (MAPE) was estimated to measure the accuracy of calibrated SPFs. Results show that the lowest MAPE for 4ST is 0.644 when LCF is 0.532; and the lowest MAPE for 3ST is 0.454 when LCF is 0.617. Finally, a LCF of 0.532 for 4ST and 0.617 for 3ST was recommended to the Alabama Department of Transportation for implementing HSM predictive models.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04860
Paper Title	**Crossing Conflict Models for Un-Signalized T-Intersections**
Abstract	The safety of un-signalized intersections is assessed by correlating the number of crashes with traffic volume and intersection geometry-related characteristics. However, crash-based safety assessment has known drawbacks related to data quality and coverage. Further, the crash-based analysis does not explicitly account for the fact that not all vehicles are interacting unsafely. Therefore, with these drawbacks, analysing traffic conflicts is a more prudent approach for analysing safety. The present study develops crossing conflict-based safety performance functions (C-SPFs) for urban un-signalized T-intersections. Traffic video data for eight un-signalized T-intersections with variable intersection geometry (with or without Central Island) and traffic flow characteristics is collected. Crossing conflicts at the selected study intersections were analysed using post encroachment time (PET) as a most suitable surrogate safety measure (SSM). The crossing conflicts were bifurcated into critical and non-critical conflicts based on the PET values. The C-SPFs were modelled as a function of traffic flow and intersection geometry-related characteristics using the generalized estimating equations with the Tweedie distribution (GEE_TD) regression approach. The results revealed time of the day, intersection geometry, vehicular composition (both offending and conflicting stream), and traffic volume (both offending and conflicting stream volume) as the most significant variables that influence the number of critical and non-critical crossings conflicts at un-signalized T-intersections. The developed C-SPFs can provide insights into how the crossing conflicts vary at un-signalized T-intersections, enabling safety engineers to develop measures aimed at reducing crossing conflicts at un-signalized T-intersections.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01286
Paper Title	**Planning-Level Crash Prediction Models in Southern California**
Abstract	Macro-level or planning-level crash prediction models (CPMs) differ from traditional predictive safety models in that they predict crashes for a geographic area rather than at a specific segment or intersection site. These models lend themselves to traditional planning-level activities, particularly when the exact design or dimensions of a road facility have yet to be determined. This paper describes a research effort conducted by the Southern California Association of Governments (SCAG) to develop a series of models to support safety analysis as part of the agency's quantitative planning approach. These models can support SCAG's planning at two scales: one series of models addresses annual performance measure target setting for the entire SCAG region by predicting severe injuries per year (i.e., annual fatalities, serious injuries, and non-motorized fatalities and serious injuries), and a second series of models predicts crashes that contribute to agency-wide performance measures, but at a community or neighborhood level. These latter community models predict crashes at a scale that assists in evaluating scenarios for future projects or local community growth. The models developed through this research are consistent with previous research and display promising ability to accurately predict crashes and injuries that are key benchmarks for regional safety planning.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01754
Paper Title	**Using macro-level safety performance functions in province-wide sustainable mobility plans**
Abstract	The Safety Performance Functions (SPFs) play a key role in identifying black spots. Most SPFs have been built at the micro-level, such as for road intersections or segments. On the other hand, in case of regional transportation planning, it may be useful to estimate SPFs at the macro-level (e.g., counties, cities, or towns) to prioritize interventions. This study has the purpose of developing a predictive framework for crash frequencies at a province-wide level. The applicability of macro-level SPFs is investigated in the context of a province-wide Sustainable Urban Mobility Plan. In this context, the 41 areas of cities and towns belonging to the Province of Bari (Italy) are used as a base for the spatial aggregation. The spatial aggregation for the macro-level SPFs development is aimed at highlighting cities or towns which may evidently need safety interventions, considering 4 safety performance indicators and 28 predictors. These indicators were differentiated into rural and urban, thus obtaining a set of 4 x 2 dependent variables. Safety performance indicators were linked to the dependent variables by means of Negative Binomial (NB) count data models. After, stepwise regression algorithms and model comparisons based on likelihood ratio tests were used to select the optimal combination of variables in terms of model fit. The five models obtained from the regression were divided into rural and urban models. Results showed that the network length increase the rural crash frequency, while several relationships were found between geographic variables, the transport system, socio-economic factors and the urban crash frequency.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-00053
Paper Title	**Estimation of Crash Type Frequencies on Individual Collector Roadway Segments**
Abstract	Individual collision types have different underlying causes and thus the relationships between roadway/traffic characteristics and crash frequency are likely to differ across unique collision types. While developing separate statistical models for each collision type is the most straightforward approach, it can be very tedious and can produce unreliable estimates for rare collision types. Moreover, ignoring correlations between different collision types may result in biased and inefficient parameter estimation. To overcome these limitations, researchers have adopted a multivariate approach and a two-stage approach. In two-stage approach, a model which predicts total crash frequency is combined with proportion model to predict frequency of different collision types. More efficient one-stage joint models, in which both the frequency and proportion model are estimated simultaneously and predictions are provided more directly, have also been proposed for macro-level analysis. This study investigates the performance of joint model paradigm in analyzing unique collision type frequencies on individual road segments. For this, a joint negative binomial-multinomial fractional split (NB-MFS) model is used. Moreover, this study also proposes the use of a multinomial logit (MNL) model to estimate the proportion of different collision types. As total crash frequency NB model and MNL utilize different datasets, a two-stage estimation process is required, which leads to the two-stage NB-MNL model proposed here. The goodness of fit statistics show that the NB-MNL model performs better than collision-specific NB models, multivariate negative binomial (MVNB) model and joint NB-MFS model and is thus a promising approach in predicting crash frequency by collision type.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-00658
Paper Title	**Safety Prediction Method for Freeway Facilities with High Occupancy Lanes**
Abstract	The objective of this paper is to describe the development of a safety prediction method for freeways with High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes, collectively referred to as HO lanes. This method has been developed and documented in a manner that is consistent with the safety evaluation methods in Part C of the Highway Safety Manual (HSM). Such a predictive methodology would assist State DOTs in explicitly considering safety performance impacts when planning, designing, and operating freeway facilities with HO lanes. Data were collected in California and Washington to support development of the predictive methodology. This method focuses on the evaluation of one freeway travel direction with each application. The paper summarizes key differences and similarities between this method and the current predictive method for freeways in Chapter 18 of the HSM Supplement. The method includes models for predicting total crash frequency and multiple-vehicle crash frequency. The method applies to freeway facilities with continuous HO lane access, buffer-separated HO lanes with intermittent access, and barrier/pylon-separate HO lanes with intermittent access between the HO lane(s) and the GP lanes. The method does not differentiate between HOV and HOT designation.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01141
Paper Title	**Estimation of Freeway Segment Project Design-Level SPFs and Adjustment Factors using Ohio Data**
Abstract	Safety performance functions (SPFs), and associated adjustment factors (AFs), play a critical role in reliable crash prediction. SPFs are mathematical equations that predict average crash frequency for a facility based on traffic volume, segment length, and other roadway characteristics. Project design-level SPFs help to quantity and compare the safety performance of alternative geometric design and traffic operations characteristics. Agencies generally have two options for obtaining SPFs: 1) calibrating national SPFs or 2) developing jurisdiction-specific SPFs. The objective of this effort was to engage in developing project design-level SPFs to improve the prediction of safety performance for project design alternatives on freeway segments in Ohio. A further objective was to evaluate the predictive performance of the Ohio Department of Transportation's (ODOT's) calibrated version of the Highway Safety Manual (HSM) predictive model, a new bi-directional predictive method, and a new one-direction predictive method. The results indicated the one-direction predictive method provided reliable predictions for all crash types and severities when compared to the baseline of the calibrated version of the HSM predictive method. The one-direction method is easier to implement on complex alignments, provides a broad set of AFs, but does exclude some factors that may be relevant to practitioners. Additional external crash modification factors may be considered with the onedirection predictive method, as needed, to analyze the factors that are excluded from the onedirection predictive method.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01138
Paper Title	**Short-Term Safety Performance Functions for Freeways Including HOV Lanes**
Abstract	Short-term Safety Performance Functions (SPFs) were proposed to achieve accurate and dynamic crash frequency predictions and bridge the gap between annual crash frequency prediction and real-time crash likelihood prediction. The proposed short-term SPFs consider the temporal variation in crashes and traffic characteristics. This study contributes to the literature by developing short-term SPFs at hourly aggregation levels for freeways that include HOV lanes using loop detector data from Arizona State. Variables that capture the short-term traffic turbulence were prepared and considered in the developed SPFs. Further, this study investigated the factors contributing to crash frequency using three different ways to represent the hourly traffic: Annual Average Hourly Traffic (AAHT), Annual Average Weekday Hourly Traffic (AAWDHT), and Annual Average Weekday Peak Hour Traffic (AAWDPT). The results indicated that the traffic volume variable was found to be significant in all the developed models. Further, the variables that represent the speed and occupancy differences between HOV lanes and general-purpose lanes were positively associated with crash frequency. This study proposed a series of variables that reflect the short-term traffic turbulence. The models comparison results showed an improvement in ρ^2 of 2.4% to 12.8% when including the proposed variables. Further, the results indicated that the Poisson Lognormal approach outperformed the basic Negative Binomial model in both AAWDHT, and AAWDPT models. Further, the AAWDPT model was found to have the best performance in terms of AIC and ρ^2

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-02306
Paper Title	**Developing Safety Performance Function at Different Aggregation Levels for Freeway with High Occupancy Toll Lanes**
Abstract	As the operation of High Occupancy Toll (HOT) lanes has increased, more related research has been actively conducted. Many studies have been conducted to establish the design standards for HOT lanes and investigate their operational efficiency. Although some studies have been conducted to connect safety with HOT lanes' operation, no research was conducted to investigate the effects of differences in traffic condition between HOT lanes and General Purpose (GP) lanes on safety. Therefore, the main purpose of this study is to develop safety performance functions (SPFs) for freeways with HOT lanes that could evaluate the safety of HOT lanes along freeways. Since the usage pattern of HOT lanes varies according to the time of day, it may be difficult to accurately derive factors affecting crashes with highly aggregated data such as AADT widely used in conventional SPFs. Hence, this study developed short-term SPFs considering the relationship between the traffic variables of HOT lanes and those of GP lanes. The results showed that the difference in occupancy between HOT lanes and GP lanes, which could not be captured in the model using AADT, affects crash frequency. In particular, the difference in occupancy is more significant during the peak periods compared to off-peak periods. Therefore, congestion management of HOT lanes is important not only in terms of operational efficiency but also in terms of traffic safety. This study provides important insights into the safety and operation of HOT lanes.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-02314
Paper Title	**Development of Short-term Safety Performance Functions (SPFs) for Freeway Sections with Variable Speed Limit (VSL)/Variable Advisory Speed (VAS)**
Abstract	Variable Speed Limit (VSL) and Variable Advisory Speed (VAS) signs are efficient, cost-effective and state-of-the-art Active Traffic Management (ATM) strategies. They adopt the idea of dynamically changing posted speed limits to improve highway safety performance and operation by harmonizing traffic speed. VSL/VAS system involves changing speed limits according to real-time traffic events and weather conditions. Hence, traditional Average Annual Daily Traffic (AADT) based crash prediction models may not capture the temporal effect of traffic characteristics due to the high level of aggregation. To address this issue, short-term Safety Performance Functions (SPFs) with aggregation levels of Average Annual Weekday Hourly Traffic (AAWDHT) and Average Annual Weekday Peak Traffic (AAWDPT) along with AADT based SPFs were developed using high-resolution traffic detector and VSL/VAS operational data. In this study, the Poisson Log-Normal model was well-performed at each level of aggregation and so recommended for developing short-term SPFs. In line with previous studies, traffic volume as an exposure variable and standard deviation of speed were found to be positively associated with crash frequency in all the estimated models. In addition, it was found that implementation of VSL/VAS significantly reduced crash frequency by 14.78% and 34.22% for the AAWDHT and AAWDPT models, respectively. The safety improvement was captured in the short-term models in a more distinguished way than the highly aggregated AADT based model. It can be assumed that the findings of this study could pave the way for practitioners and policymakers to evaluate and select important parameters for VSL/VAS strategy implementation on freeways.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-02066
Paper Title	**Understanding Patterns of Contributing Factors in Encroachment-Related Work Zone Crashes**
Abstract	Work zone safety is one of the critical goals of transportation agencies. Vehicles change the 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. Frequency of the roadway departures at work zones, higher risk of fatality, and little insights about encroachment types at work zones assert the need for a thorough study. This study aims 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 a unique data mining method known as Cluster Correspondence Analysis (CA). This method identified four clusters in ‘non injury’ and ‘fatal and injury’ crash data separately. Major factors contributing to vehicle encroachment were identified. Three dominating clusters are median related crashes on two lane divided high volume roadways, single vehicle overturning collisions on two-way divided roadways with unprotected median, and overturning crashes on two-lane undivided roadways in controlled traffic. The findings of this study will be useful for safety engineers to contribute reducing encroachment related work zone crashes.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-02205
Paper Title	**Statistical Analysis of Inter-Crash Time Under The Impact of A Long-term Work Zone**
Abstract	Disrupted traffic in work zones introduces mobility and safety concerns for both road users and maintenance personnel. To assist long-term work zone traffic management to improve safety performance, it is critical to investigate the impact of work zone on traffic accidents in terms of crash frequency and severity. In this study, we present the survival analysis based inter-crash time modeling before and during a major rehabilitation project in New Jersey, and identify the influencing factors that may accelerate the occurrence rate of crashes with the presence of the longterm work zone. The regression model applied in the study could serve as a crash warning system with different crash risk indicators and prepare traffic operators with potential changes of crash risk under different situations in the work zone area.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03922
Paper Title	**From the Past to the Future: Modeling the Temporal Instability of Safety Performance Functions**
Abstract	Safety Performance Functions (SPFs) are statistical crash prediction models that relate crash frequency to base site conditions. The relationships between crash frequency and observed site conditions are assumed to be stationary from the past (when the model data were collected) to the future (for which SPFs are applied). The assumption using the past to represent the future could be fundamentally problematic. This study proposes a modeling framework that can relax this assumption. Specifically, temporal modeling and time-series analysis strengthen the current SPF estimation methods. The temporal modeling approach is Temporally Weighted Negative Binomial Regression (TWNBW), and the time-series analysis is tried by employing the Seasonal Autoregressive Integrated Moving Average (SARIMA) and Artificial Neural Networks (ANN) methods. The temporal modeling is to uncover the temporal variations of SPFs and the time-series analysis explains the relationship between the SPF's temporal variations and time. The outcome is a set of Future SPFs that capture the temporal unobserved heterogeneity in safety data and describes the predicted relationships between safety performance and site characteristics in the future (as correlated to the safety data collection period). A case study using six-year safety datasets from Georgia was conducted to illustrate the key components of the modeling framework. The modeling results showed significant variations in SPFs across time. The parameters for traffic volume, i.e., Average Annual Daily Traffic (AADT), and segment length are associated with an increasing trend with time, and for access point density there is a descending trend. Further discussions are available in the paper.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-02934
Paper Title	**Investigation of Spatial Transferability of Alternative Parameterizations for the Dispersion Function in Negative Binomial Models Predicting Crash Counts by Severity**
Abstract	Negative binomial (NB) regression is commonly preferred to Poisson regression for modeling crash counts since it employs a dispersion parameter to allow the variance to differ from the mean. Recent researchers have gone further, defining the dispersion parameter as a function varying with geometric and traffic features to better fit the data. This study evaluates five alternative dispersion functions (DF) (one fixed, two varying with segment length only, and two varying with both segment length and traffic volume) in negative binomial models for predicting five crash severity counts on five types of rural and urban roadway segments using data from the Highway Safety Information System (HSIS). Models are evaluated on fit as well as spatial transferability. Model fit using each DF is tested using log-likelihood and Bayesian Information Criteria (BIC) and predictive accuracy is tested using holdout sample prediction for multiple draws. Spatial transferability is tested by predicting for data from a different state. In most cases, models with two dispersion parameters fit the data better than models with fixed or one dispersion parameter. However, models with one dispersion parameter (fixed or varying with segment length or traffic volume) have better holdout prediction accuracy than models with two dispersion parameters. Including traffic volume with segment length in the DF significantly improved the prediction accuracy for freeways. Models with one-parameter DFs have better transferability accuracy than those with two parameters. The fixed DF and one-parameter DF with segment length and traffic volume are best for non-freeway and freeway facilities, respectively.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03136
Paper Title	**A Comparative Study to Evaluate the Application of Different Negative Binomial-Lindley Variations in Crash Data Modeling**
Abstract	It has been shown by many studies that the Negative Binomial Lindley (NB-L) distribution offers a better performance compared to the commonly used Negative Binomial (NB) distribution, especially when the dataset is highly dispersed or includes many zero observations. Consequently, different variations of the NB-L distribution have been introduced through mixing the NB distribution with different Lindley generalizations. However, little is known on how these models perform or compared in different data domains. In addition, there are also multiple Lindley distributions that have not yet been tried in mixture with the NB distribution. This study conducted a comparative analysis among different variations of the NB-L distribution to determine which variation performs the best. We considered several previously developed, as well as two newly proposed variations, negative binomial weighted Lindley (NB-WLindley) and negative binomial quasi Lindley distributions. Results confirmed that the proposed NB-WLindley performs better in majority of data domains used in the simulation analysis. This study also examined the application of the NB-WLindley in generalized linear modeling (GLM). We found that the NB-WLindley GLM performs better relative to the traditional NB as well as the NB-L GLM proposed in the past.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03499
Paper Title	**Finite Mixture Negative Binomial-Lindley to Model Heterogeneous Crash Data with Many Zero Observations**
Abstract	Crash data are often highly dispersed; it may also include a large amount of zero observations or have a long tail. The typical Negative Binomial (NB) model cannot model these data properly. The Negative Binomial-Lindley (NB-L) model has been proposed as an alternative to the NB to analyze data with these characteristics. Research studies have shown that the NB-L model has a superior performance comparing to the NB when data includes numerous zero observations or have a long tail. In addition, crash data often are collected from sites with different spatial or temporal characteristics. Therefore, it is not unusual to assume that crash data are drawn from multiple subpopulations. Finite mixture models are powerful tools to account for underlying subpopulations and capture the population heterogeneity. This research documents the derivations and characteristics of the Finite mixture NB-L model (FMNB-L) to analyze data generated from heterogeneous subpopulations with many zero observations and a long tail. We demonstrated the application of the model to detect subpopulations with a simulation study. We then used the FMNB-L model to estimate statistical models for Texas 4-lane freeway crashes. These data have unique characteristics; it is highly dispersed, have many locations with very large number of crashes, as well as significant number of locations with zero crash. We used multiple goodness-of-fit metrics to compare the FMNB-L model with the NB, NB-L and the finite mixture NB models. The FMNB-L detected two subpopulations in datasets. The results show a significantly better fit comparing to other analyzed models.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04133
Paper Title	**Is Using a Calibration Function Better than the Scalar Factor when Calibrating Safety Performance Functions?**
Abstract	The Highway Safety Manual (HSM) recommends calibrating crash prediction models -also called as Safety Performance Functions (SPFs) - using a scalar calibration factor. Recently, a few studies explored the merits of estimating a calibration function instead of a calibration factor. Although it seems a promising approach, it is not clear when a calibration function should be preferred over a scalar calibration factor. On the one hand estimating a scalar factor is easier than estimating a calibration function; on the other hand, the calibration results (i.e., statistical fit) may be improved using a calibration function. This study performs a simulation study to compare the two calibration strategies. We simulated data that covers a wide range of data characteristics (i.e.: mean and variations of data) as well as sample size and used a goodness-of-fit measure to compare the two methods. We found that as the sample size increases, or variation of data decreases, the calibration function performs better than the scalar calibration factor. If the analyst can collect a sample of at least 150 locations, calibration function is recommended over scalar factor. If the HSM recommendation of 30-50 locations is used and the analyst desires a better statistical fit, calibration function is recommended only if the coefficient of variation of data is less than 2. Otherwise, calibration factor yields better results.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04494
Paper Title	**HSM Calibration Sample Size based on Calibration Factor Statistical Properties**
Abstract	The Highway Safety Manual (HSM) provides guidance for the calibration of Safety Performance Functions (SPFs) to adjust their predictions to new jurisdictions. The HSM also provides guidance on minimum sample sizes for calibration of SPFs. However, related research literature suggests that more data than HSM recommended may be needed to achieve successful calibration. This paper revises the problem of determining the sample size for calibration from the statical properties of the estimator of C, calibration factor defined in the HSM. General results confirmed prior research suggesting that the uncertainty of the C estimator is proportional to the crash coefficient of variation. Furthermore, under assumptions of negative binomial (NB) distributions of crashes, this paper showed that the standard error of the C estimator depends on the following features: sample size, the crash average, and the NB dispersion parameter. The paper proposes a formulation for the minimal sample size for estimating C, based on the desired precision, level of confidence, and the three influential features listed above. The paper briefly presents an application of the proposed formulation on Texas highway segment data. Finally, the paper identifies future work and provide recommendations based on these results.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03921
Paper Title	**Behavioral Safety Analysis Using Integrated Multidisciplinary Data and Countermeasure Development**
Abstract	Driver errors contribute to more than ninety percent of traffic crashes on roadways. Predicting driver behavior-related crashes precisely plays a dominant role in identifying the sites with the highest potential for safety improvement and implementing effective countermeasures in reducing driver errors to improve highway safety. This study employs integrated multidisciplinary data to estimate crash prediction models for driver behavior-related crashes, including crash data, roadway geometry and traffic information, crime and citation data, toxicology data, socioeconomic and demographic data, and business data. Crash prediction models are estimated using the negative binomial model at the town level for six types of driver behaviors, i.e. impaired driving related crashes, aggressive driving related crashes, young driver involved crashes, motorcycle involved crashes, pedestrian involved crashes and distracted driving related crashes. The principal component analysis is conducted to account for the multicollinearity issue in the data. Moreover, this study proposes a procedure of collecting and standardizing countermeasures related to driver behaviors from different resources which can be used by practitioners to mitigate driver behavior-related issues and improve highway safety.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03926
Paper Title	**Roadway Crash Prediction Model Updating in Guangzhou, China**
Abstract	Roadways, significant carriers of urban traffic, are essential to city safety improvement. Crash prediction models assist traffic administrators in identifying risk factors and estimate crash frequency, which play an essential role in traffic safety management. With crash occurrence and influencing factors change over time, however, the crash prediction models might not be suitable for current circumstances and even provided the wrong estimation for crash prediction. In order to explore the change of risk factors and crash frequency, this study conducted a longitudinal safety comparison of the urban roadway in Guangzhou, China. Utilizing the Bayesian negative binomial model framework, the relationships of crashes and safety influencing factors, such as road geometric characteristics, traffic operation characteristics, and road isolation facilities, have been accurately captured. Additionally, a two-stage Bayesian updating method was adopted to update the crash prediction model for 2020, based on informative prior information obtained from 2015. Modeling results indicated that updating an existing model is better than establishing a new model. Moreover, safety influencing factors had significant differences towards crashes longitudinally. The findings could be applied to long-term risk factors and hot spots identification, and more effective and well-targeted improvement measures can be implemented.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04188
Paper Title	**Evaluation of Struck Parked Vehicle Crashes**
Abstract	Struck parked vehicle (SPV) crashes account for 3% of fatal and injury crashes in New Jersey—the same as head-on crashes—but SPV crashes are vastly under-researched. Moreover, SPV crashes are the state's fifth-highest crash type, accounting for 11% of all New Jersey crashes and amounting to an estimated cost of $845,847,000 in property damage and injury related expenses in 2018 in the state of New Jersey. SPV crashes are even more common on local roadways, accounting for 26% of municipal crashes and more than 20% of some counties' crashes. Despite the frequency of SPV crashes, there are few countermeasures to deploy against such crashes. The research described in this paper included a review of existing research on SPV crashes as well as a statewide analysis of SPV crash trends in New Jersey. One of the identified countermeasures, to stripe a parking lane, was further researched as a case study in a New Jersey municipality that frequently employs edgelines. An analysis of the case study findings show that there were 14% SPV crashes per mile on sections where there was an edgeline, compared with 20% SPV crashes per mile on section were there was not an edgeline.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04220
Paper Title	**The COVID-19 pandemic and its effects on road crashes and crash outcomes in Alabama**
Abstract	With the rising number of cases and deaths from the COVID-19 pandemic, nations and local governments, including many across the U.S., imposed travel restrictions on their citizens. This travel restriction order led to a significant reduction in traffic volumes and a generally lower exposure to crashes. However, recent preliminary statistics in the US suggest an increase in fatal crashes over the period of lockdown in comparison to the same period in previous years. This study sought to investigate how the pandemic affected road crashes and crash outcomes in Alabama. Daily vehicle miles traveled and crashes were obtained and explored. To understand the factors associated with crash outcomes, four crash-severity models for manner of collision and time of the year were developed using the first 28 weeks of crashes recorded in 2020. The findings reveal that although traffic volumes and vehicle miles traveled had significantly dropped during the lockdown, there was an increase in the total number of crashes and major injury crashes compared to the period prior to the lockdown order, with speeding, DUI, and weekends accounting for a significant proportion of these crashes. These observations provide useful lessons for road safety improvements during extreme events that may require statewide lockdown, as has been done with the COVID-19 pandemic. Traffic management around shopping areas and other areas that may experience increased traffic volumes provide opportunities for road safety stakeholders to reduce the occurrence of crashes in the weeks leading to an announcement of any future statewide or local lockdowns.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01944
Paper Title	**VT-Grid: A Three-Step Gradient Boosting Approach for Crash Frequency Prediction Utilizing Geospatial, Roadway Geometry, and Pavement Condition Information**
Abstract	In this study, we propose a framework for crash frequency prediction utilizing Virtual Traffic Grids (VT-Grid). Our proposed framework utilizes a combination of crash data with traffic, roadway geometry, and pavement condition information for a selected geo-fenced area of interest, generating a geographic grid with cells of varying traffic, geometrical and pavement conditions, and historical crash frequencies. We optimize the size of the grid and hence the number and characteristics of the generated cells, which are used to train, validate, and test a Gradient Boosting Machine (GBM) model for predicting the crash frequencies. We compare the GBM model to multiple popular machine learning algorithms. The optimal GBM model was able to achieve an overall R2 of 73% for continuous crash frequency prediction, with an R2 of 94% for predicting crash frequencies that fall within the 90th percentile of the observed crashes rate, and an accuracy of 84% for crash frequency multi-class classification. The proposed framework and results of this exploratory study provide a highly reproducible and scalable blueprint for crash frequency prediction utilizing factors that transportation agencies can readily control or account for (namely, traffic, roadway geometry, and pavement condition). This will aid practitioners in assessing how different roadway maintenance and traffic demand management strategies may impact the expected number of car crashes within a certain geographical area where they can influence those factors.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01507
Paper Title	**Effects of Inclement Weather Events on Road Surface Conditions and Traffic Safety – An Event-based Empirical Analysis Framework**
Abstract	Pavement friction has been widely recognized as an important winter road maintenance performance indicator for objectively assessing the level of service required to maintain safe driving conditions during inclement weather events. Despite significant efforts being put forth by road agencies, prevailing road surface conditions during snowstorms can yield negative consequences that compromise the safety of the traveling public. Acknowledging the vast road network that needs to be monitored and the uncertainty associated with the randomness of hazardous road weather conditions, this paper presents a novel event-based framework aimed at investigating the magnitude of the effect of varying pavement friction levels in urban environments on traffic safety during snowstorms. Negative Binomial safety performance functions developed using hourly weather datasets and road surface conditions information found a strong statistically significant relationship between pavement friction and traffic safety. This meant that, with the accumulation of snow and ice during snowstorms, road surface conditions were found to deteriorate thereby increasing the likelihood of collision occurrence. The event-based models developed also suggested that the risks of driving during snowstorms varied dramatically depending on varying surface states represented by friction coefficients; collisions were expected to significantly decrease whenever pavement friction was above 0.6, while at conditions where pavement friction deteriorated to below 0.35, collisions were predicted to significantly increase. Additionally, arterial roads were shown to experience a significantly higher number of collisions than collectors further justifying why arterials should be prioritized in snow clearing policies which most cities adopt.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-03731
Paper Title	**Work Zone Crash Occurrence Prediction based on Planning Stage Work Zone Configurations Using an Artificial Neural Network**
Abstract	Work zones are essential to maintain and improve the nation's road infrastructure. However, work zones affect traffic safety, and crashes and fatalities associated with work zones in the U.S. have increased substantially. Most existing work zone crash studies are not able to support the improvement of work zone planning and configuration, despite providing insights about individual crash level attributes. This study proposes an artificial neural network (ANN) based approach to predict the crash occurrence in work zones only using work zone configurations and design parameters. The goal is to explore whether using simple work zone configuration features available at the planning stage as the input can achieve satisfying work zone crash prediction. The performance of the proposed model is satisfying and comparable with existing studies using more comprehensive features. The proposed approach, early at the work zone design and planning stage, can provide designers and decision-makers with quick work zone safety evaluation for design alternatives and suggest extra resources and attention needed.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (ACS20)
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00377
Paper Title	**Overfitting Prevention in Accident Prediction Models: Bayesian Regularization of Artificial Neural Networks**
Abstract	In the present paper, we implemented the Bayesian Regularization (BR) backpropagation algorithm for calibrating an Artificial Neural Network (ANN) as Accident Prediction Model (APM) to be used on Italian four-lane divided roads. We chose the BR-ANN since it efficiently allows dealing with limited data and avoiding overfitting issues by the addition of a regularization term in the objective function to be minimized during training. Moreover, BR-ANNs are sparsely employed in road safety analyses, and their peculiarities deserve to be emphasized. In our work, the BR-ANN aims to predict the number of Fatal and Injury (FI) crashes for both road segments and road intersections across 236 road elements, for a total length of 78 km. The input features are road element length, horizontal and vertical alignment, road section geometry, operative speed, traffic flow, free viewing distance, and road element type (road segment or road intersection). An amount of 3,413 FI crashes that occurred between 2015 and 2019 have been considered as output targets. Training and test phases of the BR-ANN have been evaluated by Determination Coefficient (R2), Root Mean Square Error (RMSE), scatterplots, residuals analysis, and by the same ANN architecture trained with the Gradient Descent backpropagation algorithm (GD-ANN). Results demonstrate that the BR-ANN markedly outperforms the GD-ANN, which suffers from severe overfitting issues. BR-ANN does not overfit data, reports a satisfactory R2 (0.726), and shows a Gaussian residual distribution with zero mean. Road authorities should consider regularized ANNs for performing appropriate safety analyses, especially in contexts of limited data.

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Sponsoring Committee	Standing Committee on Safety Performance Analysis (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.

5 Crash Severity Prediction

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University of Naples Federico II

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

The subcommittee identified **forty papers** dealing with crash severity prediction. The large number of papers dealing with crash severity prediction highlighting how this issue is becoming important for the scientific community. Great emphasis is given to serious injuries crashes also at political level. The EU set the target of halving the number of serious injuries in the EU by 2030 from the 2020 baseline using a common definition based on the MAIS 3+ trauma scale.

The papers are scattered across various sessions, with most papers presented at the poster sessions:

1056 Safety of Motorcyclists and Active Transportation Modes (Monday, January 10 8:00 AM- 9:30 AM ET), 1268 TRB Minority Student Fellows Research Presentations (Tuesday, January 11 10:30 AM- 12:00 PM ET), 1304 Safety Performance and Strategies (Tuesday, January 11 1:30 PM- 3:00 PM ET), 1340 Advancing New Methods and Data (Tuesday, January 11 4:00 PM- 5:30 PM ET), 1073 The Role of Speed in a Safe System (Monday, January 10 10:30 AM- 12:00 PM ET), 1219 Safety Management Systems Poster Session (Tuesday, January 11 8:00 AM- 9:30 AM ET).

From a **methodological perspective**, several approaches were used.

Most studies used discrete outcome models treating injury severity as either a nominal or ordered variable.

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

- Binary Logit model (22-00451);
- Mixed Binary Logit model (22-00451);
- Multinomial Logit model (MNL) (22-02915, 22-04269, 22-03987);
- Fractional Multinomial Logit model (22-02546);
- Fractional Split Multinomial Logit model (22-02579);
- Logistic Regression models (22-04321, 22-04613, 22-04858, 22-01750);
- Multinomial Logistic Regression model (22-03546, 22-04306);
- Recursive Bivariate Probit (RBP) (22-03684)
- Multinomial logit latent class (MNL-LC) modeling method (22-04196)
- Pandom Parameter Logit model (22-04224);
- Multinomial Probit model (MNP) (22-01011);
- Random Parameters Probit model with Heterogeneity in Means (22-00336);
- Panel random effect model (22-02574);

- Random Parameter Multinomial Logit models with Heterogeneity in Mean and Variance (22-04360);
- Random-intercept Bayesian Logistic approach (22-04672);
- Bayesian Binary Logistic Regression model (22-04728); and
- Hierarchical Bayesian approach (22-04468).

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

- Ordered Logistic Regression (OLR) model (22-04109, 22-04792);
- Partial proportional odds (PPO) model (22-02981);
- Random parameters (mixed) Ordered Probit model with Heterogeneity in Means (22-01843); and
- Random parameters Ordered Logit model (RPOL) (22-01464).

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

- Convolutional Neural network (CNN) algorithm (22-03145)
- Association Rule Analysis (22-00813, 22-01377);
- Bayesian Network Model (22-00270);
- K-means Method (22-00919);
- Chi-square automatic interaction detector (CHAID) (22-02737);
- Decision Tree (22-04547);
- Random Forest (22-01811, 22-01811, 22-01681);
- Deep neural network (DNN) (22-02969, 22-01811);
- Structure Equation Models (SEM) (22-00639, 22-02905);
- XGBoost model (22-04306);
- Adaboost (22-01811, 22-01681);
- Gradient Boosting Decision Tree (GBDT) (22-01681);
- Extremely Randomized Trees (ET) (22-01681); and
- GcForest (22-01681).

One paper developed a pedestrian count model (22-00872) to analyze the severity of a pedestrian crash that has occurred in Charlotte, NC. Another paper used a new gradient boosting algorithm XGBoost and multiclass logistic regression (22-04306) for studying pedestrian Injury severity.

One paper applied the logistic regression models in order to determine the factors that have significant impacts on the increasing likelihood of pedestrians being seriously injured or killed. Another paper used a combination of count-data model and Multinomial Logit (MNL) model (22-03987) to provide the expected number of crashes for each severity.

One paper developed four crash-severity models (22-04220) for manner of collision and time of the year to understand the factors associated with crash outcomes. Another paper employed random-intercept Bayesian logistic approach (22-04672) to analyze the dichotomous injury severity response and capture the between-crash variance.

One paper combined machine learning predictive models (DT) and spatial analysis (22-04547) in order to predict crash severity in the Southeast Michigan region. Another paper adopted a hybrid

econometric modeling approach (22-01022) to offer interesting insights on body region severity evolution over time.

One paper employed a deep neural network (DNN) to model crash injury severity outcomes and compared it with the multinomial logistic regression model. Another paper developed both binary logit model and mixed binary logit models (22-00451) to investigate characteristics which influence driver injury severity in deer-vehicle crashes (DVCs).

One paper used four machine learning methods (Random Forest, AdaBoost, XGBoost, and Deep Neural Network) (22-01811), the SHAP (SHapley Additive exPlanation) method and SMOTE-based oversampling technique to investigate the collaborative variable effects on crash severity. Another paper developed five machine learning methods (Adaboost, Random Forest, Gradient Boosting Decision Tree, Extremely Randomized Trees and GcForest) (22-01681) and SMOTE-based oversampling technique to analyse crash severity.

Twenty-six papers investigated **vulnerable road users**, such as:

- Pedestrians (22-01227, 22-00639, 22-0087, 22-00872, 22-00813, 22-01478, 22-01843, 22-02546, 22-02579, 22-04196, 22-04306, 22-04321, 22-04858, 22-03097).
- Cyclists (22-04109, 22-02915, 22-02546, 22-02579, 22-02981, 22-04269); and
- Powered Two-Wheelers (22-01072, 22-01365, 22-01377, 22-03546, 22-03684, 22-04224, 22-04613, 22-04792);

The number of papers dealing with vulnerable road users had increased compared to the previous year (19 paper in 2021 - 26 paper in 2022), stressing that Pedestrian, Cyclist and Powered Two-Wheelers safety is a growing concern for transportation planners and safety engineers.

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	Md Amdad Hossen, West Virginia University Kakan Dey, West Virginia University Md Tanvir Ashraf, West Virginia University Bhaven Naik, Ohio University Alex Phares
Sponsoring Committee	ACS10
Session Number	1073
Session Title	**The Role of Speed in a Safe System**
Paper Number	22-04109
Paper Title	**Effectiveness of Vision Zero Initiatives on Cyclists' Safety in New York City**
Abstract	In New York City (NYC), safety initiatives under the Vision Zero (VZ) action plan have successfully reduced pedestrian and motorist-involved crashes. However, cyclist-involved crashes have increased since the beginning of VZ initiatives in 2014. This study investigated the significant factors affecting cyclist-involved crash severity in NYC, including VZ initiatives by developing a Ordered Logistic Regression (OLR) model. Model results showed that crash locations, time of day, time of the year/season, driver-related factors, roadway factors, cyclist's error, and five VZ initiatives (i.e., bike priority area, priority corridor, priority zone or area, safe street for seniors, and signal retiming) were significantly associated with cyclist injury severity. Locations within or near a bike priority area and along a signal retimed corridor increased cyclist injury severity by 2.1% and 1.85%, respectively, compared to cyclist crashes in locations without these VZ initiatives. Cyclist crashes within 150 ft of a priority corridor, priority zone, and safe street for seniors decreased cyclist injury severity by 1.73%, 2.35%, and 2.6%, respectively, compared to cyclist crashes in locations without these VZ initiatives. In addition to safety improvement projects, safe streets for seniors and educational outreach to senior centers initiatives effectively reduced cyclist crash severity. Based on the findings of this study, NYC VZ program could emphasize implementation of priority corridor, priority zone or area, and safe street for seniors which were found to be effective in improving cyclist safety.

Authors	Jintai Li Zhan Zhao, University of Hong Kong
Sponsoring Committee	ACS10
Session Number	1219
Session Title	**Safety Management Systems Poster Session**
Paper Number	22-02915
Paper Title	**Impact of COVID-19 travel-restriction policies on road traffic accident patterns with emphasis on cyclists: A case study of New York City**
Abstract	Since the first COVID-19 outbreak, travel-restriction policies widely adopted by cities across the world played a profound role in reshaping urban travel patterns. One important aspect of this shift is road traffic accidents. In this paper, by analysing the accidents data in the New York City and estimating three fixed effects logit models on whether types of accidents happen in a zip code in a certain time interval, we derived the following findings. First, while the overall number of road traffic accidents plummeted in the NYC after the stay-at-home policy was implemented, the average severity increased. The average number of cyclists killed or injured per accidents more than tripled relative to levels in similar times in previous years. Second, the declaration of the New York state stay-at-home order was significantly associated with a higher risk of accidents resulting in casualties. The number of Citi Bike trips in the area at the time overwhelmingly predicted severe risk for cyclists. Last, we applied the models to detect hot zones for cyclists' severe accidents. We found that these hot zones tend to be spatially and temporally concentrated, making it possible to target safety measures. This paper reveals higher risk for cyclists as an unintended consequence of travel-restriction policies, and provides a tool for evaluating impact on road safety should future travel restrictions be considered.

Authors	Syed Idnan Haider Fengxiang Qiao, Texas Southern University Shuyan Chen, Southeast University Yongfeng Ma, Southeast University Hanzhen Wang, Texas Southern University Tianyang Cui
Sponsoring Committee	ACS10
Session Number	1219
Session Title	**Safety Management Systems Poster Session**
Paper Number	22-03145
Paper Title	**Identifying the Impacts of COVID-19 Pandemic on Crashes in Texas Based on a Convolutional Neural Network Algorithm**
Abstract	The unprecedented COVID-19 pandemic has become one of the most challenging global problems. This unforeseen pandemic has created a new culture of online or web-based solutions, though the world still logistically and largely relies on the movement of vehicles. Crashes are still causing severe injuries during the pandemic, and the correlation between the COVID-19 cases and crashes is significantly higher. This paper presents an innovative way to explore the impact of COVID-19 pandemic on the basis of crashes that happened during the tenure. To determine the relativity and impacts of COVID-19 cases over the number of crashes, the convolutional neural network (CNN) algorithm is identified, which has been widely considered as one of the complex problem-solving algorithms in many research domains such as image processing, natural language processing, and data science. The pandemic data as well as the traffic related data are aligned to fed into the CNN model, while the outputs are the severity levels of crashes, namely suspected serious injury (SSI), suspected minor injury (SMI), possible injury (PI), fatal injury (FI), not injured (NI), and unknown (Un). The training and validation losses of the CNN model are quite low, and a set of traditional performance metrics are employed to evaluate the identified model, such as recall, precision, F-score, accuracy, and root mean square error (RMSE). Besides, the correlations between the attributes of the model as well as the confusion matrix are presented, which illustrates a satisfied prediction of crash severity levels.

Authors	Lining Liu Xiaofei Ye, Ningbo University Tao Wang, Guilin University of Electronic Technology Xingchen Yan, Nanjing Forestry University Song Li Jun Chen, Southeast University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-00270
Paper Title	**Key Factors Analysis of Severity of Automobile to Two-Wheeler Traffic Accidents Based on Bayesian Network**
Abstract	The purpose of this paper is to deeply analyze the complex coupling relationships among accident factors contributing to the automobile and two-wheeler traffic accidents by establishing the Bayesian network model of the severity of traffic accidents, so as to minimize the negative impact of automobile to twowheeler traffic accidents. According to the attribution of primary responsibility, traffic accidents were divided to two categories, the automobile and two-wheeler traffic as the primary responsible party respectively. And two Bayesian network accident severity analysis models for different primary responsible parties were proposed by innovatively combining Kendall correlation analysis method with Bayesian network model. 1560 accidents involving automobile and two-wheeler in Guilin, Guangxi province were applied to calibrate the model parameters and validate the effectiveness of the models. The result shows that the Bayesian network models could reflect the real relationships among the influential factors of the two types of traffic accidents. For traffic accidents of automobile and two-wheeler as the primary responsible party respectively, the biggest influential factors leading to fatality were weather and visibility, and the corresponding fluctuations in the probability of occurrence were 32.2% and 27.23%, respectively. The most influential combinations of the factors leading to fatality were: {Off-peak Period → Driver of Two-wheeler: The elderly → Driving Behavior of Two-wheeler: Parking} and {Drunk Driving Twowheeler → Having a License of Automobile → Visibility: 50m~100m} respectively. The results provide theoretical basis for reducing the severity of automobile to two-wheeler traffic accidents.

Authors	Haniyeh Ghomi, McMaster University Mohamed Hussein, McMaster University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-00639
Paper Title	**Analyzing the Safety Consequences of Pedestrian Spatial Violation at Mid-blocks: A Bayesian Structural Equation Modelling Approach**
Abstract	The objective of this study is to understand the impact of a variety of factors on the frequency and severity of pedestrian-vehicle collisions that involve pedestrian spatial violations (jaywalking) at mid-blocks. To that end, the historical collision records of the City of Hamilton between 2010 and 2017 were obtained, and collisions that occur at mid-blocks were filtered out. A Bayesian Structural Equation Modelling (SEM) framework was developed to investigate the impact of a wide range of factors on such collisions. First, a classical SEM was developed to group the different factors into sets of latent variables. Four latent variables were defined, including location amenities and attractions, pedestrian/road network characteristics, exposure parameters, and location/collision-specific factors. Then, the Bayesian SEM was implemented to investigate the relationship between the latent variables and collisions. The results showed that amenities and attractions of a location (e.g., parks, schools, bike-share stations, and bus stops) were the most influential factor on the frequency of collisions that involve jaywalking, followed by the pedestrian network characteristics. Pedestrian network characteristics and location/collision-specific factors were found to be the most influential factors on the severity of collisions. The location of bikeshare stations, pedestrian network connectivity, exposure to walkers, and the number of lanes were the four observed variables that explained the highest percent of the variance in each latent group, respectively. The results of this study should assist engineers and planners to develop better design concepts to mitigate collisions that are caused by pedestrian spatial violations in urban areas.

Authors	Ian Hamilton, VHB Kristin Kersavage, VHB Richard Porter, VHB Vikash Gayah, Pennsylvania State University, University Park Josie Sanchez Keith Smith, VHB Carol Tan, Federal Highway Administration (FHWA) Ana Maria Eigen, Federal Highway Administration (FHWA)
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-00872
Paper Title	**Application of Emerging Data Sources for Pedestrian Safety Analysis in Charlotte, NC**
Abstract	Pedestrian safety is a growing concern for transportation planners and safety engineers at both the local and State levels. Continued advancements in data availability, data integration abilities, and analysis methodologies offer new opportunities to identify factors influencing pedestrian safety and quantify their effects to inform data-driven road safety management. The main objective of this study was to spatially integrate Highway Safety Information System (HSIS) data with multijurisdictional and emerging datasets to analyze two measures of pedestrian safety performance in Charlotte, NC: 1) the severity of a pedestrian crash that has occurred, and 2) the probability that a pedestrian crash will occur on a given roadway segment. To accomplish the study objectives, the study explored several high-priority research topics in safety data and analysis, including pedestrian exposure analysis and probe data integration. The research team developed a pedestrian count model to predict pedestrian volumes at locations without pedestrian counts and integrated speed information from probe data to supplement other roadway and contextual transportation data available from several agencies. Pedestrian exposure at a given intersection was found to be significantly influenced by demographic and socioeconomic characteristics, employment, land use, sidewalk presence, transit access, and roadway and intersection characteristics. The project team identified numerous significant factors that influenced pedestrian crash severity and probability, including outputs from the pedestrian exposure model, observed vehicle speeds, traffic volumes, intersection proximity, and other crash-related factors. The results can be used to identify locations that are more susceptible to pedestrian safety issues.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette Raju Thapa, Louisiana Transportation Research Center (LTRC) Julius Codjoe, Louisiana Department of Transportation and Development
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-00813
Paper Title	**Applying Association Rules Mining to Investigate Pedestrian Fatal and Injury Crash Patterns Under Different Lighting Conditions**
Abstract	The pattern of pedestrian crashes varies greatly depending on lighting circumstances, emphasizing the need of examining pedestrian crashes in various lighting conditions. Using Louisiana pedestrian fatal and injury crash data (2010-2019), this study applied Association Rules Mining (ARM) to identify hidden pattern of crash risk factors according to three different lighting conditions (daylight, dark-with-streetlight, and dark-no-streetlight). Based on the generated rules, the results show that daylight pedestrian crashes are associated with children (<15 years), senior pedestrians (>64 years), older drivers (>64 years), and other driving behaviors such as 'failure to yield', 'inattentive/distracted', 'illness/fatigue/asleep'. Additionally, young drivers (15-24 years) are involved in severe pedestrian crashes in the daylight condition. This study also found pedestrian alcohol/drug involvement as the most frequent item in the dark-with-streetlight condition. This crash type is particularly associated with pedestrian action (crossing intersection/midblock), driver age (55-64 years), speed limit (30-35 mph), and specific area type (business with mixed residential area). Fatal pedestrian crashes are found to be associated with roadways with high-speed limits (>50 mph) during the dark without streetlight condition. Some other risk factors linked with 'high-speed limit' related crashes are pedestrians walking with/against the traffic, presence of pedestrian dark clothing, pedestrian alcohol/drug involvement. The research findings are expected to provide improved understanding of the underlying relationships between pedestrian crash risk factors and specific lighting conditions. Highway safety experts can utilize these findings to conduct a decision-making process for selecting effective countermeasures to reduce pedestrian crashes strategically.

Authors	Reuben Tamakloe, University of Seoul Subasish Das, Texas A&M Transportation Institute Eric Aidoo Dongjoo Park, University of Seoul
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-01377
Paper Title	**Investigating Chains of Factors Influencing Motorcycle Crash Casualty Severity at Signalized and Non-Signalized Intersections in a Developing Country**
Abstract	Despite the countless benefits derived from motorcycle usage, it has become a significant public health concern, particularly in developing countries, due to the plateauing number of fatalities associated with it. Although it is well documented that the frequency and fatality rates of intersection-related motorcycle crashes are worrisome, limited research efforts have been made to explore the contributory factors influencing motorcycle crashes at these locations. Interestingly, no study investigating the latent patterns and chains of factors that simultaneously contribute to the injury severity sustained by motorcycle crash casualties at intersections under different traffic control conditions exists. This study employs a plausible data mining tool to explore hidden rules associated with motorcycle crashes at both signalized and non-signalized intersections in Ghana's most densely populated region, Accra, using three-year crash data spanning 2016-2018. Relative frequency analysis of risk factors in the database shows that shoulder and median absence at non-signalized and signalized intersections, respectively, are less frequent factors. According to the rule discovery results, while full license status, daytime/daylight, and shoulder presence increased the risk of fatal injuries at signalized intersections, factors such as inattentiveness, good road surface, nighttime, shoulder absence, and young rider were highly likely to increase casualty fatalities at non-signalized intersections. By controlling all or some of these risk factors, the level of injury severity on the roadways could be reduced. Based on the findings, we provide enforcement, education, and engineering-based recommendations to help improve motorcycle safety in developing countries.

Authors	Adebola Olowosegun, Edinburgh Napier University Nathaniel Babajide Adeyemi Akintola Grigorios Fountas, Edinburgh Napier University Achille Fonzone, Edinburgh Napier University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-01843
Paper Title	**Analysis of Pedestrian Accident Injury-Severities at Road Junctions and Crossings in Scotland using an Advanced Random Parameter Modeling Framework**
Abstract	This paper investigates the determinants of injury severities in pedestrian-vehicle accidents at signalised and unsignalised junctions, and at physically-controlled and human-controlled crossings in Scotland. The accident data were drawn from the UK police crash report database (STATS19) spanning a period between 2010 and 2018. Correlated random parameter ordered probit models with heterogeneity in the means were estimated to identify the determinants of the pedestrian accident injury-severities and account for unobserved heterogeneity. Possible correlations among the random parameters and the consideration of heterogeneity in the means of the random parameters' distributions can shed light on the interactive effects of the unobserved characteristics that are captured by the random parameters. Model estimation results indicate that the severities of pedestrian injuries are affected by roadway, location, weather, vehicle, and driver characteristics as well as temporal attributes (including time and day of the accident). Factors such as the urban context, lighting and weather conditions and pavement surface conditions were found to result in correlated random parameters, thus capturing the intricate, yet interactive effects of unobserved heterogeneity. Vehicle type and driver's gender are observed to induce further variations in the random parameters' distributions and their effect on injury severities. Empirically, the results showcase slight variations in the determinants of injury severities at signalised and unsignalised junctions, and at physically-controlled and human-controlled crossings. Methodologically, the integrated modelling approach offered comparative advantages over the conventional approaches given its ability to better capture the impact of unobserved heterogeneity, hence leading to greater explanatory power and more robust insights.

Authors	Enru Zhou Yanqi Lian, Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-02546
Paper Title	**Safety-in-Numbers Effects in the Perspective of Injury Severity in Pedestrian and Bicycle Crashes: An Intersection-Level Study**
Abstract	Safety-in-numbers (SIN) phenomenon refers to the hypothesis that an individual in a larger group has a lower propensity to be involved in a mishap or an accident. The SIN effect for pedestrians and bicyclists have been proven in previous studies. Nevertheless, the prior studies have focused on the probability of crash involvement (or crash rate) but has not considered the probability of having a severe injury when a crash occurs. Thus, this study aims to explore the existence of safety-in-numbers in the aspect of injury severity in a crash. Crash data of 280 urban intersections in Florida and 42 associated variables were estimated by the fractional multinomial logit model. The modeling results confirms that the hypothesis that increased exposure of bicyclists and pedestrians would reduce the injury severity of a crash. Moreover, the number of lanes, sidewalk width, gender, health insurance and primary industry are significantly associated with injury severity. Therefore, it is plausible to focus on intersections with a smaller number of pedestrians and bicyclists to reduce the injury severity among vulnerable users. The study is the first to investigate the safety-in-numbers phenomenon in the perspective of injury severity, which would help transportation policymakers save more lives of vulnerable road users from crashes.

Authors	Yanqi Lian, Central South University Enru Zhou Jaeyoung Lee, Central South University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-02579
Paper Title	**Does the Safety-in-Numbers Effects Exist in the Aspect of Injury Severity? A Macroscopic Analysis for Bicyclists and Pedestrians**
Abstract	A number of studies have confirmed the existence of the safety-in-numbers effect for vulnerable road users. The safety-in-numbers effect refers to the phenomenon when the number of pedestrians or bicyclists is larger, the risk of each user being involved in a crash is lower. It has not yet been studied whether the safety-in-numbers effect can still be observed when analyzing injury severity for vulnerable road users. In this study, the relationships between the number of pedestrians and bicyclists and the proportions of crashes involvement of pedestrians and bicyclists by severity are investigated. Two fractional split multinomial logit models are estimated using crash data at the county level from Florida. The model estimation results clearly show a relatively lower proportion of severe injuries for pedestrians and bicyclists at a higher level of daily pedestrian or bicycle traffic, indicating the safety-in-number effect. Several explanatory variables (i.e., the proportion of people aged 65 and older, the proportion of commuters using public transportation, the proportion of recreational land-use) are found to have a significant effect on the proportion of pedestrian/bicycle crashes by injury severity for pedestrians and bicyclists. The findings are expected to provide recommendations to promote the use of active transportation, which will improve the safety of vulnerable road users in the future.

Authors	Yang Li, University of Wisconsin, Milwaukee Farah Al-Mahameed, John Wiley and Sons, Inc. Xiao Qin, University of Wisconsin, Milwaukee Robert Schneider, University of Wisconsin, Milwaukee
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-02737
Paper Title	**New Insights on Vulnerable Road User (VRU) Safety Analysis through Crash Database Improvement**
Abstract	To better understand the reasons behind crashes and to comply with the Model Minimum Uniform Crash Criteria (MMUCC) 5TH Edition, Wisconsin Department of Transportation (WisDOT) replaced the old version of the motor vehicle crash report form (MV4000) in 2017 with a new form (DT4000) that provides more relevant and complete information through new and expanded fields. This study analyzed the values of new data fields and attributes in the DT4000 form for crashes involving pedestrians and bicyclists, as known as vulnerable road user (VRU), using exploratory data analyses (EDA) and the Chi-square automatic interaction detector (CHAID). Specifically, we want to know if the new attributes added significant value to the VRU crash data. EDA produced the descriptive statistics for a selected list of data fields; and CHAID helped to select and rank variables by their prediction power on the VRU injury severity levels. The two forms produced different distributions and patterns of the same data. Results show that the new attributes and data fields offered a better opportunity to enable a more specific and comprehensive analysis, such as VRU locations, VRU's actions, and intersection-related roadway characteristics, involved parties' conditions, distracted driving involvement, and the action of a bicyclist immediately prior to a crash. Such information can provide examples of how better data collection and data quality can significantly improve safety analysis, especially for VRU.

Authors	Laura Harris, University of Tennessee, Knoxville Numan Ahmad, The University of Tennessee Knoxville Asad Khattak, The University of Tennessee Knoxville Subhadeep Chakraborty, University of Tennessee
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-03097
Paper Title	**Exploring Visibility Factors Effect on Vehicle-Pedestrian Crash Injury Severity**
Abstract	The objective of this work was to determine the effect of visibility-related factors on the severity of pedestrian-vehicle crashes. It was hypothesized that decreasing visibility, contributed by factors such as lighting, number of lanes, road-grade, weather, and road alignment are associated with an increase of injury severity. The data used was from the Tennessee Vulnerable Road User dataset from 2018-2020, with a sample size of 4119. The pedestrian crashes were distributed as 7.2% property damage, 61.4% suspected minor injury, 19.8% suspected major injury, and 11.5% fatal injury. Some of the key results are that downhill road grade (coeff. = 0.387), compared to level roads; and curved roadways (coeff. = 0.594) compared to straight roadways are significantly correlated with increased pedestrian injury severity. Cited studies generally agree with the results found herein. This work contributes by providing evidence that improving visibility factors can play an important role in potentially reducing serious and fatal injuries. Implications of this study could help influence a desire to develop pedestrian safe corridors which are well-lit, level, straight, and include a small number of vehicle lanes. Additionally, drivers could be alerted to such corridors similar to how they are for regions prone to animal crossings. Furthermore, if properly planned, the convenience of such corridors may discourage pedestrians from crossing in unmarked places. Education for drivers and pedestrians could be promoted which informs drivers of specific visibility concerns and pedestrians on how visibility factors such as large number of lanes affect drivers differently than a pedestrian.

Authors	Milan Zlatkovic, University of Wyoming Sarah Zlatkovic, Claremont Graduate University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-03546
Paper Title	**Assessment of Motorcycle Crash Severities and Contributing Factors in Wyoming: Multinomial Logistic Regression Modeling Approach**
Abstract	Motorcycle riders and passengers are much more likely to be killed or severely injured in a crash, and on average about 15% of all traffic fatalities include motorcyclists. Between 2008 and 2016, the average motorcycle crash frequency in Wyoming was 286 crashes/year, while the number of fatal motorcycle crashes was 17 fatal crashes/year. This paper performs an assessment of injury severity of motorcycle-related crashes in Wyoming, as a function of multiple contributing factors. The study uses 12 years of motorcycle crash data (2008-2016) and applies multinomial logistic regression modeling to determine the odds ratios for injury severity on the KABCO scale as a function of various exposure measures. Four models were developed and analyzed: (1) rural single motorcycle crashes; (2) rural multi-vehicle motorcycle-related crashes; (3) urban single motorcycle crashes; (4) urban multi-vehicle motorcycle-related crashes. Overall it was found that the most common factors affecting injury severity in motorcycle-related crashes in all four models include vehicle maneuver, driver action, junction relation, alcohol, animal and speed involvement, and helmet use. The vicinity of intersections significantly increases the odds of injury crashes in both urban models and the rural multi-vehicle model, compared to no injury. Vehicle maneuvers such as overtaking/passing, changing lanes, negotiating a curve also increase the severity level in most crashes. Helmet use was found to reduce fatal and serious injuries in all crashes, except rural multi-vehicle crashes, where other factors were more significant. Future work will include more detailed analysis on vehicle and person levels.

Authors	Runan Yang, University of South Florida Zhenyu Wang, University of South Florida Chanyoung Lee, Center for Urban Transportation Research at USF
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-03684
Paper Title	**Recursive Bivariate Probit Analysis of Fatalities and Improper Actions in Motorcycle- Vehicle Crashes on Horizontal Curves**
Abstract	A cause-effect chain, which describes the relationship between contributing factors, driver/rider improper pre-crash actions, and crash outcome (injury severity), exists in motorcycle-vehicle crashes on horizontal curves. Previous studies did not address the correlation between injury severity and improper actions in identifying risk factors. This study aimed to develop a recursive bivariate analysis to simultaneously investigate the effects of covariates on motorcyclist fatality and improper actions (for both riders and drivers) in curve-related motorcycle-vehicle crashes. Two recursive bivariate probit models were developed to identify significant factors that contribute to riders' or drivers' improper actions, factors that directly impact motorcyclist fatality only, and factors that influence motorcyclist fatality and riders' or drivers' improper actions simultaneously. The direct, indirect, and joint marginal effects of the identified contributing factors on motorcyclist fatality risk were addressed based on fitted models. The model results indicate that either riders' or drivers' improper actions in a motorcycle-vehicle crash significantly increase motorcyclist fatality risk. Riders' physical defects and alcohol/drug involvement are the most significant factors contributing to both riders' improper pre-crash actions and motorcyclist fatality. Curve design features were also found to have significant but diverse impacts on rider/driver improper actions and/or motorcyclist fatality risk. Other significant factors included roadway, rider, and driver characteristics. The recursive bivariate probit analysis approach produced fruitful results and provided useful information about concealed causal factors in injury severity analysis.

Authors	William Agyemang, University of Alabama Emmanuel Kofi Adanu, University of Alabama Jun Liu, University of Alabama Steven Jones, The University of Alabama
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04196
Paper Title	**A Latent Class Analysis of Factors Associated with Injury Outcomes of Pedestrian Crashes on Inter-Urban Highways in Ghana.**
Abstract	Over the years, the uncontrolled interaction of human and vehicular activities of settlement areas along highways in Ghana has witnessed a rise in road traffic fatalities and injuries involving vulnerable road users, especially pedestrians. The increase in these pedestrian injury outcomes has been attributed to the problem of land planning usage and lack of pedestrian crossing facilities for safe crossing of the road. This study used Ghana as a case study to identify the factors associated with pedestrian injury outcomes. The multinomial logit latent class (MNL-LC) modeling method was employed to account for unobserved heterogeneity in the crash data used. Pedestrian-vehicle crash data from 2014 to 2018 on highways totaling 3037 was used for the modeling. The model estimation results show that speeding, hit and run and no shoulder was more likely to result in fatal injury while crashes involving pedestrians who were crossing the road had a 0.56% increase likelihood to result in hospitalized injury outcomes. Also, it was found that multiple-vehicle crashes increase the chance of minor injury outcomes and the road shoulder with over-grown weeds variable increased the probability of all the other injury outcomes except in fatal injury. The findings of the study provide bases for the development of appropriate countermeasures to reduce the number of pedestrian deaths and injuries in Ghana and other countries in the sub-region.

Authors	Elaine (Zhenxi) Wu, University of Michigan, Ann Arbor Aditi Misra, University of Michigan Shan Bao, University of Michigan
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04306
Paper Title	**Modeling Pedestrian Injury Severity: A Case Study of Using Extreme Gradient Boosting vs Random Forest in Feature Selection**
Abstract	Walking and bicycling are lauded for their negative net carbon impact and for their health benefits. During the ongoing pandemic, walking and biking have also proved to be one of the most popular modes of getaway without risking exposure to the virus. Therefore, in the interest of a sustainable, resilient and equitable transportation system, it is our responsibility to make walking/biking viable for everyone. Towards that, one of the most talked about feature of our automated transportation future is an increase in safety. However, multiple incidences involving AVs have been reported recently indicating that the technology needs more training on real world scenarios and conflicts. This research is motivated by the need of contextual data and related level of harm in potential conflict scenarios in mixed traffic and we use a national police reported crash dataset, CRSS, to address this need. Our study uses a new gradient boosting algorithm XGBoost for identifying important features among a host of seeming significant variables. We compare the performance of XGBoost with more frequently used random forest method and find that XGBoost is more reliable and the features extracted are more aligned to findings from previous research on the topic. We further use the features extracted using XGBoost in a multiclass logistic regression to quantify the effect of these features on different levels of pedestrian injury. Our findings indicate that speed limit, light conditions, precrash movements and location of pedestrian are important contributors to crash severity, along with driver distraction and impairment.

Authors	Amjad Pervez, Central South University Jaeyoung Lee, Central South University Helai Huang, Central South University Show Abstract
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04224
Paper Title	**Identifying Factors Contributing to the Injury Severity of Single-vehicle Motorcycle Crashes in Pakistan**
Abstract	The existing research on motorcycle safety has shown that single-vehicle motorcycle crashes account for a higher fatality rate than other types of crashes. Also, motorcycle safety has become one of the critical issues of traffic safety in Pakistan due to its growing number and lack of sufficient relevant infrastructure. However, the available literature on motorcycle safety and single-vehicle motorcycle crashes in the country is limited. This study, therefore, established a random parameter logit model to examine the factors associated with the injury severity of single-vehicle motorcycle crashes. The analysis is based on two years of data collected through the road traffic injuries surveillance system from Karachi city, Pakistan. The results indicate that the summer, morning, weekends, elder riders (age ≥ 55), collision with fixed objects, speeding, and overtaking are positively while young riders (age < 25) and presence of pillion passengers are negatively associated with fatal crashes and have signs consistent with engineering intuitions. More importantly, in the particular context of Pakistan, female pillion passenger clothes stuck in the wheel, riding under the influence, intersection, and collision due to loss of control were also found to influence the injury severity of single-vehicle motorcycle crashes significantly. Based on the research findings, multiple appropriate countermeasures are recommended to improve single-vehicle motorcycle crashes in Pakistan.

Authors	Dania Ammar, University of Michigan-Dearborn Aditi Misra, University of Michigan Shan Bao, University of Michigan
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04269
Paper Title	**Identify Factors related to Crash Injury Levels involving Bicyclists: A Crash Data Analysis**
Abstract	The safety of vulnerable road users has become an increasing society concern. The purpose of this paper is to provide a unique analysis of identifying significant factors that impact on bicyclists' crash injury levels through comparisons of several models. This paper describes the application of three standard multinomial logit models on the Crash Report Sampling System data from three consecutive years. Bicyclists' injuries were classified into three levels: Possible, Moderate, and Severe. The study found several significant factors were associated with the increasing likelihood of severe injuries on travel lanes including the time period between 2 am and 5:59 am, the year period between July and August , rural areas, crosswalks' availability, and unsignalized, uncontrolled and unleveled roadways . On the other hand, the occurrence of crashes during weekends and at non-trafficways or driveway access were the factors leading to lower probability of higher severities on non-travel lanes. Factors associated with higher likelihood of moderate and severe injuries at both locations were vehicles' high speed , straight moving direction compared to turning right , and crash with trucks , drivers' age being less than 30, and bicyclists' age being greater than 55 . Interestingly, bicyclists aged within 19-55 tend to be at a higher risk of developing severe injuries at other locations than those who are younger. Results of this study contributes to understanding crash scenarios and dictating the level of damage to the bicyclist allow the alteration of some circumstances characterizing these crashes, when possible, to reduce potential injuries

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Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04321
Paper Title	**An Examination of Pedestrian Safety at Intersections through Crash Data Analysis**
Abstract	Pedestrians are the most vulnerable road users and are at risk of severe consequences when involved in traffic accidents. The purpose of this research is to determine the factors that have significant impacts on the increasing likelihood of pedestrians being seriously injured or killed when involved in a collision with a single vehicle at an intersection over past six years. Both 20132015 GES and 2016-2018 CRSS crash data from NHTSA were used in the analysis. The logistic regression models for the crash data showed that pedestrian age, light, vehicle type, and vehicle pre-motion are significant variables affecting pedestrians' injury severity levels. The pairwise comparison of the coefficients of the common factors in both models using the Wald chi-square statistic test shows similar results with few exceptions. Specifically, the GES data distinguished the weather, driver's age, pedestrian pre-crash movement, and speeding as further significant factors while CRSS data distinguished the year quarter and the number of lanes. The GES dataset factors imposing a higher threat on pedestrians were the drivers' belonging to the 19-25 age group, their speeding, pedestrians' roadway crossings compared to working or playing, and unexpectedly adverse weather conditions. On the other hand, the increasing number of lanes and crashes happening in the year period between July and August were the triggering factors for higher severities in the CRSS dataset. The variables indicating a higher likelihood of pedestrians' severe injuries in both datasets were pedestrians older than 26, dark lighting conditions, light trucks, and vehicles' right turning maneuvers.

Authors	Ming-heng Wang, Taiwan Police College
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04613
Paper Title	**Investigating the Difference of Factors Contributing to Motorcyclist Fatality in Single Motorcycle and Multiple Vehicle Crashes**
Abstract	Motorcyclists account for more than sixty percent of traffic fatalities in Taiwan, and nearly thirty percent of them were in single-motorcycle crashes. Five years of motorcycle-involved crash data were divided into three subset data of single-motorcycle (SM), motorcycle-motorcycle (MM), and motorcycle-vehicle (MV) crashes. Three logistic regression models were conducted to identify the factors contributing to motorcyclist fatalities and to examine the relevant variables for determining the odds of motorcyclist fatality. The results showed the significant factors for all motorcycle-involved crashes include crash time, lighting condition, speed limit, gender, age, helmet use, engine size, and BAC values. Specific factors in SM crashes include hitting fixed objects, run-off-road, riding without a license, crashes on the curve, grade segments, and road median with barriers or traffic islands. In MM and MV crashes, the significant factors include head-on collisions, crashes on rural roads, good weather conditions, improper turns and violating the right of way. Collisions with big heavy motorcycles and all other motor vehicles, unlicensed, speeding, improper turning, violating the right of way, distracted, positive BAC motorcyclists or vehicle drivers are also factors for MM and MV crashes. Law enforcement should focus on unlicensed, impaired, speeding motorcyclists and drivers, and those who violate the right of way and have improper turns. Roadside objects and facilities such as utility poles, traffic devices, or traffic islands should be checked for the appropriate locations and equipped with reflective devices or injury protection facilities.

Authors	Sina Asgharpour, University of Illinois, Chicago Mohammadjavad Javadinasr, University of Illinois, Chicago Zeinab Bayati, Sharif University of Technology Abolfazl (Kouros) Mohammadian, University of Illinois, Chicago
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04792
Paper Title	**Investigating Severity of Motorcycle-Involved Crashes in a Developing Country**
Abstract	Despite paying special attention to the motorcycle-involved crashes in the safety research, little is known about their pattern and impacts in developing countries. The widespread adoption of motorcycles in such regions in tandem with the vulnerability of motorcyclists exacerbates the likelihood of severe crashes. The main objective of this paper is to investigate the underlying factors contributing to the severity of motorcycle-involved crashes through employing crash data from March 2018 to March 2019 from Iran. Considering the ordinal nature of three injury classes of property-damage-only (PDO), injury, and fatal crashes in our data, an ordered logistic regression model is employed to address the problem. The data statistics suggest that motorcycle is responsible for 38% of injury and 15% of all fatal crashes in the dataset. The results indicate that significant factors contributing to more severe crashes include collision, road, temporal, and motorcycle rider characteristics. Among all attributes, our model is most sensitive to the motorcycle-pedestrian accident, which increases the probability of belonging a crash into injury and fatal crashes by 0.289 and 0.019, respectively. Moreover, we discovered a significant degree of correlation between young riders and riders without a license. Finally, upon the insights obtained from the results, we propose safety countermeasures, including 1) strict traffic rule enforcement upon riders and pedestrians, 2) educational programs, and 3) road-specific adjustment policies.

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Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04858
Paper Title	**Assessing the Spatial Correlation between Land Use and Injury Severity of Pedestrian-Involved Crashes that Do Not Occur at Intersections: A NetworkBased Case Study in Northwest Florida**
Abstract	Crashes are of growing importance worldwide and pedestrians are the vulnerable roadway users due to their particular characteristics including their fragility. While focusing on the pedestrian-involved crashes, there is a need to study the relationship between the crash severities and the land use types around the locations these crashes occurred. To address this issue, we proposed a network-based analysis to evaluate the impact of distances between pedestrian-involved crash locations and centroids of various land use types using logistic regression models. Moreover, a set of logit models were developed to evaluate the contribution of crash-related factors, such as speed limit and daylight, on the severity of crashes accruing around each land use area. Results indicate several land use types to be influential on the severity of pedestrian-involved crashes at locations that are not intersections. The probability of a severe pedestrian involved crash increases around commercial land use such as retail stores or night clubs whereas it decreases if the crash occurred around university campuses. Among the crash attributes, daylight is a determinant factor on the severity of pedestrian crashes regardless of the surrounding land use type while the average traffic and alcohol abuse are found statistically significant factors for the crashes occurred only around parking lots and office buildings, respectively. Whereas pedestrian-involved crashes mostly occurred in the vicinity of office buildings during daylight hours, they were less likely to be severely injured. The findings provided valuable insight into the measurements concerning pedestrian safety with respect to various types of land use.

Authors	Maya Mayes, Tennessee State University Suleman Swai, Tennessee State University Deo Chimba, Tennessee State University Hellen Shita, Tennessee State University
Sponsoring Committee	AJE00
Session Number	1268
Session Title	**TRB Minority Student Fellows Research Presentations**
Paper Number	22-01011
Paper Title	**Safety Analysis of Near Intersections Parking**
Abstract	This study evaluated occurrence of crashes due to parked vehicles near intersections. The frequency and the severity of the crashes were assessed using crash data spanning 2007 to 2017. The study analyzed crashes that occurred within 100ft of the intersections throughout Tennessee. The analysis showed about 89% of these types of crashes were property damage only (PDO), 9% were minor injury, and 2% were severe injury or fatal crashes. The Zero Inflated Negative Binomial (ZINB) and Multinomial Probit (MNP) were used to assess the severity and crash frequency respectively. It was found that higher number of lanes, higher directional split, and higher AADT increases the likelihood of crashes involving parked vehicles near intersections. Injury severity modeling using Multinomial Probit (MNP) regression showed that the urban landuse, total number of vehicles involved in a crash, and presence of street lighting all have a significant influence to injury severities.

Authors	Wen Fu, Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-00336
Paper Title	**Relationship between Vehicle Safety Ratings and Crash Injury Severity in the Context of Gender Disparity**
Abstract	Studies have analyzed the relationship between vehicle safety ratings from crash tests and actual crash injury severity. Nevertheless, no study has investigated the relationship between vehicle safety ratings and crash injury severity in the context of gender disparity. The main objective of this paper is to explore the validity of the 5-star ratings from the U.S. National Highway Traffic Safety Administration in the protectiveness for drivers in traffic crashes by gender. A Probit model with heterogeneity in means of random parameters was developed using 2015-2020 two-vehicle crash data from Maryland. After controlling other factors, the results show male drivers in vehicles with 4-5 stars are approximately 30% less likely to be injured than those in vehicles with 2-3 stars. Moreover, vehicles with 4-5 stars are negatively associated with the propensity of injury for over 90% of male drivers. On the other hand, only 31.4% and 52.7% of female drivers in vehicles with 4 and 5 stars are less likely to be injured, respectively. Side-impact star ratings show a larger gender disparity than front-impact star ratings. Furthermore, in-state drivers, driving characteristics, the first point of impact, and environmental characteristics are significantly associated with the injury severity.

Authors	Seyedmirsajad Mokhtarimousavi, Florida International University Angela Kitali, University of Washington Tacoma Jason Anderson, Portland State University Priyanka Alluri, Florida International University Armin Mehrabi, Florida International University Show Abstract
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01464
Paper Title	**Impact of COVID-19 on Injury Severity of Drivers Involved in Run-Off-Road Crashes**
Abstract	This study examined the impact of the lockdown during the COVID-19 pandemic on the severity of drivers involved in Run-Off-Road (ROR) crashes. A random Parameter Ordered Logit (RPOL) modeling framework was utilized to account for the ordinal nature of severity outcome and capture the potential unobserved heterogeneity. The data used in this study contained ROR crashes that occurred from April to September for 2019 and 2020 as non-pandemic and during pandemic time periods, respectively. Separate driver injury severity models were developed across the two time periods, and the overall stability of the model estimates was examined through likelihood ratio tests. The impacts of various potential contributing factors, including crash-, driver-, and vehicle-related variables, roadway geometric characteristics, environmental conditions, and traffic-specific factors, were assessed. The analysis results showed that, although the developed models share some common features, the model specifications indicated a strong temporal instability among the estimated parameters. Compared to the non-pandemic period, the following variables resulted in increased driver injury severity in ROR crashes during the pandemic: drivers 65 years or older, careless driving, and absence of traffic control devices.

Authors	Paolo Intini, Politecnico di Bari Nicola Berloco, Politecnico di Bari Stefano Coropulis, Politecnico di Bari Vittorio Ranieri, Polytechnic University of Bari
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01750
Paper Title	**Exploring relationships between urban crash-related factors and aberrant behaviors considering the spatial variability within the same country**
Abstract	Crash data analyses based on accident datasets often do not include human-related variables because they can be hardly reconstructed from crash data. However, records of crash circumstances can help for this purpose, since crashes are classified considering aberrant behaviors undertaken by the drivers. In this case, urban crash data from the 10 greatest Italian cities were used to develop four logistic regression models having as dependent variable the human-related crash circumstance (distracted or careless driving, illegal maneuvering, pedestrian hit and speeding) and the other crash-related factors as predictors (information about the users and the vehicles involved and about road geometry and conditions). Another model was built to account for injury severity. The spatial variability across the 10 different cities was considered through a multilevel approach, which however revealed the spatial variability only for distraction-related crashes. In the other models, the effect of the spatial variability was unsignificant instead, indicating quite homogeneous behavioral aspects related to crashes within the same country. Results showed several relationships between crash factors (driver, vehicle or road-related) and human-related crash circumstances and severity. The presence of crossings and unsignalized intersections was particularly related to crashes with illegal maneuvering as crash circumstance while the night period was clearly related to speeding crashes and to severe crashes, as well as vehicles different than cars, as expected. This study was conceived for exploring relationships between crash factors and human-related crash circumstances, but it also provides practical insights concerning safety measures in the urban environment, based on crash data analysis.

Authors	Shamsunnahar Yasmin, Queensland University of Technology Md. Mazharul Haque, Queensland University of Technology Naveen Eluru, University of Central Florida
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-02574
Paper Title	**Addressing Endogeneity in modeling Speed Enforcement, Crash Risk and Crash Severity Simultaneously**
Abstract	Speeding is one of the major causes of significant increase in crash risk and the associated injury severity outcomes. To combat such significant safety concern, increased speed limit enforcement system has been adopted widely all around the world. This study aims to present an econometric approach that estimate the casual effect of speed enforcement on safety, while also addressing the endogeneity issue by employing an instrumental variable approach in conjunction with a simulated maximum likelihood approach. In our study, safety enforcement is represented as number of speeding tickets issued from the speed camera systems, while safety profile is presented as two dimensions of interests including total crash risk and crashes by injury severity levels. The proposed econometric model takes the form of a correlated panel random effect model with speed enforcement endogeneity. The empirical analysis is demonstrated by employing roadway segment-level crash data and speeding tickets data from Queensland, Australia for the year 2010 through 2013. The outcome of the study will allow the decision makers to identify a robust resource allocation and speed camera deployment plan.

Authors	Alireza Jafari Anarkooli, Transoft Safety Lab (Transoft Solutions Inc.) Lana Samara, Transoft Safety Lab (Transoft Solutions Inc.) Paul St-Aubin, Transoft Safety Lab (Transoft Solutions Inc.) Luis Miranda-Moreno, McGill University
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-03987
Paper Title	**A Validation Study on Conflict-Based Crash Prediction Considering Crash Severity for Signalized Intersections**
Abstract	Traffic conflicts are the most widely used surrogate safety measures to harness data on critical safety events. However, the main body of the road safety literature has mainly focused on the relationship between traffic conflicts and total crashes, with very limited, if any, consideration of crash severity. The main goal of this study is to contribute to filling this gap by providing a validation study, using a rich dataset from 14 signalized intersections in the City of Bellevue, with over 3 million road users and 200,000 conflicts. Conflict data, measured by time to collision (TTC) and post-encroachment time (PET), was obtained using TrafxSAFE, a video analytics software, for one week of data. Crash data was obtained for a 6-year period. The modelling framework is based on a two-stage approach. First, the number of crashes is estimated using a count-data model that utilizes traffic conflicts. Then, assuming a crash has happened, the probability of the crash being in a certain injury level is computed using a Multinomial Logit (MNL) model. The results show that traffic conflicts are highly correlated with crash counts, highlighting that the safety analysis at signalized intersections, which are currently mainly based on traffic volume, could significantly benefit if conflicts were included in the models. Also, the results of MNL model provide the probabilities of each injury level given a crash has happened. The combination of the results of these two stages provides the expected number of crashes for each severity level, given different scenarios of crashes.

Authors	Emmanuel Kofi Adanu, University of Alabama Sunday Okafor, University of Alabama, Tuscaloosa Steven Jones, The University of Alabama
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04220
Paper Title	**The COVID-19 pandemic and its effects on road crashes and crash outcomes in Alabama**
Abstract	With the rising number of cases and deaths from the COVID-19 pandemic, nations and local governments, including many across the U.S., imposed travel restrictions on their citizens. This travel restriction order led to a significant reduction in traffic volumes and a generally lower exposure to crashes. However, recent preliminary statistics in the US suggest an increase in fatal crashes over the period of lockdown in comparison to the same period in previous years. This study sought to investigate how the pandemic affected road crashes and crash outcomes in Alabama. Daily vehicle miles traveled and crashes were obtained and explored. To understand the factors associated with crash outcomes, four crash-severity models for manner of collision and time of the year were developed using the first 28 weeks of crashes recorded in 2020. The findings reveal that although traffic volumes and vehicle miles traveled had significantly dropped during the lockdown, there was an increase in the total number of crashes and major injury crashes compared to the period prior to the lockdown order, with speeding, DUI, and weekends accounting for a significant proportion of these crashes. These observations provide useful lessons for road safety improvements during extreme events that may require statewide lockdown, as has been done with the COVID-19 pandemic. Traffic management around shopping areas and other areas that may experience increased traffic volumes provide opportunities for road safety stakeholders to reduce the occurrence of crashes in the weeks leading to an announcement of any future statewide or local lockdowns.

Authors	Mouyid Islam, Virginia Tech Transportation Institute
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04360
Paper Title	**An Empirical Analysis on Driver Injury Severity on Freeways in Florida during COVID-19: Accounting for Unobserved Heterogeneity**
Abstract	During COVID-19 pandemic, risky driving behaviors were observed on Florida highways. Despite a significantly lower traffic volume in 2020 compared to 2019, major freeways in Florida including I-4, I-10, I-75, and I-95, were found to experience elevated risk of severe injury crashes. With changes in traffic patterns due to COVID-19, it is important to investigate the risks of single-vehicle crashes and injury outcomes associated with risky driving under lower volume conditions on these major freeways in Florida. The study applied random parameter multinomial logit models with heterogeneity in mean and variance to model driver injury severity in 2020 and compared their differences in different freeway systems. The estimated model results uncovered a significant variability among contributing factors including spatial and temporal characteristics, weather, traffic volume, vehicle characteristics, roadway geometry and harmful events charcteristics, and driver characteristics. There were 31 statistically significant variables in one of these freeway systems in Florida. Of these 31 variables, only two variables, namely, normal driving and restraint usage were found statistically significant across these freeway systems. The estimated model results showed the factors contributed to severe driver injury are mostly predominant on I-95 relative to other freeway systems in 2020. The effect of COVID-19 in highway network challenges our current understanding of safety performance measures when low traffic volume complicates perceived safety of the motorists. The findings of this study clearly add value to our understanding of highway safety during pandemic and assist the state highway agencies for better preparation for potential future occurrence.

Authors	Irfan Ahmed, HDR Mohamed Ahmed, University of Wyoming
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04672
Paper Title	**Temporal Instability in Injury Severity Outcomes of Clear and Adverse Weather Crashes on Rural Mountainous Highways**
Abstract	Driver injury severity analysis based on weather conditions on rural highways is limited in the literature. Such analyses provide useful insights to transportation planners in optimizing the allocation of limited resources based on weather conditions. Furthermore, if there is a possibility of factors exhibiting temporal instability, then aggregated analyses can lead to erroneous allocation of funds. In this study, separate models for clear and adverse weather conditions were developed for each of the years from 2017 to 2019 using crash data of rural mountainous highway corridor. A random-intercept Bayesian logistic approach was used to analyze the dichotomous injury severity response and capture the between-crash variance. An efficient Markov Chain Monte Carlo sampling technique known as No-U-Turn Hamiltonian Monte Carlo was employed to sample the posterior distributions of the parameter estimates. Likelihood Ratio tests provided statistical significance of the temporal instability and also the differences in driver injury severities resulting from clear and adverse weather crashes. While most of the variables demonstrated temporal instability, some factors exhibited temporal stability for crashes during clear weather conditions only. Findings from separate models suggest that there are major differences in both the combination and magnitude of the significant contributing factors. Implementation of confirmatory warning signs, variable message signs, connected vehicle technology, strict enforcements during different times and locations, and driver awareness programs have been recommended as suitable countermeasures. The findings and the recommendations from this study could potentially be used to help guide the respective agencies in formulating injury severity mitigation policies and strategies.

Authors	Ahmed Kabli, University of Central Florida Tanmoy Bhowmik, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01022
Paper Title	**Exploring the Temporal Variability of the Factors Affecting Driver Injury Severity by Body Region Employing a Hybrid Econometric Approach**
Abstract	The current study contributes to safety literature by incorporating the influence of temporal factors (observed and unobserved) within a multivariate model system for medical professional generated body region specific injury severity score. For this purpose, we adopt a hybrid econometric modeling approach that accommodates for the unobserved factors using two mechanisms. First, we parameterize unobserved temporal factor variation through the customization of the variance by time cohort (heteroscedasticity). Second, the common unobserved factors affecting severity across various body regions is accommodated through traditional random parameter consideration process. The proposed model system is estimated using data drawn from the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) database for the time cohorts 2003, 2006, 2009, 2012, and 2015. For the current analysis, we consider 6-point Abbreviated Injury Scale (AIS) for eight body regions (head, face, neck, abdomen, thorax, spine, lower extremity, and upper extremity). The proposed model system offers interesting insights on body region severity evolution over time. The model estimation is supplemented by a hypothetical illustration task.

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Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-04547
Paper Title	**Machine Learning Methods to Analyze and Predict Crash Injury Severity Based on Contributing Factors for Southeast Michigan**
Abstract	Traffic safety is a critical aspect of transportation. Transportation agencies and researchers have been continuously making an effort to ensure minimal error margins in the road system. There is a growing interest in the Southeast Michigan region because of the active role of original equipment manufacturers (OEM) in spurring research in the new mobility field and autonomous vehicle technology. As new jobs are created and commuting trips increase, traffic safety even becomes more important. Thus, this study presents one of the first efforts to study crash patterns for Southeast Michigan using machine learning models to analyze and predict crash severity in the region based on various contributing factors. We combine a threestep method of correlation analysis, machine learning predictive models, and spatial analysis to develop a rigid schema for crash prediction. Results show that decision tree classifiers provide accurate predictions and rapid computations. Also, spatial plots of predicted injury severities reveal disproportionate errors in model predictions at intersections prompting the need to stratify the crash data for further analyses. This significantly improves severe injury predictions at non-intersection locations and highlights pedestrians as a main important feature. The converse holds for intersections which identify motorcycles as the main feature for severity prediction. Further results are elucidated in this paper.

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Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-02969
Paper Title	**A Deep Learning Model for Crash Injury Severity Analysis Using Shapley Additive Explanation Values**
Abstract	Analysis of traffic crash and associated data provides insights and assists with identification of cause-and-effect relationships with crash probabilities and outcomes. This study utilized eight years of police-reported Nebraska crash data using a deep neural network (DNN) to model crash injury severity outcomes. Prediction performances and model interpretability were examined. The developed DNN exceled in prediction accuracy, precision and recall but was computationally intensive compared to a baseline multinomial logistic regression model. While the lack of interpretability power of deep learning models limits their usage, the adoption of SHapley Additive exPlanation (SHAP) values was an improvement. Conclusions drawn from the DNN model are generally consistent with the estimated baseline model. For instance, the variable total number of pedestrians was found significant in both scenarios of the MNL model indicating a strong relationship with more severe crash injury outcomes. It was also found important in all three sets of parameters in DNN. SHAP values also allow in-depth analysis of prediction results on a single observation, such as the variable crash type (same direction sideswipe) contributing to classifying a single observation as property damage only. These findings are beneficial for making more informed transportation safety-related decisions.

Authors	Uttara Roy, University of Wyoming Khaled Ksaibati, University of Wyoming
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-00451
Paper Title	**Modeling Driver Injury Severity in Deer-Vehicle Crashes Using Random Parameters**
Abstract	This study investigated different driver, vehicle, environment, roadway and traffic characteristics which influence driver injury severity in deer-vehicle crashes (DVCs) by using random parameters. The data for the study were collected from Wyoming Department of Transportation (WYDOT) from 2010 to 2019. Both binary logit model and mixed binary logit models were developed taking different levels of driver injury severity as response variables. In addition to random effects, interaction effects were also considered. The mixed binary logit models disclosed several random parameters which would have been unidentified in the binary logit model's results. The results showed that younger drivers as well as drivers who used some sort of restraint systems reduced the probability of severe injuries. Crashes that took place between the months of June and November tended to increase driver injury severity. Also, the probability of driver injury severity increased when the road surface was dry and when AADT was lower than or equal to 1000. Both dark and unlit condition as well as dark and lighted condition decreased the likelihood of severe injuries. This was probably because drivers took caution and reduced their speed while it was dark. The likelihood of severe injuries increased when vehicle was towed and when airbag was deployed. The factors which identified in this study impacted driver injury severity will be helpful to identify effective countermeasures which will reduce the injury severity of drivers involved in DVCs.

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Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01811
Paper Title	**Apply Explainable Machine Learning Techniques in Daily Crash Occurrence and Severity Modeling for Rural Interstates**
Abstract	Conventional traffic crash analysis methods often use highly aggregated data, making it difficult to understand the effects of many time-varying factors on crash occurrence. Although studies have used data with small aggregation intervals, they typically analyze the effect of a single factor on crash occurrence. In this study, the collaborative effect of roadway geometry, speed distribution, and weather conditions on crash occurrence and severity is investigated using explainable machine learning methods on daily level crash data. The data are collected from four different sources on rural interstate highways in Texas. Four machine learning methods: Random Forest, AdaBoost, XGBoost, and Deep Neural Network, are tested on the dataset. The model comparison results show that XGBoost performs the best on the imbalanced dataset. In the feature selection process, the Pearson correlation coefficient is applied to remove highly correlated variables. The study then uses the synthetic minority over-sampling technique (SMOTE) method to mitigate the data imbalance issue. The XGBoost model is trained twice on all crash occurrence and severe crash occurrence. Finally, the SHAP (SHapley Additive exPlanation) method is applied to investigate the contribution of all variables to the model's output. The results show that weather condition factors have a significant contribution to all crash occurrences. However, speed distribution factors have a stronger impact on severe crash occurrences. Precipitation has a positive impact on all crash occurrences, while for severe crash occurrences precipitation does not have an obvious impact. Instead, nighttime speed standard deviation becomes important for severe crash occurrence.

Authors	Xiaomeng Dong, Old Dominion University Kun Xie, Old Dominion University Hong Yang, Old Dominion University
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-02905
Paper Title	**Analysis of Contributing Factors to Crash Severity via Structural Equation Modeling during COVID-19's Lockdown**
Abstract	Risky driving behaviors such as speeding and failing to signal have been witnessed more frequently during the COVID-19 pandemic, resulting in higher rates of severe crashes. This study aims to investigate how the COVID-19 pandemic impacts the likelihood of severe crashes via changing driving behaviors. Structural equation modeling (SEM) is used to capture the complex interrelationships between crash injury severity, COVID-19, driving behaviors, and other risk factors. The SEM constructs two latent variables aggressiveness and inattentiveness, which are indicated by risk driving behaviors such as speeding, drunk driving, and distraction. One great advantage of SEM is that the measurement of latent variables and interrelationship modeling can occur simultaneously in one statistical estimation procedure. Results show that aggressiveness and inattentiveness of drivers increase significantly after the outbreak of COVID-19, leading to a higher likelihood of severe crashes. Failing to account for the indirect effect of COVID-19 via changing driving behaviors, the conventional probit model suggests an insignificant impact of COVID-19 on crash severity. Findings of this study can provide policy makers and researchers insights into the effect of changing driving behaviors on safety during disruptive events like COVID-19.

Authors	Weixi Ren Bo Yu, Tongji University Yuren Chen, Key Laboratory of Road and Traffic Engineering of the Ministry of Education Kun Gao, Chalmers tekniska hogskola
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-04468
Paper Title	**Divergent Effects of Factors on Crashes under Autonomous and Conventional Driving Modes Using A Hierarchical Bayesian Approach**
Abstract	Influencing factors on crashes involved with autonomous vehicles (AVs) have been paid increasing attention. However, there is a lack of comparative analyses between influencing factors on crashes of AVs and human-driven vehicles. To fill this research gap, the study aims to explore the divergent effects of factors on crashes under autonomous and conventional driving modes. This study obtained 154 publicly available autonomous vehicle crash data (70 for the autonomous driving mode and 84 for the conventional driving mode), and 36 explanatory variables were extracted from three categories, including environment, roads, and vehicles. Then, a hierarchical Bayesian approach was applied to analyze the impacting factors on crash type and severity under both driving modes with considering unobserved heterogeneities. The results showed that some factors affected both driving modes, but their degrees were different. For example, daily visitors' flowrate had a greater impact on the crash severity under the conventional driving mode, while the presence of turning movement led to a larger decrease in the likelihood of rear-end crashes under the autonomous driving mode. More influencing factors only had a significant impact on one of the driving modes. For example, in the autonomous driving mode, two sidewalks decreased the severity of crashes, and on-street parking was positively associated with rear-end crashes, but they were not significant in the conventional driving mode. This study could contribute to the understanding and development of autonomous driving systems and the better coordination and complementarity between autonomous driving and conventional driving.

Authors	Yanyan Chen, Beijing University of Technology Yuntong Zhou, Beijing University of Technology xin gu, Beijing University of Technology Yinjia Guo Bingxin Cao
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-01681
Paper Title	**Comparative analysis of crash severity prediction models using five machine learning methods and SMOTE-based oversampling technique**
Abstract	Traffic crashes remain a major concern and challenge in countries worldwide. This paper aims to conduct a comparative analysis of crash severity prediction models using five machine learning methods and SMOTE-based oversampling technique. The crash data of BeiJing in 2015 was used, and points of interest (POIs) data, road conditions, population data were selected for crash severity modelling. Models using Adaboost, Random Forest, Gradient Boosting Decision Tree, Extremely Randomized Trees and GcForest were proposed with balanced and unbalanced crash data. Results show that the prediction accuracy of the balanced dataset is significantly improved, which proves the effectiveness of SMOTE. The model results also suggest that the gcForest gets the best prediction performance with the highest overall detection accuracy of 93.94%, while the recall was 93.47%. Moreover, Cross section element, median type, physical separation of road, type of roadside protection as well as density of road were found to be factors that have a significant impact on traffic crash injury severity. Based on the findings of this study, several countermeasures are recommended.

6 Crash Modification Factors

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

This year, the subcommittee identified **eleven papers** dealing with crash modification factors (CMF) and did not identify any papers dealing with crash modification functions.

The papers are scattered across various sessions, with most papers presented at the poster sessions: 1056 Safety of Motorcyclists and Active Transportation Modes (Monday, January 10, 8:00 AM - 9:30 AM), 1304 Safety Performance and Strategies (Tuesday, January 11, 1:30 PM - 3:00 PM), 1340 Advancing New Methods and Data (Tuesday, January 11, 4:00 PM - 5:30 PM), 1376 Safety Studies on Low-Volume Roads (Wednesday, January 12, 8:00 AM- 9:30 AM), and 1219 Safety Management Systems Poster Session (Tuesday, January 11, 8:00 AM - 9:30 AM).

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

- Empirical Bayes before-after method (22-01057, 22-01847, 22-01905, 22-03185, 22-04367, 22-04393);
- Mixed effects negative binomial models (22-02852);
- Naïve before and after (Naïve) method (22-04367);
- Bayesian zero-inflated negative binomial regression model (22-04437); and
- Random intercept Bayesian approach (22-04681).

Different papers evaluated countermeasures focused on **safety improvement of vulnerable users**. One paper analyzed safety impacts of road diets for vehicle, pedestrian, and bicycle modes (22-04367). Another paper analyzed safety impacts of the Rectangular Rapid Flashing Beacons (RRFB) installations on total and injury pedestrian crashes (22-04393). Another paper quantified the safety effectiveness of pedestrian safety treatments at midblock locations (22-04437).

The evaluated countermeasures were mainly related to **geometric treatments**:

- Road diet conversion from an existing four-lane undivided roadway to a three-lane roadway, reducing the section to two through lanes and a center two-way left-turn lane (22-01847);
- Median U-Turn intersections, also known as “Michigan lefts”, “boulevard turnarounds”, or “Michigan loons” (22-01173);
- Change in the skew angle of intersections on rural two-lane highways (22-04083);
- Coordinated ramp metering systems installation for segments in the vicinity of ramps (22-01057).

One paper investigated horizontal curvature on rural two-lane county road segments finding CMFs varying by curve design speeds (22-02852). Another paper estimated the CMFs for wildlife-vehicle

crashes which include crossing structures with fencing and wildlife warning signs (22-04681). One paper described the efforts to evaluate the safety impacts of increasing the speed limit on selected two-lane, two-way state highway road segments (22-03185).

Below, for each of the eleven papers involving Crash Modification Factors, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract. Papers are ordered according to their ID number.

Authors	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.

Authors	Jonathan Kay, Michigan State University Timothy Gates, Michigan State University Peter Savolainen, Michigan State University Md Shakir Mahmud, Michigan State University
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-01173
Paper Title	**Safety Performance of Unsignalized 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. MUT intersections (also known as “Michigan lefts”, “boulevard turnarounds”, or “Michigan loons”) are one such design that accommodates all left-turn movements via directional U-turn crossovers within the median. Prior work has consistently shown that MUTs can provide superior safety performance when used in the appropriate conditions. However, research which is specific to unsignalized reduced left-turn conflict intersections continues to be limited to work conducted prior to the Highway Safety Manual or which includes RCUT intersections. This study included the evaluation of historical traffic crashes and volume data at 95 unsignalized intersections in the state of Michigan. This included the collection of data for 39 MUT sites and 56 reference group sites in order to estimate SPFs and CMFs which can be used when considering future conversions. Ultimately, CMFs for fatal and injury crashes of 0.438 and 0.686 are recommended when converting intersections with undivided two-lane two-way major approaches and four-lane divided boulevard major approaches, respectively. While there was no significant difference in PDO crashes associated with converting intersections with undivided two-lane two-way major approaches, a CMF of 1.325 is recommended for PDO crashes specific to conversions with four-lane divided boulevard major approaches.

Authors	Yuying Zhou, VHB Scott Himes, VHB Thanh Le, VHB Jeff Gooch, VHB Kayla Northup, VHB Peter Pavao, VHB
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-01847
Paper Title	**Safety Effectiveness of the Road Diet Treatment in Rhode Island**
Abstract	A Road Diet is a low-cost countermeasure which typically involves converting an existing four-lane undivided roadway to a three-lane roadway, reducing the section to two through lanes and a center two-way left-turn lane (TWLTL). The objective of this evaluation was to estimate the safety effectiveness of Road Diets by developing a Rhode Island-specific crash modification factor (CMF). To account for potential selection bias and regression-to-the-mean, an empirical Bayes (EB) before-after analysis was conducted, using reference groups of untreated 4-lane undivided roadways with similar characteristics to the treated sites. Results indicated a 29 percent decrease (CMF = 0.71) in total crashes and a 37 percent reduction in fatal and injury crashes (CMF = 0.63). The expected results of the evaluation will help RIDOT to determine a statewide direction for implementation of the countermeasure.

Authors	Boris Claros, University of Wisconsin, Madison Erynn Schroeder, University of Wisconsin, Madison Kentin Brummett Madhav Chitturi, University of Wisconsin, Madison Andrea Bill, University of Wisconsin, Madison David Noyce, University of Wisconsin-Madison Show Abstract
Sponsoring Committee	ACS10
Session Number	1219
Session Title	**Safety Management Systems Poster Session**
Paper Number	22-01905
Paper Title	**Safety and Economic Evaluation of the Highway Safety Improvement Program (HSIP): Is There a Return on Investment?**
Abstract	The Highway Safety Improvement Program (HSIP) is a Federal-aid program aimed at achieving a significant reduction in traffic fatalities and serious injuries on all public roads. Projects are selected based on the potential reduction of severe crashes and the greatest return on investment. In this paper, a step-by-step process and methodology were developed to evaluate Wisconsin HSIP projects implemented between 2013 and 2019. Safety effectiveness evaluation and economic assessment were conducted at the site specific and project level using the Empirical Bayes (EB) method. Crash cost benefit of implemented projects was quantified to find the benefit-cost (B/C) for a horizon of 10 years and observed period of analysis. With data available from project evaluations, Crash Modification Factors (CMF) for common treatments were developed. A total of 64 HSIP projects were evaluated. B/C ratios greater than one were observed in 43 projects. For a 10-year horizon, the aggregated B/C ratio was 2.71. Alternatively, using the observed data during the study period of each project, the observed overall crash cost benefit was equal to $72 million which corresponds to a B/C ratio of 1.10 (benefit already surpassed project costs at three to five years). Approximately 536 crashes were prevented which translates to seven lives saved, 379 injuries prevented, and avoided 1,067 property damage losses.

Authors	Steven Stapleton, Virginia Polytechnic Institute and State University (Virginia Tech) Timothy Gates, Michigan State University
Sponsoring Committee	AKD30
Session Number	1376
Session Title	**Safety Studies on Low-Volume Roads**
Paper Number	22-02852
Paper Title	**Crash Modification Factors for Horizontal Curvature on Rural Two-Lane County Road Segments**
Abstract	Crash modification factors (CMFs) were developed for evaluating horizontal curvature along rural two-lane county roadway segments in Michigan. Five years of crash data (2011 - 2015) were analyzed for more than 7,400 miles of rural county roadways, covering 30 of Michigan's 83 counties and representing all regions of the state. Three separate models were developed to estimate annual deer-excluded crashes on rural county roadways: 1) paved federal aid segments, 2) paved non-federal aid segments, and 3) unpaved non-federal aid segments. To account for the unobserved heterogeneity associated with differing county design standards and unique site characteristics, mixed effects negative binomial models with county- and site-specific random effects were utilized on all paved segments. Horizontal curves were parameterized by curve design speed, and all roadways included in the sample had a speed limit of 55 miles per hour. It was found that substandard curvature generally resulted in increases in crash occurrence; on paved roadways, crash occurrence monotonically increased with decreasing curve design speed. All substandard curve design speeds were associated with increased crash occurrence on paved federal aid highways and unpaved roadways, while only curve design speeds below 45 miles per hour were associated with a significant increase in crash frequency on paved non-federal aid roadways.

Authors	Anthony Ingle, Michigan State University Timothy Gates, Michigan State University
Sponsoring Committee	ACS20
Session Number	1304
Session Title	**Safety Performance and Strategies**
Paper Number	22-04083
Paper Title	**Crash Modification Functions for Rural Skewed Intersections**
Abstract	This study evaluates the safety influence of intersection skew angle on rural two-lane two-way facilities by calibrating crash modification factors. Ten years of crash history among federal aid and non-federal aid highways was used to develop crash modification functions at three-leg and four-leg stop-controlled intersections. Skew angle was investigated as a parameter in the SPF models both as a continuous variable, with observed values ranging from 0 to 80 degrees, and categorized into bins. A few transformations of the skew parameter were considered such as the flexible form model having skew interaction with AADT, and a Hoerl curve. Three-leg intersections exhibited a decreasing relationship to increasing skew angle, with the flexible form model predicting up to 56% fewer crashes at the most highly skewed intersections. Among four-leg intersections, a skew angle between 10 to 25 degrees experienced 21% more crashes, while intersections with a skew angle greater than 45 degrees did not have significantly different crash occurrence than perpendicular intersections.

Authors	Yige Tang, The Goodman Corporation T. Donna Chen, University of Virginia Linda Lim, University of Virginia
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04367
Paper Title	**Road Diet Safety Impact on Multimodal Transportation**
Abstract	A road diet's objective is to improve safety for all roadway users, while increasing livability by creating a bicycle and pedestrian friendly environment. This study analyzes safety impacts of 57 road diets completed in five states in the United States over the last 15 years for vehicle, pedestrian, and bicycle modes, using the Empirical Bayes (EB) method where traffic volume data was available and Naïve Before and After (Naïve) method where volume data was unavailable. EB analysis of 85 segments and 107 intersections (from 24 road diet projects) estimated segment crash modification factors (CMFs) of 0.66 for vehicle-only crashes, 0.89 for vehicle-pedestrian crashes, and 0.35 for vehicle-bike crashes; intersection CMFs were estimated to be 0.53 for vehicle-only crashes, 0.44 for vehicle-pedestrian crashes, and 0.41 for vehicle-bike crashes. The Naïve method analysis of all 57 road diet projects estimated CMFs of 0.85 for vehicle-only crashes, 1.12 for vehicle-pedestrian crashes, and 0.98 for vehicle-bike crashes. Results suggest that road diet safety impacts on pedestrians are not conclusive, especially given the rising numbers of pedestrian crashes in recent years. Furthermore, the lack of standard bicycle and pedestrian volume data across different states limits the ability to measure mode-specific safety impacts of road diets across larger samples of project locations, highlighting the need to increase data collection efforts on non-motorized modes.

Authors	Amrita Goswamy, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Nada Mahmoud, University of Central Florida Qing Cai, Waymo
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04393
Paper Title	**Safety Effectiveness of Rectangular Rapid Flashing Beacons (RRFB)**
Abstract	In 2017 about 5,977 pedestrians were killed in traffic crashes in the United States. Mid-block crossings of streets, particularly large busy arterials, can be unsafe as drivers may often fail to stop or yield to pedestrians in the uncontrolled marked crosswalks. The Rectangular Rapid Flashing Beacons (RRFB) is a pedestrian crosswalk countermeasure system that caution drivers by providing them with real-time warning about the presence of pedestrians in an upcoming crosswalk. This paper investigated the safety effectiveness of existing RRFBs installed in the state of Florida between 2013 to 2018 on state and county roadways with speed limit ranging from 25 to 55 mph. Data from all seven districts of Florida was incorporated. The study evaluated 154 treatment sites with RRFB installations and 158 control sites without RRFB with similar roadway and traffic characteristics. Safety performance functions were developed using negative binomial models and crash modification factors were calculated using the Empirical Bayes (EB) methodology for total pedestrian crashes, injury and non-injury pedestrian crashes. A Crash Modification Factor (CMF) of 0.31 for total pedestrian crashes was observed showing that RRFB have the potential to reduce 69% of total pedestrian involved crashes that included fatal, injury and property damage only crashes. The study also calculated the CMF for fatal and injury pedestrian crashes grouped together to be 0.30 and the CMF for injury pedestrian crashes was calculated to be 0.27. This showed that RRFBs have good potential to reduce injury crashes.

Authors	Cecilia Kadeha, Florida International University Angela Kitali, University of Washington Tacoma Jimoku Salum, Florida International University Priyanka Alluri, Florida International University
Sponsoring Committee	ACS20
Session Number	1056
Session Title	**Safety of Motorcyclists and Active Transportation Modes**
Paper Number	22-04437
Paper Title	**Safety Performance of Midblock Pedestrian Crossing Treatments**
Abstract	Pedestrian safety is a serious concern, especially at midblock locations. Crossing streets at uncontrolled midblock locations can pose a serious risk to pedestrians. Midblock crosswalks offer a safer, more visible, and more direct route for pedestrians to cross and encourage pedestrians to cross at designated locations. This study quantified the safety effectiveness of pedestrian safety treatments at midblock locations in Florida. A cross-sectional analysis using a Bayesian zeroinflated negative binomial regression model was used to evaluate the safety of midblock segments and develop crash modification factors (CMFs) for different geometric, traffic, land-use, and census variables. The analysis was based on five years (2012-2016) of midblock pedestrian crashes in Florida. The analysis results revealed that the following variables significantly increased (at a 90% Bayesian credible interval) the frequency of pedestrian crashes: natural logarithm of AADT; proportion of the low-income population; density of bus stops; density of bars and food establishments; and density of shopping centers. On the other hand, the rise in proportion of senior population (aged 65 or older) and logarithm of the total population reduced the frequency of pedestrian crashes. Although not significant at the 90% Bayesian credible interval, midblock segments with crosswalks had a CMF of 0.82, indicating an 18% reduction in pedestrian crashes. Moreover, the posterior probability distribution indicates 71% chance midblock pedestrian treatments will reduce pedestrian crashes. The results could help practitioners strategically install pedestrian crossing treatments that could improve pedestrian safety at midblock locations.

Authors	Irfan Ahmed, HDR Mohamed Ahmed, University of Wyoming
Sponsoring Committee	ACS20
Session Number	1340
Session Title	**Advancing New Methods and Data**
Paper Number	22-04681
Paper Title	**Investigating the Safety Effectiveness of Wildlife-Vehicle Crash Countermeasures using a Bayesian Approach: A Comparison between Carcass Removal Data and Traditional Crash Data**
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. 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. The results suggest that the treatment of implementing wildlife warning signs on hotspots of high WVC has been ineffective. This can be attributed to the noncompliance to the signs, perhaps due to the stationary nature of the information provided. The crossing structures are found to be effective with an estimated CMF of 0.65 and 0.54 using the carcass data and crash data, respectively. Recommendations could be made to implement more active information dissemination via dynamic message signs where crossing structures may not be feasible. The findings from this study indicate that the carcass removal data is more comprehensive than the crash data, despite the underreporting issue existing in both datasets. Therefore, a unique identifier should be added in both datasets to enable merging the data and obtain more complete results from the analyses.

7 Surrogate Measures of Safety

Fatima-Zahra Dahak and Nicolas Saunier
Polytechnique Montreal

This year, **thirty-five papers** related to surrogate measures of safety (SMoS) were identified.

From the review, the studies can be classified in the same five main topics as last year: **intersections**, **non-motorized users**, **applications of SMoS** (implementing SMoS or proposing frameworks), **real time safety monitoring** and **safety simulation**. Nine articles analyze safety at **intersections** (22-00403, 22-02161, 22-02933, 22-02948, 22-03540, 22-03730, 22-03987, 22-04486, 22-04860). In addition, the safety of **pedestrians, bicyclists, and other non-motorized users** was analyzed in six papers (22-01478, 22-02948, 22-03730, 22-04849, 22-02933, 22-04849). Various **SMoS applications** were presented in fourteen papers (22-00641, 22-00911, 22-01040, 22-01478, 22-01524, 22-01786, 22-02224, 22-02434, 22-02716, 22-02721, 22-02777, 22-03105, 22-03304, 22-04486). Studies involving **real time safety monitoring** or **safety simulations** were finally identified in thirteen papers (22-00520, 22-00919, 22-01252, 22-01545, 22-02434, 22-02572, 22-02762, 22-03214, 22-03628, 22-04592, 22-04756, 22-04784, 22-00354).

Fourteen papers deal with **traffic encounters or conflicts** (22-00354, 22-00403, 22-00520, 22-00919, 22-01478, 22-01524, 22-01545, 22-02224, 22-02933, 22-02948, 22-03628, 22-03987, 22-04592, 22-04860). **Time-to-collision** (TTC) was the main traffic conflict indicator used in six papers (22-00354, 22-00919, 22-01524, 22-02572, 22-03987, 22-04486). Also, **post-encroachment time** (PET) was used in four papers (22-02933, 22-03987, 22-04486, 22-04860). **Other crash nearness measures** were used such as **modified time to collision** (MTTC), used in two papers (22-00403, 22-02224). **Time exposed time to collision** (TET), **extended time to collision** (ETTC), **anticipated collision time** (ACT) and other indicators were used in six papers (22-00911, 22-00919, 22-02434, 22-02777, 22-03214, 22-04784).

Several types of input data were used. **Vehicle and user trajectories** were used the most in nineteen papers (22-00354, 22-00520, 22-00911, 22-00919, 22-01040, 22-01252, 22-01524, 22-01545, 22-01786, 22-02434, 22-02762, 22-02777, 22-02933, 22-03214, 22-03628, 22-03730, 22-04592, 22-04756). **Video data** were also used in six papers (22-02434, 22-02224, 22-02933, 22-03730, 22-03987, 22-04860). As well, **naturalistic driving data** were used in nine papers (22-00641, 22-01478, 22-02161, 22-03540, 22-02572, 22-02716, 22-03214, 22-03304, 22-04784). In addition, **ranging sensors** such as LIDAR were used to collect data in four papers (22-01545, 22-03105, 22-03628, 22-04486). **GNSS** (global navigation satellite system) data was utilized in two papers (22-01786, 22-03105).

When classifying the methodology, eighteen papers used **statistical methods** (22-00354, 22-00919, 22-01524, 22-01786, 22-02224, 22-02434, 22-02572, 22-02716, 22-02721, 22-02777, 22-02933, 22-03304, 22-03987, 22-04592, 22-04860, 22-04784, 22-03628, 22-01252), while thirteen papers used **machine learning algorithms** (22-00403, 22-00520, 22-00641, 22-00911, 22-01040, 22-01545, 22-02161, 22-02762, 22-02948, 22-03105, 22-03540, 22-03730, 22-04486).

The thirty five papers dealing with SMoS are ordered below according to their ID numbers.

Authors	Yang-Jun Joo, Seoul National University Dong-Kyu Kim, Seoul National University Seung-Young Kho, Seoul National University Eui-Jin Kim, Seoul National University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-00354
Paper Title	Evaluating the Effects of Sampling Rate in Predicting Traffic Conflicts
Abstract	A connected environment provides real-time data about adjacent vehicles and enables a continuous decision-making process with naturalistic driving data (NDD) collected to develop behavioral algorithms in highly automated vehicles. However, the high-resolution data (i.e., high-sampling rate data) with redundant and predictable information is inefficient due to computational costs, while low-resolution data is unsafe because it cannot observe possible risks between samples. In addition, the sampling rate of the data is heavily correlated with the safety and reliability of self-driving algorithms, as it may result in conflict-prone decision-making. Therefore, this study investigates the dilemma of sampling rate in terms of safety and efficiency by predicting traffic conflict. First, we down-sample vehicle trajectories and evaluate their extrapolated (i.e., predicted) trajectories to observe changes in errors by the sampling rate. Then, we perform the prediction of the conflict using predicted trajectories and corresponding time-to-collision (TTC), and evaluate its prediction accuracy according to the sampling rate. The evaluation results show that current TTC, spacing, and sampling rate significantly affect conflict probability and predictability. Finally, the effect of sampling rates on safety and efficiency is evaluated by changes in the near-conflict domain where reliable prediction of traffic conflict cannot be achieved. The analysis of a near-conflict domain allows us to identify safe and efficient sampling rates given traffic conditions.

Authors	Lai Zheng, Harbin Institute of Technology Zhenlin Hu Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-00403
Paper Title	Traffic Conflict Prediction at Signal Cycle Level Using Bayesian Optimized Machine Learning Approaches
Abstract	This study develops nonparametric models to predict traffic conflicts at signalized intersections at the signal cycle level using machine learning approaches. Three different datasets are used, one from Surrey, Canada and the other two from Los Angeles and Georgia, USA. Traffic conflicts measured by modified time to collision (MTTC) and traffic parameters such as traffic volume, shock wave area, platoon ratio, and shock wave speed were extracted from the three datasets. Multilayer perceptron (MLP), support vector regression (SVR) and random forest (RF) models were developed based on the Surrey dataset, and the Bayesian optimization approach was adopted to optimize the model hyperparameters. The optimized models were applied to the Los Angeles dataset and Georgia dataset to test their transferability, and they were also compared to the traditional safety performance function (SPF) developed using negative binominal regression. The results show that the three Bayesian optimized machine learning models have high predictive accuracy and acceptable transferability, and MLP model is a little bit better than the SVR and RF models. In addition, the three models outperform the traditional SPF in terms of predictive accuracy. The model sensitivity analysis also show that traffic volume and shock wave area are positively associated with traffic conflicts, while platoon ratio has negative association.

Authors	Chen Yuan, Central South University Helai Huang, Central South University Ye Li, Central South University Zhenhao Sun Yuping Hu Ruifeng Gu, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-00520
Paper Title	Real-time Conflict Risk Analysis and Prediction Based on High-resolution Trajectory Data
Abstract	The real-time conflict risk model is much less studied compared to the crash-based model. This study aims at exploring the association of conflicts and traffic flow characteristics with the consideration of heterogeneity and develop real-time prediction models to identify conflict-prone conditions. The high-resolution trajectory collected from the HighD dataset is used as empirical data. A novel method with the virtual detector approach for macroscopic traffic data extraction and a hybrid data analytic framework is proposed for the trajectory data analysis. The hybrid analytic framework consists of an exploratory study by random parameter logit model with heterogeneity in means and variances and a comparative study on machine learning methods, including eXtreme Gradient Boosting (Boosting), Random Forest (Bagging), Support Vector Machine (Single-classifier), and Multilayer-Perceptron (Deep neural network). Modeling results indicate that (1) traffic flow characteristics have significant impacts on conflict probability; (2) the statistical model considering mean heterogeneity outperforms the counterpart and lane differences variables are found to significantly impact the means of random parameters for both lane variables and lane differences variables; (3) eXtreme Gradient Boosting trained on an under-sampled dataset turns out to be the best model with the highest AUC of 0.871 and precision of 0.867. Re-sampling techniques have significant effects on model improvement. The proposed model seems to be sensitive to the conflict threshold. The sensitivity analysis on feature adoption further confirmed that the conflict risk prediction should consider both the subject lane features and lane difference features.

Authors	Jose Cazares, Texas A&M University Ivan Damnjanovic, Texas A&M University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-00641
Paper Title	Evaluating Safety Benefits of V2X Sensor Sharing on Rural Highways Using Microscopic Simulation Model
Abstract	Safety is a critical aspect of transportation design and operations. Practioners utilize various references to ensure that roadways meet safety, operational, and sustainability requirements. Despite this, human error remains as a factor that contributes to unsafe driving behavior and potential crashes. Connected and autonomous vehicles (CAVs) are expected to improve traffic safety and operations. Although sensor perception ranges and capabilities may pose challenges, the sharing of information via Vehicle-to-Everything (V2X) communication provides drivers with an effective solution for overcoming sensor limitations. Sharing data obtained through a vehicle's sensors can allow a follower to understand what lies beyond its perception range and assist in making informed decisions pertaining to their future behavior. The objective of this study is to use microscopic traffic simulation to assess the safety impacts of using V2X for sharing sensor-obtained roadway information with a CAV. Several scenarios are tested in a simulated environment where drivers on a straight tangent must react to a sharp horizontal curve. Performance is evaluated using the measured values for longitudinal jerk, lateral jerk, and speed variance. The results of this study indicate that V2X sensor sharing (V2X-SS) can provide significant benefits to CAV performance. CAVs receiving sensor-obtained information were observed to behave in a manner more akin to their human-driven counterparts in comparison to those receiving BSMs. CAVs using sensor-obtained information maintain braking and lateral jerk values within safety thresholds. Additionally, speed variance was observed to be at its lowest when CAVs utilized V2X sensor information.

Authors	Dan Wu, Central South University Lu Xing Ye Li, Central South University Ruifeng Gu, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-00911
Paper Title	Optimizing control model parameters of connected automated vehicles using empirical trajectory data
Abstract	This study proposed a new method to obtain more realistic trajectory data of connected automated vehicle (CAV) based on empirical trajectory data, and further improved the safety condition by optimizing the CAV model parameters. Firstly, the initial car-following pairs (I-CFP) were extracted. Secondly, we took the selected parameters as input of the simulation models (the autonomous Adaptive Cruise Control (ACC) and Cooperative ACC (CACC) vehicle model), to obtain the trajectory data of the simulated car-following pairs (S-CFP), where the CAV is the following vehicle. Thirdly, the optimized two parameters (k1 and k2) and the optimized three parameters (t , k1 and k2) were taken as input to obtain the optimized & simulated car-following pairs (O&S-CFP), respectively. Fourthly, we evaluated the safety condition of the I-CFP, S-CFP and O&S-CFP, and compared them from the perspective of the number of car-following pairs at risk (N- CFPR) and the aggregated Time Exposed Time to Collision (TET). It was found that the safety condition of S-CFP is better than that of I-CFP. And the safety condition of the O&S-CFP has been further improved. Finally, we used a situation as example to verify the car-following effect of the CAV, which denotes whether the speed change of the CAV is basically consistent with that of leading vehicle. It was found the CAV in the S-CFP and O&S-CFP have good car-following effects by comparing the speed trend graphs, and the effect in the O&S-CFP is better, which means the model optimization is valuable.

Authors	Yuping Hu Ye Li, Central South University Helai Huang, Central South University Ruifeng Gu, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-00919
Paper Title	Modeling Conflict Risk with Real-time Traffic Data for Road Safety Assessment Using A Copula-based Joint Approach
Abstract	This study proposes a conflict-based traffic safety assessment method by combining conflict frequency and severity with short-term traffic states. Instead of analyzing historical crash data, this study employs microscopic trajectory data to quantify the relationship between conflict risk and traffic characteristics. Time-to-collision (TTC) index is used to detect conflicts, then a severity index (SI) is proposed on the basis of Time-integrated-TTC (TIT) indicator. With SI, k-means algorithm is applied to classify and define the conflict severity within a specific time and space. Zero truncated poisson regression and ordered logit regression are employed to estimate the effect of short-term traffic states on conflict frequency and severity. Furhermore the copula-based joint modeling method is applied to explore the potential non-linear dependency of conflict risk attributes, and different risk levels are considered. The HighD dataset from German is utilized to examine the proposed method, and a total of 18 copula models are tested to select the best one. Results show that the correlations between traffic states and conflict risk (frequency and severity) are significant, and the dependency of conflict risk various among different risk levels. Findings indicate that the proposed method is practicable to assess real-time traffic safety within a specific region by using short-term (30-second time interval) traffic states, which also contribute to the design of proactive safety strategies under different risk levels. Keywords: Conflict frequency, Conflict severity, Safety assessment, Copula model

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing New Methods and Data
Paper Number	22-01040
Paper Title	Development of Pattern-based Surrogate Safety Measure using Individual Vehicle Data
Abstract	In order to evaluate safety performance of specific roadway sections, a sufficient crash data is needed. To overcome this issue, many studies have tried to use the surrogate safety measures (SSM) estimated from the microscopic traffic simulations. However, it is difficult to adopt these developed SSM to reflect real world traffic conditions when the developed network in the simulation is not calibrated and validated accordingly. This article proposed a method to develop the pattern-based surrogate safety measure (PSSM) using individual vehicle trajectory data. The PSSM can be estimated based on nine different types of hazardous driving behavior (HDB) patterns. Using Digital Tacho Graph (DTG) data collected from the commercial vehicles such as buses, taxis, and trucks in 4 cities in Korea, HDB patterns were obtained. Various PSSMs were developed and validated with the observed crash data using random forest. Then, the surrogate safety performance function (SSPF) was estimated based on the frequency of HDB. To enhance model performance, machine learning and data mining techniques were applied. The results show that sudden deceleration, sudden lane change, sudden overtaking and sudden U-turn are related to traffic crashes during HDB. The results also show that high potential for safety improvement (PSI) was identified in the road section linking the urban and suburban areas. The findings from this study can provide new approach to adopt real-time individual vehicle trajectory data to evaluate safety performance of network levels.

Authors	Pei Li, University of Michigan Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-01252
Paper Title	Improving Spatio-temporal Transferability of Real-Time Crash Likelihood Prediction Models Using Transfer Learning Approaches
Abstract	A real-time crash likelihood prediction model is an important component of the proactive traffic safety management system. Over the past decades, numerous models were proposed and achieved promising results on predicting real-time crash likelihood. However, most studies ignored the model transferability, especially for deep learning models. The transferability of a model could be referred to as applying the pretrained model to new data from other locations or periods. Transfer learning aims to improve the performance of the pretrained model on new data. The purpose of this study is to improve the spatial-temporal transferability of the deep learning crash likelihood prediction model. Trajectory and crash data from five arterials in Florida were collected. Different features were generated from the trajectory data for predicting crash likelihood, such as average speed, the standard deviation of speed, the number of hard accelerations, etc. A two-layer Long Short-term Memory (LSTM) model was used for predicting the crash likelihood. Two scenarios were created to investigate spatial and temporal transferability. Extensive experimental results suggested that the crash likelihood prediction model could be accurately transferred to new data by using the fine-tuning approach. The transferred models achieved higher predictive accuracy compared with models directly developed on new data. Moreover, spatial transfer learning outperformed temporal transfer learning in terms of sensitivity and false alarm rate. The results from this study could be applied to transfer pretrained crash likelihood prediction models to new locations when few crashes are available or trajectory data is limited.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	Safety of Motorcyclists and Active Transportation Modes
Paper Number	22-01478
Paper Title	Safety margin evaluation of pedestrian crossing through critical thresholds of surrogate measures of safety (SMoS): area with zebra crossing (AWZC) versus the area without zebra crossing (AWOZC)
Abstract	Although many studies have been carried out on pedestrian crossing safety, comprehensive research on evaluating the vehicle-pedestrian conflict in the area with zebra crossing (AWZC) versus the area without zebra crossing (AWOZC) is still neglected. In the present study, through a Naturalistic Driving Study (NDS), the drivers' behavior was recorded on AWZC and AWOZC. The vehicle-pedestrian conflicts are evaluated by examining the evasive maneuver behavior of drivers and pedestrians based on surrogate measures of safety (SMoS). The severity of conflicts by a K-means clustering method was categorized into three specific groups based on the critical thresholds of SMoS. The evasive maneuvers performed by pedestrians and drivers were classified into three levels: normal, slight, and serious. In conflicts resulting in normal and serious maneuvers, drivers would attempt to prevent collisions by changing the speed and direction of the vehicle. Moreover, a pedestrian at the slight level of conflict was the determinative factor in reducing the possibility of collisions by performing actions such as returning to the curb of the street or increasing the speed of walking. Also, the results showed that pedestrians were more likely to cross with a less safe margin in AWOZC than AWZC. This study explains that both pedestrians and drivers play a crucial role in preventing collisions during different levels of conflict. Given this finding, conducting future research to evaluate the interaction between drivers and pedestrians may lead to the establishment of a basic framework for designing an algorithm to detect the possibility of a pedestrian collision.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-01524
Paper Title	Conflict Risk Analysis at Tunnel Toll Plaza Using Modified Time-to-collision Based on High-Resolution Trajectory Data
Abstract	Toll plaza is a designated area of expressway, bridge or tunnel that has a collection of toll booths, which can accommodate high traffic demand and different toll collection types. Both operational and safety characteristics of a toll plaza are different from those of other entities of the freeway. Surrogate safety indicators including time headway, acceleration rate, and time-to-collision have been widely applied to assess the safety levels of freeway segments. These indicators are usually longitudinal. To better model the safety risk attributed to the diverging, merging and weaving movements of vehicles, which can have complicated maneuvers, in the toll plaza, a modified traffic conflict measure, that considers the dimensions (i.e., width and length), and lateral and longitudinal movements of vehicles, is proposed. Then, random parameter multinominal logit models are set out to measure the association between traffic conflict risk and possible influencing factors. Both the prevalence and severity of rear-end and sideswipe conflicts are assessed. Results indicate that distance between vehicles, toll collection type, vehicular speed, vehicle location and vehicle type all significantly affect the conflict risk. Findings should shed light for appropriate remedial measures including traffic control, lane markings, and traffic signs that can mitigate the potential safety risk of tunnel toll plazas.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-01545
Paper Title	Application of Explainable Machine Learning for Real-time Safety Analysis Toward Connected Vehicles Environment
Abstract	Due to the difficulty of obtaining traffic flow data and conflicts simultaneously, real-time safety evaluation by using macroscopic traffic features is much less studied. This study aims to analyze real-time safety by taking conflict analysis as a disaggregate study and apply explainable machine learning to provide insights into the impact of traffic features on conflict occurrence. A virtual fixed detectors approach is employed to capture the cross-sectional traffic data in the HighD dataset and the trajectory data of vehicles is also considered, assuming these data can be obtained under connected vehicles (CV) environment. Subsequently, the CV Market Penetration Rate (CV-MPR) is analyzed to reveal its influence on improving the safety evaluation. The results show that the Random Forest model outperforms eXtreme Gradient Boosting, Support Vector Machine and Adaptive Boosting and achieves the best performance with the highest AUC of 0.827. By the result of SHAP (SHapley Additive exPlanation) analysis, several traffic features are found to have a relatively more significant impact on the occurrence of conflict and their influences on conflict occurrence are then discussed. Additionally, the feature dependency analysis is conducted for three pairs of features. The result suggests that the impacts of traffic features are not always fixed and there may exist specific patterns of paired features affecting real-time safety. The findings help explain the complex conflict mechanism in traffic flow. Experimental result regarding CV-MPR demonstrates that the model performance will be gradually enhanced as the penetration rate increasing.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-01786
Paper Title	Exploring Driving Styles Using Large-Scale GPS Trajectory Data: A Latent Dirichlet Allocation Topic Approach
Abstract	Driving style identification has become a highlight in recent years and of great significant in the field of traffic safety research. This study aims to identify and analyze driving styles using largescale GPS trajectory data taking different time periods, traffic and weather conditions into account. The k-means clustering algorithm and Latent Dirichlet Allocation (LDA) topic model are employed to recognize and classify driving styles. Before driving style recognition, data is preprocessed and the optimal value of the number of clusters and the number of topics is explored. Results of the classification show that driving styles are composed of three driving states with different probability combinations. The driving style in the morning peak is much more cautious whereas the one in the evening rush hours is more changeable and the style in other period of the day depends more on the drivers themselves. Driving styles in a working day show more conservative following states than the ones in a non-working day. Moreover, the driving style is also affected by the weather and it is more cautious and conservative when it happens to be rainy. Findings of this study can be helpful for traffic management under driving context and contributes to the research on traffic safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-02161
Paper Title	Incorporating Driving Volatility Measures in Safety Performance Functions Improving Safety at Signalized Intersections
Abstract	Every year, about 40 percent of the crashes in the US are related to intersections. To deal with such crashes, Safety Performance Functions (SPFs) are vital elements of the predictive methods in the Highway Safety Manual. The predictions of crash frequencies and potential reductions due to countermeasures are based on exposure and geometric variables. However, the role of driving behavior factors, e.g., hard accelerations and declerations, which can lead to crashes, are not explicitly specified in SPFs. One way to capture driving behavior is to harness connected vehicle data and quantify performance at intersections in terms of driving volatility measures. Studies have found driving volatility to be associated with risk and safety-critical events. Therefore, volatility can serve as a surrogate for driving behavior. This study incorporates driving volatility measures in the development of SPFs for four-leg signalized intersections. The Safety Pilot Model Deployment (SPMD) data containing over 125 million Basic Safety Messages generated by over 2,800 connected vehicles are harnessed and linked with crash, traffic, and geometric data belonging to 102 signalized intersections in Ann Arbor, Michigan. The results show that incorporating driving volatility measures in the intersection SPFs substantially improves the goodness-of-fit and predictive performance of the models. Also, the best results were obtained by applying Bayesian hierarchical Negative Binomial Models in which the spatial correlation between the signalized intersections are taken into account. The results of this study can have implications for practitioners and transportation agencies.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-02224
Paper Title	On The Transferability of Peak-Over Threshold Extreme Value Models for Estimating Crash Frequency-By-Severity Using Traffic Conflicts
Abstract	Traffic conflict techniques represent the state-of-the-art for road safety assessments. However, the lack of research on transferability of conflict-based crash risk models, which refers to applying the developed crash risk estimation models to a set of external sites, can reduce their appeal for large-scale traffic safety evaluations. Therefore, this study investigates the transferability of multivariate peak-over threshold models for estimating crash frequency-by-severity using two approaches: an application-based approach involving a direct application of the uncalibrated base model to the target sites and an estimation-based approach involving calibration of conflict thresholds of Modified Time-To-Collision (MTTC) and Delta-V indicators using local data from the target sites. They were benchmarked against a complete re-estimation approach where all the model parameters were estimated using local data. These approaches were tested for a set of signalized intersections in Southeast Queensland, Australia. Results show that for target sites where the conflict data have been collected for longer durations, the application-based approach provides reasonably accurate and precise predictions of crash frequency-by-severity. The estimation-based approach may improve the prediction performance further but should be proceeded with cautiously only when reasonable estimates are not achieved from the uncalibrated approach. On the other hand, complete re-estimation of models for individual target sites yields inferior fits and less precise crash estimates since they utilize fewer traffic conflict extremes in their development than the larger dataset utilized in base model development. The study results can significantly advance the applicability of traffic conflict models for crash risk estimation at transport facilities.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-02434
Paper Title	Dynamic Updating Evaluation of Vehicle Collision Risks at the Upstream Toll Plaza Area
Abstract	This study aims to estimate the real-time vehicle collision risk in diverging area of toll plaza. With the trajectory data extracted from unmanned aerial vehicle (UAV) videos, six different discrete sampling methods are employed to reduce calculation pressure. Using the extended time to collision (ETTC) as an indicator to measure vehicle collision risk, Bayesian dynamic logistic regression (LR) model is developed to estimate the vehicle collision risk and its contributing factors in diverging area with different sampling methods, and compared the prediction accuracy with Standard LR model by using Area under Receiver Operating Characteristics curve (AUC). Furthermore, the sensitivity analysis of forgetting parameter and AUC in Bayesian dynamic LR models of different sampling methods is tested. The results show that the AUC values of all Bayesian dynamic LR models and Standard LR models are more than 0.9, which indicates that they have good prediction performance. Due to the Bayesian dynamic LR model could significantly reduce estimation time of dynamic data, it has higher calculation efficiency and better performance of collision risk evaluation.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-02572
Paper Title	Modeling Aggressive Driving Behavior Based on Graph Construction
Abstract	The occurrence of aggressive driving behavior is a random process among time-varying transversion. Regression models, which are based on the normal data construction (mean and S.D.), are not advanced in characterizing the driving feature among a large set of time-series attributes. This paper models aggressive driving behavior based on graph construction. The raw data are used to extract the pieces of the graph. Each graph represents a specific driving trip that includes driver characteristics, environment, and driving behavior variables. The effect of graph construction was verified based on the Shanghai Naturalistic Driving Study data. 17 variables related to aggressive driving are extracted based on statistical analysis. The result shows that a 5-sec time window is suitable for aggressive driving behavior modeling. 11 variables (speed, longitudinal acceleration, lateral acceleration, lateral placement, gender, age, distracted, drowsy, weather, flat curve, time-to-collision) can be used for graph construction based on high significance features. Both normal data construction and graph construction are used for modeling. The models based on a mean plus S.D. and graph construction can achieve higher accuracy and smaller error than normal (mean only), and graph construction present the best model performance. This paper also extracted the weight of each variable in the model. The main factor associated with aggressive driving is TTC, and the main factor of driving behavior that influences aggressive driving is the duration of aggressive longitudinal acceleration. This method can be used in real-world applications for improving driving safety with the applications in the Advanced Driver Assistance Systems.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-02716
Paper Title	Crashes and Near Crashes Causation Analysis Using Naturalistic Driving Data
Abstract	Determining crash causation has always been a focus and a difficulty in the field of traffic safety. Previous research has had to rely on insufficient crash data and crash causation analysis methods limited to a single crash, and has not taken advantage of the application value of pre-crash scenarios in causation analysis. This study therefore proposed a two-stage crash causation analysis method based on pre-crash scenarios, and analyzed crashes and near crashes (CNCs) using naturalistic driving data. From the Shanghai Naturalistic Driving Study (SH-NDS), 572 CNCs were extracted, and 25 pre-crash scenarios were identified using the Pre-Crash Scenario Typology. In-depth investigations of CNCs in the same scenario were analyzed to determine the causes of crashes using the proposed systematic crash causation derivation framework, which summarizes the causation patterns in each scenario based on the interaction of humans, vehicles, infrastructure, and environment subsystems. The differences between the causation patterns of three common pre-crash scenarios (rear-end, lane change and pedalcyclist collisions) were determined through statistical analysis. Following too closely and non-driving-related distraction were important causes of rear-end scenarios. Distraction, as well as willful behavior and violation of traffic laws was a common pattern (61.2%) in lane change pre-crash scenarios. Pedalcyclist scenarios leading to CNCs were particularly impacted by pedalcyclists violating traffic regulations, visual obstructions, and inadequate lanes for non-motorized vehicles. Based on causation patterns, this study suggests countermeasures for the three scenario types. These findings provide support for safety improvement projects and the development of advanced driver assistance systems.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-02721
Paper Title	Modeling Reliability and Unreliability of Safety in the Network Equilibrium Model: An α-Reliable Mean-Excess Approach
Abstract	In this study, a network equilibrium model accounting for both the traveler's safety concern and travel time concern is proposed. Since the travelers might not only worry about the average safety condition of their routes, but also the reliability and unreliability aspects of safety (e.g., crash risk). Thus, reliability and unreliability aspects of safety are modeled using the concept of α-reliable mean-excess traffic equilibrium model (METE). Crash risk cost (CRC) distribution is adopted, and the travelers are assumed to have gained the knowledge of CRC distribution based on their traveling experience, which they incorporate into their long-term habitual user equilibrium (UE) flow pattern. The proposed model ensures the reliability aspect of safe arrival at a specified confidence level α and also accounts for the unreliability aspect of encountering the worst safety condition beyond the acceptable effective CRC in the distribution tail of 1-α. The variational inequality formulation is being reformulated as an unconstrained smooth gap function. Using a numerical example, the proposed model is compared with the Mean CRC (MCRC) and Effective CRC (ECRC) user equilibrium models to elaborate the differences in properties of the models and also highlight the realism of using the mean-excess CRC user equilibrium (MECRC-UE) model. It is argued that the proposed model captures a more realistic behavior of road users.

Authors	Qinghong Chen, Central South University Ye Li, Central South University Jaeyoung Lee, Central South University Helai Huang, Central South University Ruifeng Gu, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-02762
Paper Title	Predicting the lane-changing decision and execution risks: A pre-emptive approach for the whole lane-changing process
Abstract	Lane-changing (LC) maneuver has significant impacts on traffic safety. Instead of focusing on a specific stage of the LC process and the posterior LC risk estimation, this study proposed a pre-emptive LC risk prediction approach to explore the complete process of the LC decision (LCD) and execution. The execution process includes either implementing the LC (LCI) or keeping the current lane (LK). The HighD dataset was employed and three kinds of datasets were further extracted, i.e., the LCD datasets, the LCI datasets, and the LK datasets. For each dataset, we extracted features from trajectory data in three different time periods and constructed three sub-datasets. Then, we applied four machine classifiers to predict the LCD and the risk of LCI and LK, including the Decision Tree (DT), the Random Forest (RF), the Support Vector Machine (SVM), and the eXtreme Gradient Boosting (XGBoost). The results indicate that the simplest classifier DT performs very well on the LC decision datasets. In addition, the XGBoost performs better than the rest three classifiers on the LCI and LK datasets. According to the predictive performances of the classifiers on the highest risk level, we provide suggestions about which time period of the trajectory data should be selected for feature selection. The proposed approach could have the potential of being integrated into the advanced driver assistance system and vehicle-to-vehicle communication in the near future.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-02777
Paper Title	A cross-country comparison and risk analysis of lane-changing behaviors using vehicular trajectory data
Abstract	Improper lane-changing leads to deaths, injuries, and property damages. Although many studies have employed the vehicular trajectory data to conduct lane-changing safety analyses, most of them only utilized one single dataset, which is collected from one country with limited traffic conditions. The differences in lane-changing behavior in different countries are rarely investigated. This study aims to compare the lane-changing behaviors in different countries and to investigate the contributing factors of lane-changing collision risks. We employed three different datasets collected from three different countries to extract the lane-changing behaviors. 11 key features of the lane-changing behaviors are selected and compared. The lanechanging risk index (LCRI) is calculated to quantify the collision risk of lane-changing vehicle groups. We further divided the LCRI into different levels by the k-means algorithm. To investigate the contributing factors of lane-changing collision risks, we established a random parameter ordered logit (RPOL) model for each dataset. The main results suggest that (1) the lane-changing behaviors are quite different in different traffic conditions and different countries. In congested conditions, the drivers usually change the lane in a shorter distance with larger steering angles; (2) even with similar traffic conditions, the drivers in Germany are more aggressive than the drivers in the Netherlands. (3) the number and the effects of variables are different in different RPOL models, and a possible reason might be the differences in traffic conditions and driving habits. This study points out the portability issues of the researches based on a single trajectory dataset.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	Safety of Motorcyclists and Active Transportation Modes
Paper Number	22-02933
Paper Title	Investigating Conflict Behaviors of Two-Wheel Vehicles at Non-Signalized Intersections Based on Trajectory Data
Abstract	Unsafe acts occurred at intersections have become a primary contributor to traffic accidents and fatalities. A majority of studies have focused on signalized intersections in the past decade. Non-signalized intersections only raise limited concerns from previous researchers although they commonly exist on campus or suburban areas and have resulted in high-consequence accidents recently. Two-wheel vehicles (e.g., bicycles and e-bikes) are gaining popularity worldwide due to high mobility and low carbon emissions. Meanwhile, they are proven to be one of the most vulnerable transportation modes with high accident frequency and fatality rates. This study investigated the two-wheel vehicle-involved conflicts at non-signalized intersections based on trajectory data automatically collected from big video data. A practical framework was firstly proposed and employed to gather and process the microscopic trajectory data. To detect two-wheel vehicle-involved conflicts, this study employed a near-crash identification along with a post encroachment time (PET) indicator. These framework and methodology have been applied in a case study of one university campus in Shanghai. The traffic-related statistics and Chi-Square tests show that a higher proportion of conflicts occurred at the intersection entrances and yielding behaviors were not taken by a large proportion of the road users in conflicts. Ultimately, the analytical results can contribute to the development of intersection-specific countermeasures in traffic safety from the perspectives of education, engineering, and law enforcement. The vision-based methodology framework can also be adapted to other transportation scenarios to enhance safety management with accessible video data.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	Safety of Motorcyclists and Active Transportation Modes
Paper Number	22-02948
Paper Title	Quantifying Diverse Types of Pedestrian-Vehicle Conflicts at Actuated Signal Control Intersections with Lightgbm and SHAP
Abstract	Signalized intersections are crash prone locations for pedestrians. Traditional crash modeling methods have limited capability, since they depend on historical crash data amount and quality. Traffic conflict are considered to be highly correlated with crash, with much higher frequency. Therefore, conflict-based safety modeling methods have been extensively used in recent years. In order to explore pedestrian risk at signalized intersections, three typical four-leg signalized intersections in Bellevue, Washington were selected in this study. Based on collected data, a Light Gradient Boosting Machine (LightGBM) was developed to identify the relationship between three types of pedestrian conflicts (i.e., left turn traffic, right turn traffic, and through traffic) with traffic volume, control type and roadway geometrics. A Shapley Additive explanation (SHAP) method was used to visualize and explain the impact of significant factors. Important findings include: (1) protected left turn phase may need to be considered, since higher left turn volume(>150 pcu/h) and pedestrian volume would cause higher risk with permitted left turn; two-stage pedestrian crossing and phase switch time adjustment could be considered to decrease risk between left turn traffic (>300 pcu/h) and pedestrians who have not cleared the intersection, for lag left turn protected control; (2) a certain level of traffic volume(600-800 pcu/h) may increase the risk of pedestrians who violate the pedestrian signal control; (3)when right turn traffic volume is high (>150 pcu/h), a long pedestrian red flashing time may increase jaywalking and risk. The research findings could provide valuable knowledge for pedestrian safety improvement at signalized intersections.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-03105
Paper Title	Automated Vehicle Data Pipeline for Accident Reconstruction: New Insights from LiDAR, Camera, and Radar Data
Abstract	As automated vehicles are deployed across the world, it has become critically important to understand how these vehicles interact with each other, as well as with other conventional vehicles on the road. One such method to achieve a deeper understanding of the safety-implications for Automated Vehicles (AVs) is to analyze instances where AVs were involved in crashes. Unfortunately, this poses a steep challenge to crash-scene investigators. It is virtually impossible to fully understand the factors that contributed to an AV involved crash without taking into account the vehicle's perception and decision making. Furthermore, there is a tremendous amount of data that could provide insight into these crashes that is currently unused, as it also requires a deep understanding of the sensors and data management of the vehicle. To alleviate these problems, we propose a data pipeline that takes raw data from all on-board AV sensors such as LiDAR, radar, cameras, IMU's, and GPS's. We process this data into visual results that can be analyzed by crash scene investigators with no underlying knowledge of the vehicle's perception system. To demonstrate the utility of this pipeline, we first analyze the latest information on AV crashes that have occurred in California and then select two crash scenarios that are analyzed in-depth using high-fidelity synthetic data generated from the automated vehicle simulator CARLA . The visualization and data analysis from these scenarios clearly demonstrate the vast improvement in crash investigations that can be obtained from utilizing state-of-the-art sensing and perception systems used on AVs.

Authors	Mostafa Tawfeek, Ain Shams University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-03214
Paper Title	Location-Based and Driver Class-based Analysis for Reaction Time in CarFollowing Situations
Abstract	This study aims at examining the differences in driver's reaction time while driving on horizontal curves and straight roadway segments and among different driver classes to better emulate human driver behavior in car-following situations. For this purpose, speed, gap, relative speed, and acceleration were extracted from naturalistic car-following trajectories to estimate the reaction time. The reaction time was estimated for two stimuli-response pairs; namely, speed-gap and relative speed-acceleration pairs using the cross-classification method. The reaction time was estimated separately for each driver and aggregated based on location (i.e., curves and segments) and based on driver class (i.e., cautious, normal, and aggressive). The results reveal that drivers' reaction time on curves is consistently higher than their reaction time on straight segments and this difference is statistically significant. Moreover, the comparison between normal drivers and aggressive drivers indicates that regardless of the location, aggressive drivers have significantly longer reaction time than normal drivers as aggressive drivers can accept closer gaps and higher relative speed. Also, cautious drivers have a longer reaction time when compared to normal drivers; however, the difference is not significant in most cases. Furthermore, cautious and normal drivers have a longer reaction time on curves when compared to their reaction time on straight segments. These findings can enhance driver behavior simulation in car-following modeling and improve the prediction of human driver reactions in mixed human-driven and autonomous vehicles environment. Also, this study highlights the importance of considering drivers' inter-and intra-heterogeneity in mixed human-driver and autonomous vehicle environments.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-03304
Paper Title	Understanding Crash Risk using a Multi-Level Random Parameter Binary Logit Model: Application to Naturalistic Driving Study Data
Abstract	This study presents a framework to employ naturalistic driving study (NDS) data to understand and predict crash risk at a disaggregate trip level accommodating for the influence of trip characteristics (such as trip distance, trip proportion by speed limit, trip proportion on urban/rural facilities) in addition to the traditional crash factors. Recognizing the rarity of crash occurrence in NDS data, the research employs a matched case-control approach for preparing the estimation sample. The study also conducts an extensive comparison of different case to control ratios including 1:4, 1:9, 1:14, 1:19, and 1:29. The model parameters estimated with these control ratios are reasonably similar (except for the constant). Employing the 1:9 sample, a multi-level random parameters binary logit model was estimated where multiple forms of unobserved variables were tested including (a) common unobserved effects for each case-control panel, (b) common unobserved factors affecting the error margin in the trip distance variable, and (c) random effects for all independent variables. The estimated model was calibrated by modifying the constant parameter to generate a population conforming crash risk model. The calibrated model was employed to predict crash risk of trips not considered in model estimation. This study is a proof of concept that NDS data can be used to predict trip level crash risk and can be used by future researchers to develop crash risk models.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-03540
Paper Title	Predicting Intersection Crash Frequency Using Connected Vehicle Data: Application of Geographical Random Forest
Abstract	Accurate crash frequency prediction is critical for proactive safety management. The emerging connected vehicles technology provides us with a wealth of vehicular motion data, which enables a better connection between crash frequency and driving behaviors. However, appropriately dealing with the spatial dependence of crash frequency and multitudinous driving features has been a difficult but critical challenge in the prediction process. To this end, this study aims to investigate a new Artificial Intelligence technique called Geographical Random Forest (GRF) that can address spatial heterogeneity and retain all potential predictors. By harnessing more than 2.2 billion high-resolution connected vehicle Basic Safety Message (BSM) observations from Safety Pilot Model Deployment in Ann Arbor, MI, 30 indicators of driving volatility are extracted, including speed, longitudinal and lateral acceleration, and yaw rate. The developed GRF was implemented to predict rear-end crash frequency at intersections. The results show that: 1) rear-end crashes are more likely to happen at intersections connecting minor roads compared to major roads; 2) a higher number of hard acceleration and deceleration events beyond two standard deviations in the longitudinal direction is a leading indicator of rear-end crashes; 3) the optimal GRF significantly outperforms Global Random Forest, with a 9% lower test error and a substantially better fit; and 4) geographical visualization of variable importance highlights the presence of spatial non-stationarity. The proposed framework can proactively identify at-risk intersections and alert drivers when leading indicators of driving volatility tend to worsen.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-03628
Paper Title	Microscopic Comparison of Traffic Accidents and Conflicts: A Behavioral Perspective Based on Trajectory Data
Abstract	Traffic conflict techniques have been widely used to analyze traffic safety in previous studies. Discriminating harmful from harmless conflicts closer to accidents would improve the performance of conflict techniques in safety evaluation. However, the microscopic features between the accident and conflict have not been compared in the literature due to the lacking of precise vehicle trajectories covering the before and after the traffic accident. This study aims to provide a comprehensive empirical analysis of the distinctive driving behaviors of traffic accidents and traffic conflicts. Firstly, we established the high-resolution traffic accident and conflict datasets with detailed vehicle trajectories automatically extracted from the drone videos. Then, we adopted the reaction pattern analysis to examine the driving behavior of the following vehicles involved in rear-end traffic accidents when the oscillation comes. After that, we conducted a descriptive empirical analysis of the interaction between the following vehicle and the leading vehicle during the oscillation to explore the inducement of traffic accidents. Finally, the task difficulty analysis was used to further estimate the relationship between the driving task demand and the driving capability of the driver. The results indicated that the driving behaviors related to reaction characteristics, acceleration, and task difficulty are significantly different between the traffic accident and the traffic conflict when the follower experiences the oscillation. The findings of this study could provide a valuable reference for accident risk evaluation and be applied in a proactive warning system in the vehicle to avoid crashes or decrease the likelihood of accidents.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	Safety of Motorcyclists and Active Transportation Modes
Paper Number	22-03730
Paper Title	Safety Analysis on Pedestrian-vehicle Exit Interactions at Non-signalized Intersections Based on YOLOv3-DeepSort
Abstract	With the development of video surveillance technology, intelligent surveillance technology has been widely used in traffic safety. Traffic safety at non-signalized intersections has always been the focus of attention all over the world. Most researchers are dedicated to studying the interaction of traffic participants at the entrance of an intersection. However, the pedestrian-vehicle interaction at the exit of the intersection is also worthy of being studied. And this type of pedestrian-vehicle interaction is rarely studied. This paper takes pedestrians and vehicles as typical targets to study the interactive behavior at the exits of non-signalized intersections, and to study methods for extracting object trajectories in videos. For that purpose, we propose a processing framework for the analysis of pedestrian-vehicle interaction behaviors based on YOLOv3-DeepSort. The methodology is confirmed by practical case study in the stop-controlled intersections from someplace, China. Different measurements are used in the case: from the interaction analysis that determines pedestrian-vehicle interactions based on a Distance-Speed (DS) model, average crossing speeds and vehicle approaching behaviors in terms of speed. We obtain these measures from the trajectory data extracted by YOLOv3-DeepSort. Based on these measures, a comparative analysis is carried out between entrance and exit interactions. Results show that it is of great significance to the safety analysis of pedestrian-vehicle exit interactions at non-signalized intersections.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-03987
Paper Title	A Validation Study on Conflict-Based Crash Prediction Considering Crash Severity for Signalized Intersections
Abstract	Traffic conflicts are the most widely used surrogate safety measures to harness data on critical safety events. However, the main body of the road safety literature has mainly focused on the relationship between traffic conflicts and total crashes, with very limited, if any, consideration of crash severity. The main goal of this study is to contribute to filling this gap by providing a validation study, using a rich dataset from 14 signalized intersections in the City of Bellevue, with over 3 million road users and 200,000 conflicts. Conflict data, measured by time to collision (TTC) and post-encroachment time (PET), was obtained using TrafxSAFE, a video analytics software, for one week of data. Crash data was obtained for a 6-year period. The modelling framework is based on a two-stage approach. First, the number of crashes is estimated using a count-data model that utilizes traffic conflicts. Then, assuming a crash has happened, the probability of the crash being in a certain injury level is computed using a Multinomial Logit (MNL) model. The results show that traffic conflicts are highly correlated with crash counts, highlighting that the safety analysis at signalized intersections, which are currently mainly based on traffic volume, could significantly benefit if conflicts were included in the models. Also, the results of MNL model provide the probabilities of each injury level given a crash has happened. The combination of the results of these two stages provides the expected number of crashes for each severity level, given different scenarios of crashes.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-04486
Paper Title	A 3D-LiDAR-based Methodology for Extracting Data for Surrogate Safety Analysis at Intersections
Abstract	Traditionally, the diagnosis of safety issues and the identification of appropriate countermeasures make use of historical crash data. However, with advancements in camera-based monitoring systems, traffic safety authorities have become able to automatically monitor and collect road users' interactions. Using road users' trajectories obtained from an automatic monitoring system, surrogate safety indicators such as time-to-collision and post-encroachment time are computed. Despite its advantages, a monitoring system using LiDAR is not widely investigated in intersection safety applications. The principal objective of this research is to develop and test a 3D LiDAR-based proof-of-concept and a methodology for monitoring intersections. As the core component of this research, supervised learning algorithms are developed to detect, track and classify road users based on point clouds collected by a 3D-LiDAR sensor. The proposed algorithm is built and tested using collected data at an intersection in Montreal. An artificial neural network is implemented for classifying users as motorized and non-motorized. The classification rate of the system is 93% on the training set and 90% on the test set. The surrogate safety indictors are computed in two different ways: like camera-based systems using the centroids and using LiDAR-based 3D point clouds. The results show that the latter approach enhances the time-to-collision and post-encroachment time. Using point cloud, the average TTC reduces by -9% to -21%, and the PET reduced by -2% to -12%, helping to identify more severe interactions. Keywords: 3D LiDAR Sensor, Intersection Monitoring, Surrogate Safety Indicator, Alternative Technologies

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-04592
Paper Title	Expressway Rear-end Conflict Evolution Mechanism Analysis under Different Traffic States
Abstract	Expressways are important components of the road network, and the proportion of rear-end crashes is the highest for expressways. One of the most effective ways to reduce the rear-end crash risk is Active Traffic Management (ATM), and knowing the mechanism of how high conflict risk happens is the foundation of ATM. However, the existing studies are mainly based on highly aggregated traffic data. It is hard to capture the evolution mechanisms of conflict risk. Thus, it is hard to effectively support the ATMs. Conflict risk mechanisms might be heterogeneous in different traffic states, e.g., smooth states and congestion states. This study explored the conflict mechanisms in different traffic states with high-resolution trajectory data. First, an ordered clustering method is used to divide a 4 km expressway section into several segments under different traffic states, and the temporal unit takes five seconds. Second, the spatial-temporal ranges are decided by the spatial-temporal correlations analyses between conflict risk and potential contributing factors. Thirdly, three types of time-series models are established for each state to quantitatively obtain the impacts of contributing factors on the future conflict risks. The factors included conflict risk of the current segment, conflict risk of nearby segments, and the traffic parameters of nearby segments in the past. The results showed the conflict risk was mainly decided by the upstream contributing factors under smooth states, and it was mainly determined by the downstream factors under congestion conditions. The results of this study might benefit in proposing different ATMs for different states.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-04756
Paper Title	Safety Evaluation of Ride-Hailing Drivers and Improvement Strategies Based on Vehicle Trajectory Big Data
Abstract	Online ride-hailing service has been popular since the 2010s because of its several advantages over conventional modes of transportation. Nevertheless, most drivers of the ride-hailing service are not professional drivers, and their driving behavior and safety should be thoroughly evaluated. Although there have been many studies for the ride-hailing service in the aspect of mode choice, OD estimation, equity, etc., no study has suggested a framework assessing microscopic driving behavior. Thus, the study aims at identifying dangerous microscopic behaviors of the ride-hailing drivers using trajectory Big Data from the largest ride-hailing service company in China along with other additional data (e.g., weather). The study also suggests effective strategies to improve driving behaviors based on 450 self-reported questionnaires collected from ride-hailing drivers. The developed framework is capable of identifying risky behaviors based on over-speeding, sudden acceleration/deceleration, and relative risky driving. Furthermore, contributing factors associated with the risky behaviors were revealed. Generally, nighttime, fog, residential street, a particular district, and bridge areas are associated with risky behavior. It is interesting that over-speeding is less observed in tunnels while sudden acceleration/deceleration and relative risky driving are more observed. The results from the questionnaire survey indicate that driving experience, at-fault crash involvement, risk awareness towards over-speeding, and sudden acceleration/deceleration have associations with drivers' willingness to improve the behavior. The methods and findings from this study will be useful for ride-hailing service companies to enhance their drivers' behavior and traffic safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1340
Session Title	Advancing new methods and data
Paper Number	22-04784
Paper Title	Proactive Safety Assessment of 3D Road Geometries Using Naturalistic Driving Data
Abstract	Road traffic crashes are increasing rapidly in the low and middle income countries. According to reports, most crashes occur on highways with complex geometries, such as horizontal curves superimposed with vertical curves. The existing safety assessment practice for complex road geometries uses geometric design consistency measures based on operating/design speed, or historical crash data. Such practices have several limitations as reported by other studies. The present study proposes a proactive safety assessment method that can effectively capture the crash risk at complex road geometries without relying on historical crash data. A novel surrogate safety indicator called Anticipated Collision Time (ACT) was used to quantify the crash risk. ACT can capture the crash risk corresponding to different crash types, which allows the designers to develop crash-type-specific mitigation strategies. A comparison of actual and estimated crash frequencies shows that the proposed method can replicate the field scenario. For a given road geometry, a correlation analysis of crash exposure and severity with distinct crash types reveals a contrasting correlation between crash types. Evidently, geometric redesign to alleviate a particular crash type may lead to the occurrence of other crash types. Therefore, the geometric design practice should consider optimal trade-off of the occurrences of all the crash types. As the improvement of geometric elements is not always the only strategy to ensure safety, it would be more appropriate to add adequate protective measures (e.g., crash barriers) or installing warning systems to minimize the crashes or their severity.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1056
Session Title	Safety of Motorcyclists and Active Transportation Modes
Paper Number	22-04849
Paper Title	Near Misses, Crashes, and Falls while E-scooting, Walking, and Bicycling in a College Town
Abstract	Dockless e-scooters were used for 86 million trips in 2019, indicating great potential as a new transportation mode in cities and on university campuses. Yet, little is known about how escooters users interact with people walking, bicycling, and driving. While several studies have examined e-scooter injuries reported in hospital data, near misses are chronically understudied in general, and even more so for this newer mode of transportation. This paper presents the results of an online survey of 1256 university staff (22% response rate) in Tempe, AZ. Using this single population, we compare the prevalence of incidents and incident types, crashes, and injuries and injury types among those who use e-scooters, walk, and bicycle. Our results indicate key differences in how e-scooter users experience safety incidents compared to people walking and bicycling, with e-scooter users more likely to report issues related to pavement, equipment, or losing control, and people walking and bicycling more likely to report conflicts with other roadway users. Our findings suggest important areas for policy and infrastructure innovation, including prioritizing separate space for e-scooters to mitigate conflicts with pedestrians, and continuing to evolve rider training and speed governance to help keep e-scooter users safe. Other findings corroborate the underreporting of injuries among non-auto users and underscore the importance of measuring near misses to develop a comprehensive picture of transportation safety.

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Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	1304
Session Title	Safety Performance and Strategies
Paper Number	22-04860
Paper Title	Crossing Conflict Models for Un-Signalized T-Intersections
Abstract	The safety of un-signalized intersections is assessed by correlating the number of crashes with traffic volume and intersection geometry-related characteristics. However, crash-based safety assessment has known drawbacks related to data quality and coverage. Further, the crash-based analysis does not explicitly account for the fact that not all vehicles are interacting unsafely. Therefore, with these drawbacks, analysing traffic conflicts is a more prudent approach for analysing safety. The present study develops crossing conflict-based safety performance functions (C-SPFs) for urban un-signalized T-intersections. Traffic video data for eight un-signalized T-intersections with variable intersection geometry (with or without Central Island) and traffic flow characteristics is collected. Crossing conflicts at the selected study intersections were analysed using post encroachment time (PET) as a most suitable surrogate safety measure (SSM). The crossing conflicts were bifurcated into critical and non-critical conflicts based on the PET values. The C-SPFs were modelled as a function of traffic flow and intersection geometry-related characteristics using the generalized estimating equations with the Tweedie distribution (GEE_TD) regression approach. The results revealed time of the day, intersection geometry, vehicular composition (both offending and conflicting stream), and traffic volume (both offending and conflicting stream volume) as the most significant variables that influence the number of critical and non-critical crossings conflicts at un-signalized T-intersections. The developed C-SPFs can provide insights into how the crossing conflicts vary at un-signalized T-intersections, enabling safety engineers to develop measures aimed at reducing crossing conflicts at un-signalized T-intersections.

8 Transportation Safety Management

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

Thirty papers describing diverse perspectives of transportation safety management will be presented in Lectern Session 1073 titled ***The Role of Speed in a Safe System***, Lectern Session 1162 titled ***Translating Safety Research to Real-World Solutions***, or Poster Session 1219 titled ***Safety Management Systems*** at the 2022 TRB Annual Meeting. The following is a brief overview of the papers.

Six papers explored **effects of COVID-19 on traffic safety** using data from different locations. Matheny et al. (22-00085) investigated the impact of COVID-19 on traffic safety and flow patterns using data from Bowling Green, Kentucky. The authors found that AADT was reduced by 37% and the overall injury crash rate has increased by ~66%. Li & Zhao (22-02915) explored impact of COVID-19 travel restrictions on cyclist crash patterns in New York. The authors revealed that the average number of cyclists killed or injured per crashes more than tripled compared with the period before the COVID-19 outbreak. Haider et al. (22-03145) probed the impact of COVID-19 on crashes in Texas using the convolutional neural network (CNN) approach. Patwary & Khattak (22-03769) investigated how traffic fatalities, total crashes, and crash harms changed after the COVID-19 pandemic in Tennessee. The authors showed that fatal crashes have increased and those occurred during the pandemic involved more speeding and reckless behaviors. Milusheva et al. (22-03847) explored how policies implemented to control the spread of COVID-19 affect traffic crashes and severity in Nairobi, Kenya. The authors found that the decrease in crashes after closing of schools and bars, but its percent decrease is smaller than that of mobility. After a curfew, crashes and injuries were rebounded back to the curfew's starting period. Lastly, the decrease in crashes is short-lived, with crashes reverting to the pre-policy levels after several weeks. Ahangari et al. (22-04687) analyzed the impact of COVID-19 on traffic safety in large U.S. cities. The authors identified that the national traffic fatalities increased by 17% in 2020 compared to 2019 but the trend was not same across different cities. It was found that the sites with a posted speed limit 5-mph reduction experienced

Four papers investigated **traffic safety at macroscopic level**. Dai et al. (22-02558) applied various boosting techniques and recommended using CatBoost algorithm model with 40% target data for macroscopic level safety updating. Pei et al. (22-02875) assessed regional traffic safety considering both crashes and violations. The major findings are (1) population density and GDP per capita play important roles in higher-risk and lower-risk town; and (2) a larger road and intersection density, and a higher percentage of collector roads are associated with higher risk levels. Wang et al. (22-03030) explored traffic fatality trends of seven developed countries since 1970. An ARIMA model was built for assessment, analysis, and forecast. Kodi et al. (22-03406) examined hotspots of crashes involving vulnerable aging road users and their spatial relationship with the built environment. A developed geographically weighted regression (GWR) revealed that crash hotspots involving aging non-motorists have a higher population density, a higher proportion of the caging population, and a higher density of bus stops.

Three papers focused on the **relationship between speed and traffic safety**. Figliozzi et al. (22-01087) evaluated the posted speed limits reduction on urban roads with a high percentage of cyclists. The sites with a posted speed limit 5-mph reduction experienced more decreases in the speed than the sites without reduction. Mahmoud et al. (22-02362) analyzed the difference between operating speed and target speed using mixed-effect ordered logit model. The results concluded that 16 variables were

significantly associated with the difference between target speed and operating speed including speed limit, volume exposure, shoulder width information, sidewalk and shared path proportions, block length, number of signals, pavement conditions, residential and mixed land use, population density, and percentage of poverty. Mbugua et al. (22-02957) studied potential reductions in road fatalities and injuries from reducing speed limits to recommended safe system speed limits in low- and middle-income countries. The authors revealed that a large reduction in all road trauma with fatal crashes reduced by 4% to 44% after the speed limit reduction.

Three papers explored traffic safety of **developing countries**. Neki et al. (22-01072) studied the profile of countries with increases vs. decreases in motorcycle fatality rates in low and middle-income countries. The authors found that motorcycle helmet usage rates showed a strong relationship with decreasing motorcycle fatality rates in low and low-middle income countries. The authors suggested that effective interventions (including increasing helmet usage) are urgently needed for improving motorcycle safety. Sheykhfard et al. (22-01484) examined four different signs near school zones in a high-risk outskirt area of Babol County in Iran to determine how effective they are at improving children's safety. As a result, all the signs reduced the speed of drivers. However, two signs were significantly effective compared to the other signs. In the next step, two signs with a higher impact were reinstalled for six months with a 3-month interval at two school zones. Agarwala & Vasudevan (22-02510) explored the role of high-speed roads and vehicle ownership on traffic fatalities in India. The results showed that increasing lengths of National Highways are associated with an improvement in traffic safety while increasing lengths of all other types of roads and total number of motor vehicles are both associated with a deterioration in traffic safety.

Two papers considered **injury severity** as a key subject. Hosseinzadeh et al. (22-01244) aims at evaluating the level of consistency in injury severity estimation among medical experts based on trauma registry data and identifying factors that contribute to misclassification of injury severity in crash reports. The results indicate that police officers tend to underestimate injuries associated with a high gore factor, increasing age, and the presence of an internal injury, specifically among trauma patients. Tanzen et al. (22-04476) proposed a method to improve highway safety project prioritization by incorporating crash severity. The method addresses crash severity and uses both empirical Bayes estimates and the excess expected crashes (EEC) metric.

Two papers investigated **effects of safety initiatives**. Hossen et al. (22-04109) studied effectiveness of Vision Zero initiatives on cyclists' safety in New York City. Locations within or near a bike priority area and along a signal retimed corridor increased cyclist injury severity by 2.1% and 1.85%, respectively, compared to cyclist crashes in locations without these Vision Zero initiatives. Cyclist crashes within 150 ft of a priority corridor, priority zone, and safe street for seniors decreased cyclist injury severity by 1.73%, 2.35%, and 2.6%, respectively, compared to cyclist crashes in locations without these Vision Zero initiatives. Shi et al. (22-04229) explored effects of safe system in Netherlands and Sweden. The authors show that since the adoption of safe system in the two countries, the risk of fatality has decreased at a rate far outpaced that in the United States, particularly for pedestrians and bicyclists.

Two papers focused on **economic assessments** or **crash costs**. Ampadu et al. (22-01341) estimated the average annual cost of crashes on Wyoming downgrades. The authors employed time series analysis and forecasting techniques to make 10-year predictions of the number of injuries, fatalities and property damages occurring on US-16 highway. The study estimated average annual cost of crashes with respect to the above-mentioned predictors is approximately $100,000,000. Claros et al. (22-01905) conducted safety and economic evaluation of the Highway Safety Improvement Program (HSIP). The results showed that a total of 64 HSIP projects were evaluated. B/C ratios greater than one were observed in 43 projects. For a 10-year horizon, the aggregated B/C ratio was 2.71. Alternatively, using the observed data during the study period of each project, the observed overall crash cost benefit was equal to $72 million which corresponds to a B/C ratio of 1.10.

Two papers explored **contributing factors to crashes**. Dowler & Stolle (22-01906) investigated contributing factors to traffic crashes on Kansas freeways. The study mainly focused on right-side road departures. Among a total 4,665 roadside departures, 15% also entered the median and 5% of roadside departures involved either fatality of incapacitating injury. Driver impairment and rear-end collisions were associated with the increased crash severity. Dong & Wood (22-02261) provided an analysis of factors that contribute to crash occurrence based on two national datasets in the US (CISS and NASS-CDS). Three taxonomies were applied in order to provide enhanced understanding of the various factors. These taxonomies were developed based on previous research and practice (e.g., human factors, vehicle factors, and roadway and environmental factors).

Two papers focused on **traffic safety improvement**. Cho et al. (22-00545) developed a systemic safety improvement plan for roadway departure crashes on two-lane rural roads in Virginia. The authors applied decision tree analysis to understand roadway characteristics that are correlated with roadway departure problems and listed up low-cost countermeasures. The countermeasures were intended to warn of curves ahead, delineate curves, and warn of lane/road departure. Anderson et al. (22-01227) proposed a framework for improving older pedestrian safety in regard to serious crashes, using Oregon as a case study. Three key systemic solutions were identified to improve older pedestrian safety, including improving pedestrian visibility and illumination, implementing treatments for left-turns, and shortening pedestrian crossing distances across the state.

Two papers analyzed **connected/automated vehicle** technology. Zong et al. (22-02476) demonstrated the application of UAVs and V2X connectivity to track the movement of road users and assess potential collisions at intersections. The proposed method combines deep-learning based tracking algorithms and time-to-collision tasks using data from UAVs. Sohrabi et al. (22-03367) proposed a framework to quantify the potential safety implications of automated vehicles in terms of preventable crashes and fatalities, accounting for some of the safety challenges of AV operation, including AV technologies' safety effectiveness, system failure risk, and the risk of disengagement from the automated system to manual driving. The results showed that automated vehicles could potentially prevent up to 50%, 46%, 23%, 6%, and 5% of crashes for automation Levels 5 to 1, respectively.

A single paper by Baig & Lee (22-00929) conducted a **scientometric analysis** to understand trends of traffic safety studies between 2010 and early 2021. The authors identified that logistic regression, psychological models, emergency health services, intelligent transportation systems (ITS), public policy, safety management systems, various transportation modes, and socioeconomic factors were the most important keywords used in the past decade for traffic safety-related research.

A single paper by Wu et al. (22-01180) developed a **proactive traffic safety management** and real-time Big Data visualization system. This paper introduced a web-based proactive traffic safety management and Real-time Big Data Visualization, which is based on an award-winning system that won the US Department of Transportation Solving for Safety Visualization Challenge and was selected as one of the USDOT Safety Data Initiative Beta Tools. State-of-the-art research, especially for real-time crash prediction. Based on the multi-sourced data, multiple modules have been developed, including real-time crash/secondary crash prediction, CCTV based expedited detection, proactive traffic safety management recommendation, data sharing, and report generation.

Authors	Steven Matheny, Western Kentucky University Ryan Love, Western Kentucky University Kirolos Haleem, Western Kentucky University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-00085
Paper Title	The Impact of COVID-19 Pandemic on Traffic Safety and Traffic Flow Patterns: A Case Study in the City of Bowling Green, Kentucky
Abstract	COVID-19 pandemic is a cutting-edge topic nowadays; however, to the authors' knowledge, there exist limited studies revolving around this topic, specifically ones that are "citywide". The study objectives are: (1) perform safety investigation of COVID-19 pandemic in the city of Bowling Green, Kentucky, (2) perform operational investigation of COVID-19 pandemic in the city in terms of annual average daily traffic (AADT) changes, and (3) propose recommendations for improving safety during future pandemics. The post-pandemic period covers the core shutdown time (i.e., March 6, 2020 through July 31, 2020). This period was compared to the previous five-year (2015-2019) average during the same period (March 6 through July 31). Operation-wise, AADT was reduced by 37% across the city's major corridors. Traffic flow drops were most prevalent in areas near the university and downtown, while less prevalent near larger commercial areas. Safety-wise, the overall injury crash rate across the city's 22 major corridors has increased by 66.17% during the pandemic (or absolute injury crash rate increase of 0.73 crashes per million vehicle miles traveled). Single-vehicle crashes experienced the highest crash type involvement post-pandemic (at 28.12%, as opposed to 17.95% pre-pandemic), due to aggressive driving and increased anxiety levels. "Traffic Control Disregard" and "Drug Involvement" were the main crash causes that saw significant increases in crash involvement during the pandemic. It is recommended to increase law enforcement presence on roadways and conduct driver education campaigns during the shutdown to help reduce reckless driving and driving under the influence of drugs and alcohol.

Authors	Hyun Cho, Virginia Transportation Research Council Benjamin Cottrell, Virginia Transportation Research Council In-Kyu Lim, Federal Highway Administration
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-00545
Paper Title	Systemic Safety Improvement Plan for Roadway Departure Crashes on Two-Lane Rural Roads in Virginia
Abstract	This study developed a systemic safety improvement plan for roadway departure crashes on two-lane rural roads using low-cost countermeasures. Segments that have the potential for safety improvement were selected using Virginia-specific roadway departure safety performance functions. Decision tree analysis was applied to perform a systemic classification of roadway characteristics that are correlated with roadway departure problems. A list of countermeasures to deploy to target specific segments and patterns was developed based on the literature and input from field staff. The countermeasures were intended to warn of curves ahead, delineate curves, and warn of lane/road departure. Before deployment, a study of the section by field district traffic engineering staff is planned in order to finalize the safety improvement plan. The output of the study will be a safety improvement plan to deploy treatments systemically to two-lane rural roads as part of Virginia Highway Safety Improvement Program.

Authors	Farrukh Baig, Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-00929
Paper Title	Trends of Traffic Safety Studies between 2010 and Early 2021: A Scientometric Analysis
Abstract	Scientometric studies are important to identify and understand the research trends and developments in a specific research domain. In support of the World Health Organization's proclaimed decade of action for road safety (2010-2020), this study aims to explore road safety research between 2010 and early 2021. Using a bibliometric analytical method with VOSviewer software, this study highlights the overall research status of road safety from the perspectives of country/region, institution, article co-citation, and keywords co-occurrence. Findings indicate a continuous increase in road safety research articles in recent years. By co-citation analysis, the leading authors and their peer network visualization were also included in this study. The most contributing institutes, countries, academic journals were highlighted for future studies on the relevant research domain. This study also included keywords co-occurrence analysis highlighting the most used methods and research trends relevant to traffic safety research in the past decade. Logistic regression, psychological models, emergency health services, intelligent transportation systems (ITS), public policy, safety management systems, various transportation modes, and socioeconomic factors were the most important keywords used in the past decade for traffic safety-related research. The study's findings are expected to be useful for road safety researchers to understand the research trends in the area.

Authors	Kazuyuki Neki, The World Bank Sudeshna Mitra, The World Bank William Wambulwa, The World Bank R. F. Job, Global Road Safety Solutions
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01072
Paper Title	Profile of Countries with Increases versus Decreases in Road Crash Fatality Population Rates in Low and Middle-Income Countries Focusing on Motorcycle Safety
Abstract	Road crash fatalities have increased significantly in Low- and Middle- Income Countries (LMICs) between 2006 and 2016. This study presents how road safety characteristics have changed in LMICs by comparing data over time and relationships between the road crash fatality increase and a wide range of data from 125 LMICs. Parametric and nonparametric methods are used to test significance. There were 7 countries including Latin America and Caribbean region, Sub-Saharan Africa region, and South Asia region where the population rate of road crash fatalities consistently increased as per country reports, World Health Organization estimates, and Global Burden of Disease estimates. In these countries, the proportion of motorcycles, including powered two or three wheelers, to registered vehicles and GDP per capita approximately doubled over the same time (statistically significant). In these countries, the helmet-wearing rate was at only 42% for drivers and 27% for passengers. These patterns were not observed in LMICs with decreasing population fatality rates. Motorcycle helmet usage rates showed a strong relationship with decreasing fatality rates per 10,000 motorcycles in low and low-middle income countries. Effective interventions (including increasing helmet usage) are urgently needed for motorcycle crash trauma in LMICs, especially where the economy and motorization rapidly grow. National strategies for motorcycle safety, conforming to the Safe System principles, are recommended. For evidence-based policy formulation, there is a need to continue to strengthen the collection, sharing, and use of data.

Authors	Miguel Figliozzi, Portland State University Jaclyn Schaefer, Portland State University Avinash Unnikrishnan, Portland State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1162
Session Title	Translating Safety Research to Real-World Solutions
Paper Number	22-01087
Paper Title	Evaluation of Posted Speed Limits Reductions on Urban Roads with a High Percentage of Cyclists
Abstract	This paper presents a before and after analysis of the impact of posted speed limit (PSL) changes on passenger car (FHWA class two vehicles) speeds in Portland, OR. The study focuses on urban roads, comparing sites that underwent a PSL 5-mph reduction (treatment sites) and sites where the PSL did not change (control sites). Sites with a high percentage of and priority for cyclists (neighborhood greenways) and sites with a more standard traffic composition were compared. Differences in speed characteristics such as mean and 85 th percentile speeds, the speed variance, and the proportion of vehicles exceeding a speed threshold (relative to the posted speed limit) were evaluated on aggregate and individual scales. A series of statistical hypothesis tests were employed to assess changes in the speed characteristics among individual dataset pairs. The results suggest distinct differences between the treatment and control groups and neighborhood greenway and non-neighborhood greenway sites. Although there is a high degree of variability, the treatment group experienced more decreases in the speed characteristics, and by a greater amount than the control group, on average. Within the treatment group, sites with a priority for cyclists were even more likely to experience a larger reduction in operating speeds.

Authors	Mohamed Abdel-Aty, University of Central Florida Yina Wu, University of Central Florida Ou Zheng, University of Central Florida Pei Li, University of Michigan Amr Abdelraouf, University of Central Florida Heesub Rim, University of Central Florida Jinghui Yuan, Oak Ridge National Laboratory Yaobang Gong, University of Utah Jaeyoung Lee, Central South University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01180
Paper Title	Proactive Traffic Safety Management and Real-time Big Data Visualization System
Abstract	Big data and data-driven analysis could be utilized for traffic management to improve road safety and the performance of transportation systems. This paper introduces a web-based Proactive Traffic Safety Management (PATM) and Real-time Big Data Visualization, which is based on an award-winning system that won the US Department of Transportation (USDOT) Solving for Safety Visualization Challenge and was selected as one of the USDOT Safety Data Initiative (SDI) Beta Tools. State-of-the-art research, especially for real-time crash prediction and PATM, are deployed in this study. A significant amount of real-time data is accessed by the system in order to conduct the data-driven analysis, such as traffic data, weather data, and video data from closed-circuit television (CCTV) live streams. Based on the data, multiple modules have been developed, including real-time crash/secondary crash prediction, CCTV based expedited detection, PATM recommendation, data sharing, and report generation. Both real-time data and the system outputs are visualized at the frontend using interactive maps and various types of figures to represent the data distribution and efficiently reveal hidden patterns. Evaluation of the real-time crash prediction outputs is conducted based on one-month real-world crash data and the prediction results from the system. The comparison results indicate excellent prediction performance. When considering spatial-temporal tolerance, the sensitivity and false alarm rate of the prediction results (i.e., High Crash Potential Event (HCPE)) are 0.980 and 0.217, respectively.

Authors	Jason Anderson, Portland State University Sirisha Kothuri, Portland State University Christopher Monsere, Portland State University David Hurwitz, Oregon State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1162
Session Title	Translating Safety Research to Real-World Solutions
Paper Number	22-01227
Paper Title	Systemic Opportunities to Improve Older Pedestrian Safety: Merging Crash Data Analysis and a Stakeholder Workshop
Abstract	This paper presents a framework for improving older pedestrian safety in regards to serious (fatal and incapacitating) crashes, using Oregon as a case study. Upon review of state and federal practices pertaining to older pedestrian safety, four years of crash data identified 112 older (≥ 65 years) pedestrian serious injury crashes. These data were explored for factors that might be addressed systemically using two methods. First, raw frequencies in the crash data were assessed to determine trends and crash-related factors that are overrepresented. Second, a random forest analysis is conducted to determine important variables for predicting older pedestrian serious injury crashes. Using these crash-related factors, a workshop was held with 18 local stakeholders and experts. As part of the workshop, key crash trends, potential causations, and potential countermeasures by priority of implementation were determined based on perspectives from workshop participants. Three key systemic solutions were identified to improve older pedestrian safety, including improving pedestrian visibility and illumination, implementing treatments for left-turns, and shortening pedestrian crossing distances across the state. The framework presented in the current study can be adopted by other agencies to systemically address a wide variety of safety concerns.

Authors	Aryan Hosseinzadeh, University of Louisville Aaron Kuzel, University of Louisville Robert Kluger, University of Louisville Raymond Orthober, University of Louisville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01244
Paper Title	Injury Severity Misclassification: Police Officers vs. Emergency Physicians Evaluation, What Drives the Difference?
Abstract	Inaccurate crash injury severity identification is a critical issue that may result in missed injuries in the field, incorrect estimation of crash-related parameters in models that rely on the data and insufficient safety policies that waste road safety investments. Therefore, identifying the factors that lead to misclassification, is crucial to improving the quality of the data. Objectives of this study are: (1) evaluating the level of consistency in injury severity estimation among medical experts based on trauma registry data, (2) identifying factors that contribute to misclassification of injury severity in crash reports. The discrepancy between police-reported injury severities and physicians' evaluations of corresponding trauma records was modeled. The trauma data was reviewed and classified by a panel of emergency physicians. Analysis of Variance was applied to model variation within the panel. An ordered probit model was used to model factors that contribute to misclassification between police reports and emergency physicians. According to the results, age, internal injury, and a proposed field - gore factor, meant to describe the visibility of injuries were found to be contributing factors to injury severity discrepancy. Internal injury and gore factor were among the trauma-related factors that were developed to explore their impact on injury severity discrepancy. Results shows inconsistency in physicians' injury severity evaluation based on injuries' detailed information. Findings indicate officers tended to underestimate injuries associated with a high gore factor, increasing age and the presence of an internal injury, specifically among trauma patients.

Authors	Vincent Ampadu, UW: University of Wyoming Shaun Wulff, University of Wyoming Khaled Ksaibati, University of Wyoming
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01341
Paper Title	Estimating the Average Annual Cost of Crashes on Wyoming Downgrades using Time Series Analysis and Forecasting
Abstract	The proportion of government funding allocated to state transportation budgets has significantly declined as a result of US policies trying to address the coronavirus pandemic. This has necessitated a more disciplined and efficient allocation of funds for various infrastructure development and rehabilitation projects. Economic assessments which include annual crash costs are usually estimated at the national level to inform resource allocation. These resources can then be used to implement measures to mitigate these crashes and the associated costs as well as to develop new technologies for continued improvement of road safety. This study employs time series analysis and forecasting techniques to make 10-year predictions of the number of injuries, fatalities and property damages occurring on US-16 highway based on historical data extracted from the Wyoming Department of Transportation database. The study determined that the estimated average annual cost of crashes with respect to the above-mentioned predictors is approximately $100,000,000. This result can be used to inform the Wyoming Department of Transportation on approximately how many dollars will be lost annually on US-16 with regards to these major crash outcomes to enable better planning and management of its infrastructure development funds.

Authors	Abbas Sheykhfard, Delft University of Technology Farshidreza Haghighi, Babol Noshirvani University of Technology Sarah Bakhtiari, Massachusetts Department of Transportation Amir Ramak
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01484
Paper Title	Improving Traffic Safety near Schools in Outskirts Areas through Internet of Thing (IoT): a Case Study in Iran
Abstract	Speeding is one of the most significant contributing factors to road crashes in the outskirt areas. However, there are not enough studies on pedestrian safety on roads in outskirt areas. The purpose of this study is to examine four different signs near school zones in a high-risk outskirt area of Babol County in Iran to determine how effective they are at improving children's safety. Therefore, this study was conducted near primary schools on the main road in outskirt areas. IoT technology was used to develop an experimental system that records and collects the speed of vehicles. Collecting data was performed in two different steps. In the first step, the effectiveness of four signs was investigated in a 30-day study. As a result, all the signs reduced the speed of drivers. However, two signs were significantly effective compared to the other signs. In the next step, two signs with a higher impact were reinstalled for six months with a 3-month interval at two school zones. The results demonstrated that sign #4 improved safety with a 95% confidence; however, sign #2 was not always effective. The impact of sign #2 reduced over time. In addition, during the experiment, the vehicles' speed did not change in a control section upstream, which shows signs impacted reducing the speed. In addition, drivers reduced the speed when they approached the signs and then increased in zones located away from the signs. The two signs with the most significant influence provided more information to drivers.

Authors	Boris Claros, University of Wisconsin, Madison Erynn Schroeder, University of Wisconsin, Madison Kentin Brummett, University of Wisconsin, Madison Madhav Chitturi, University of Wisconsin, Madison Andrea Bill, University of Wisconsin, Madison David Noyce, University of Wisconsin-Madison
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01905
Paper Title	Safety and Economic Evaluation of the Highway Safety Improvement Program (HSIP): Is There a Return on Investment?
Abstract	The Highway Safety Improvement Program (HSIP) is a Federal-aid program aimed at achieving a significant reduction in traffic fatalities and serious injuries on all public roads. Projects are selected based on the potential reduction of severe crashes and the greatest return on investment. In this paper, a step-by-step process and methodology were developed to evaluate Wisconsin HSIP projects implemented between 2013 and 2019. Safety effectiveness evaluation and economic assessment were conducted at the site specific and project level using the Empirical Bayes (EB) method. Crash cost benefit of implemented projects was quantified to find the benefit-cost (B/C) for a horizon of 10 years and observed period of analysis. With data available from project evaluations, Crash Modification Factors (CMF) for common treatments were developed. A total of 64 HSIP projects were evaluated. B/C ratios greater than one were observed in 43 projects. For a 10-year horizon, the aggregated B/C ratio was 2.71. Alternatively, using the observed data during the study period of each project, the observed overall crash cost benefit was equal to $72 million which corresponds to a B/C ratio of 1.10 (benefit already surpassed project costs at three to five years). Approximately 536 crashes were prevented which translates to seven lives saved, 379 injuries prevented, and avoided 1,067 property damage losses.

Authors	Nathan Dowler, University of Nebraska, Lincoln Cody Stolle, University of Nebraska, Lincoln
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-01906
Paper Title	Contributing Factors to Crashes on Kansas Freeways
Abstract	Roadside safety treatments are financial investments intended to provide the greatest safety benefit for the cost of the treatment. The Kansas Department of Transportation (KDOT) funded a three-phase research study to investigate the in-service performance of its cable barriers, determine warrants for additional barrier installation, and evaluate factors contributing to right-side (roadside) departures. This paper discusses the roadside departure database. Contributing factors were tabulated and their relationship with environmental conditions, traffic volumes, roadway geometry, and driver influences were examined. A total of 4,665 roadside departures were identified from 2014 to 2018, including 695 crashes (14.9 percent) which also entered the median. Approximately 4.8 percent of roadside departures involved either a fatality or debilitating injury; driver impairment and rear-end collisions were associated with increased crash severity. Rear-end collisions negatively correlated with increasing traffic volume while every other contributing factor positively correlated. Implementing a Safe Systems approach, which encompasses both crash mitigation and prevention, could lead to more safety benefits than solely shielding potential hazards. Fixed-object crashes were reviewed, and bridge pier impacts were disproportionately severe. Nine out of 49 bridge pier crashes involved at least one fatality (18.4 percent) compared to 24 fatalities in 3,199 impacts with other fixed objects (0.8 percent). Lateral offsets were measured for each bridge pier using photogrammetric techniques, and ten of the eleven bridge piers involved in severe crashes were estimated to be within the clear zone. As a result, the benefit-to-cost for bridge pier shielding should be considered in accordance with proximity to the roadway.

Authors	Ye Dong, Iowa State University Jonathan Wood, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-02261
Paper Title	Evaluation of Crash Contributing Factors
Abstract	Understanding of crash contributing factors is essential in safety management and improvement. These factors drive decisions on investments, policy, regulations, and other safety improvement activities. This paper provides an analysis of factors that contribute to crash occurrence based on two national datasets in the US (CISS and NASS-CDS) the years 2017-2019 and 2010-2015, respectively. Three taxonomies were applied in order to provide enhanced understanding of the various factors. These taxonomies were developed based on previous research and practice (e.g., human factors, vehicle factors, and roadway and environmental factors). Statistics for groupings of factor types are provided. Additionally, statistics for specific factors are provided.

Authors	Nada Mahmoud, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Qing Cai, Waymo
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1073
Session Title	The Role of Speed in a Safe System
Paper Number	22-02362
Paper Title	Analyzing the Difference Between Operating Speed and Target Speed Using Mixed-Effect Ordered Logit Model
Abstract	Desired operating speed (target speed) plays an important role in enhancing traffic operations and providing safe mobility to road users. Understanding the difference between vehicles' operating speed and target speed on arterial roads is important for achieving safer speed that is consistent with the activity generated in the context classified roadways. Hence, a mixed effect ordered logit model was proposed to examine the significant exogenous factors that affect the difference between the two speeds. To the best of the authors' knowledge, no existing research has adopted the concept of target speed. Three years of INRIX speed data and exogenous variables including traffic and roadway characteristics, land use attributes, and socio-demographic information were utilized in the models. The data included information for around 1600 roadway segments in Central Florida. The results concluded that 16 variables were significantly associated with the difference between target speed and operating speed including speed limit, volume exposure, shoulder width information, sidewalk and shared path proportions, block length, number of signals, pavement conditions, residential and mixed land use, population density, and percentage of poverty. The results also indicated the effect of different time periods on the response variable. Hence, it recommended different posted speed limits based on the time of day. Further, the study suggested the roadway measures that should be followed in order to achieve the desired target speed.

Authors	Shuya Zong, Purdue University Sikai Chen, Purdue University Majed Alinizzi, Purdue University Yujie Li, Purdue University Samuel Labi, Purdue University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-02476
Paper Title	Using UAVs for vehicle tracking and collision risk assessment at intersections
Abstract	Assessing collision risk is a critical challenge to effective traffic safety management. The deployment of unmanned aerial vehicles (UAVs) to address this issue has shown much promise, given their wide visual field and movement flexibility. This research demonstrates the application of UAVs and V2X connectivity to track the movement of road users and assess potential collisions at intersections. The study uses videos captured by UAVs. The proposed method combines deep-learning based tracking algorithms and time-to-collision tasks. The results not only provide beneficial information for vehicle's recognition of potential crashes and motion planning but also provided a valuable tool for urban road agencies and safety management engineers.

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	1219
Session Title	Safety Management Systems
Paper Number	22-02510
Paper Title	The Role of High-speed Roads and Vehicle Ownership on Traffic Fatalities in India
Abstract	The development of higher quality road infrastructure in developing countries improves ride quality but also enables greater driving speeds. Similarly, a growing middle class allows more people to afford personal vehicles but increases the number of drivers on the road. The improved mobility has historically been associated with economic growth, and its impact on traffic safety has been explored in high-income countries. However, the behavior of road users and vehicle ownership characteristics in middle-income countries are substantively different than those in high-income countries. This study explores the relationship between mobility and traffic safety at a region-wide level in India, a middle-income country. The results show that increasing lengths of National Highways are associated with an improvement in traffic safety while increasing lengths of all other types of roads and total number of motor vehicles are both associated with a deterioration in traffic safety. This study shows that safe roadway infrastructure has a huge role in enhancing overall safety even in countries with high vehicle heterogeneity, lack of driver education, and weak enforcement. This study's contribution should guide decision-makers in other middle-income countries to invest in traffic safety measures alongside any investments in higherquality road infrastructure.

Authors	Zhicheng Dai, Tongji University Xuesong Wang, Tongji University Xiaohan Yang, Tongji University Pingfan Li, China Ministry of Public Security
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-02558
Paper Title	Macro-level Safety Model Updating: Application of Boosting Techniques
Abstract	With the rapid changes in city traffic safety, there is a need to update macro safety models to predict crashes accurately at various times. Two main challenges: the homogeneous datasets and effective data collection for timely updating, have hindered researchers' ability to update the models, however. This study applied boosting techniques, which are well adapted to the conditions of data heterogeneity and small sample size, to macro safety model updating. To this end, crashes and regional characteristics were collected in 2009 and 2016 for Shanghai, China, as the source and target data domains, respectively. Four boosting-based updating models, AdaBoost.R2, two-stage TrAdaBoost.R2, Gradient Boosting, and CatBoost (an abbreviation for categorical boosting), along with a traditional two-stage Bayesian updating model, were established to evaluate and compare crash-prediction performance by Root Mean Square Error. The results showed that the CatBoost algorithm, with its ability to cope with heterogeneous datasets and categorical features, outperformed all the other methods. A further investigation into the optimal target sample size analysis was conducted. The three advanced boosting algorithms tended to have similar results around the proportion of 40% of target data (105 TAZs) in the training dataset. The two-stage TrAdaBoost.R2 and CatBoost tended to outperform other methods in the near-full sample size and small target sample size, respectively. Thus, the CatBoost algorithm model with 40% target data is recommended for macro safety model updating. These findings can be applied to the practice of long-term timely traffic safety monitoring and data collection optimization.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-02875
Paper Title	Regional Traffic Safety Assessment Considering Crashes and Violations: Safety Risk Level and Influencing Factors
Abstract	Regional traffic safety poses a public concern for many metropolitan areas, making it urgent to adopt safety assessment and analysis methods that can effectively coordinate the different needs of a city's districts. For example, safety performance in urban and suburban areas shows great disparity, making it unreasonable to assess the safety risk level of the two areas under the same criteria. Existing studies mainly use crash frequency or crash rate as indicators, but overlook that traffic violations can also measure regional traffic safety. To address these gaps, this study selected Suzhou, a rapidly developing Chinese city, for investigation. Socio-economic, roadway, land use, and police enforcement information of 115 districts in Suzhou were collected as independent variables. A composite assessment indicator was proposed considering crash rate, injury severity, violation rate, and area type. The 53 urban and 62 suburban districts were separately classified into three risk levels. Two random-effects two-level logit models (high-risk vs. moderate/low-risk, and moderate-risk vs. low-risk) were developed to capture the common influences of area types and various districts' individual characteristics on regional risk level. Results showed that (1) population density and GDP per capita play important roles in distinguishing high-risk and moderate/low-risk towns; (2) higher road and intersection density, and higher percentage of collector roads, were associated with higher risk levels. It was also demonstrated that the number of traffic police and patrol time in moderate-risk districts can be reasonably reduced to avoid wasting police resources. The proposed method shows promise for regional risk identification and improvement.

Authors	Xuesong Wang, Tongji University Abrha Asmelash, Tongji University Zaier Zaidi, NHA Pakistan Bowen Cai, Tongji University Xiaohan Yang, Tongji University George Yannis, National Technical University of Athens (NTUA)
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-03030
Paper Title	Traffic Fatality Trends of Seven Developed Countries since 1970 – Assessment, Analysis, and Forecast
Abstract	ABSTRACT In February 2020, the "Stockholm Declaration" was announced, urging states toward 50% reduction in deaths and injuries over the next decade, leading to Vision Zero by 2050. The aim of this research is to understand how road traffic fatality patterns vary across selected developed countries and to see if they are on track to achieve the United Nation's 2030 target. After identifying potential reasons behind the patterns, time - series model was used to identify the effect of exposure variables on traffic fatalities. To assess the likelihood of meeting the U.N. target, an ARIMA model was used for obtaining trustworthy forecasts of road traffic fatalities using data from the last five decades from seven high-income countries. Total number of fatalities, vehicle-km travelled, vehicle ownership, GDP, GDP per capita, urbanization, population density and population were used to develop the ARIMA model using R-software. The forecasted performance of the models was validated for each country, which and was found to be within the 95% confidence interval. Estimated forecasts in all seven countries appear to be realistic, but, except for Japan and the U.S., fall short to achieve the U.N.'s 2030 target. Considering these results, countries may review the effects of safety interventions or other socioeconomic influences. Further interventions may be added to the existing model and to ascertain their effect of predicted fatality numbers.

Authors	Jintai Li, Massachusetts Institute of Technology Zhan Zhao, University of Hong Kong
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-02915
Paper Title	Impact of COVID-19 travel-restriction policies on road traffic accident patterns with emphasis on cyclists: A case study of New York City
Abstract	Since the first COVID-19 outbreak, travel-restriction policies widely adopted by cities across the world played a profound role in reshaping urban travel patterns. One important aspect of this shift is road traffic accidents. In this paper, by analysing the accidents data in the New York City and estimating three fixed effects logit models on whether types of accidents happen in a zip code in a certain time interval, we derived the following findings. First, while the overall number of road traffic accidents plummeted in the NYC after the stay-at-home policy was implemented, the average severity increased. The average number of cyclists killed or injured per accidents more than tripled relative to levels in similar times in previous years. Second, the declaration of the New York state stay-at-home order was significantly associated with a higher risk of accidents resulting in casualties. The number of Citi Bike trips in the area at the time overwhelmingly predicted severe risk for cyclists. Last, we applied the models to detect hot zones for cyclists' severe accidents. We found that these hot zones tend to be spatially and temporally concentrated, making it possible to target safety measures. This paper reveals higher risk for cyclists as an unintended consequence of travel-restriction policies, and provides a tool for evaluating impact on road safety should future travel restrictions be considered.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1073
Session Title	The Role of Speed in a Safe System
Paper Number	22-02957
Paper Title	Potential Reductions in Road Fatalities and Injuries from Reducing Speed Limits to Recommended Safe System Speed Limits in Low- and Middle-Income Countries
Abstract	Guidelines for setting speed limits can be derived from the safe system principles which aim to eliminate deaths and serious injuries. This paper analyzes the potential road safety benefits of reducing current unsafe speed limits in low- and middle- income countries (LMICs) to recommended safe system speeds (i.e. 30kph for urban roads, 70kph for rural roads and 90kph for motorways) based on Nilsson's power model and estimates the economic benefits of reduced fatalities and serious injuries based on the iRAP methodology. The results indicate significantly high reductions in all road trauma with fatal crashes reducing by 4% to 44% depending on the road environment and region. Urban roads have the highest benefits owing to the greatest proportional drop in speed limits. A regional analysis indicates that South Asia region has the greatest potential reductions for all types of crashes and injuries on rural and urban roads, while Europe and Central Asia region has the greatest potential reductions on motorways. A total of US$ 91 billion or 0.37% of GDP in LMICs is estimated to be saved from the reduction in fatalities and serious injuries, with Africa region having the highest economic benefit relative to its GDP (0.47% of GDP). In practice, it is recommended that the reduction in speed limits be accompanied by effective sustainable speed management measures including suitable engineering treatments, automated speed enforcement, police enforcement and vehicle technologies such as speed limiters to ensure drivers' compliance and achieve profound road safety benefits.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-03145
Paper Title	Identifying the Impacts of COVID-19 Pandemic on Crashes in Texas Based on a Convolutional Neural Network Algorithm
Abstract	The unprecedented COVID-19 pandemic has become one of the most challenging global problems. This unforeseen pandemic has created a new culture of online or web-based solutions, though the world still logistically and largely relies on the movement of vehicles. Crashes are still causing severe injuries during the pandemic, and the correlation between the COVID-19 cases and crashes is significantly higher. This paper presents an innovative way to explore the impact of COVID-19 pandemic on the basis of crashes that happened during the tenure. To determine the relativity and impacts of COVID-19 cases over the number of crashes, the convolutional neural network (CNN) algorithm is identified, which has been widely considered as one of the complex problem-solving algorithms in many research domains such as image processing, natural language processing, and data science. The pandemic data as well as the traffic related data are aligned to fed into the CNN model, while the outputs are the severity levels of crashes, namely suspected serious injury (SSI), suspected minor injury (SMI), possible injury (PI), fatal injury (FI), not injured (NI), and unknown (Un). The training and validation losses of the CNN model are quite low, and a set of traditional performance metrics are employed to evaluate the identified model, such as recall, precision, F-score, accuracy, and root mean square error (RMSE). Besides, the correlations between the attributes of the model as well as the confusion matrix are presented, which illustrates a satisfied prediction of crash severity levels.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-03367
Paper Title	Safety and Equity Impacts of Automated Vehicles: A Quantification Framework and Empirical Analysis
Abstract	Automated Vehicles (AVs) have the potential to improve traffic safety by preventing crashes, but the extent of the impact is unknown, given the limitations in AV road test. Moreover, the safety implications of AVs can vary across communities with different socioeconomic and demographic characteristics. In this study, we proposed a framework to quantify the potential safety implications of AVs in terms of preventable crashes and fatalities, accounting for some of the safety challenges of AV operation, including AV technologies' safety effectiveness, system failure risk, and the risk of disengagement from the automated system to manual driving. We further defined an empirical study to examine the proposed framework and investigate inequity in AV potential safety implications. The empirical analysis was conducted using 2017 crash data from the Dallas-Fort Worth, Texas, United States area. The results showed that AVs could potentially prevent up to 50%, 46%, 23%, 6%, and 5% of crashes for automation Levels 5 to 1, respectively. Among advanced driver assistance systems, pedestrian detection, electronic stability control, and lane departure warning showed more significant potential in reducing fatal crashes. We found a U-shaped relationship between the AV-preventable fatalities and household median income and ethnically diverse communities. The findings of this study suggest that low-income and ethnically diverse communities can benefit from AV implementation. The policy recommendations of this research suggest that city and state planning and transportation agencies may consider implementing policies and strategies for making AVs available to low-income and ethnically diverse communities at a lower cost.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-03406
Paper Title	Examining Hot Spots of Crashes Involving Vulnerable Aging Road Users and their Spatial Relationship with the Built Environment
Abstract	Traffic safety is a serious concern, especially among the aging population. When involved in traffic crashes, aging pedestrians and bicyclists tend to be more vulnerable compared to other age groups. This study examines crashes involving aging non-motorists in urban and rural counties in Florida at a macroscopic level. An optimized hot spot analysis was conducted to identify the clusters with a high concentration of crashes involving aging non-motorists. Further, the spatial relationship between crashes involving aging non-motorists and the built environment was investigated using geographically weighted regression (GWR). The results indicated that hot spots of crashes involving aging non-motorists were clustered in areas with a higher total population density and a higher proportion of the aging population. Spatial analysis results showed that clusters with more crashes involving aging non-motorists were associated with a higher population density, a higher proportion of the aging population, and a higher density of bus stops. Findings from this study provide essential guidance for transportation agencies in implementing aging-focused crash mitigation strategies, including education and outreach efforts that focus on improving the safety and mobility of the aging population.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-03769
Paper Title	How did Transportation Fatalities, Total Crashes, and Crash Harm change during the COVID-19 pandemic? Evidence of Traffic Safety from Tennessee
Abstract	Major concerns have been raised about road safety during the COVID-19 pandemic in the US, as the crash fatalities have increased, despite the substantial reduction in traffic. However, a comprehensive analysis of safety-critical events on roadways based on a broader set of traffic safety metrics and their correlates is needed. In addition to fatalities, this study uses changes in total crashes and total monetary harm as additional measures of safety. A comprehensive and unique time-series database of crashes and socio-economic variables is created at the county level in Tennessee. Results show that while fatal crashes increase by 8.2%, total crashes decrease by 13% and the total harm cost is lower by about $1.38 billion during COVID-19 (2020) compared with pre-COVID-19 conditions (2019). Time-series Feasible Generalized Linear Models using first differences are estimated to rigorously quantify correlates of fatalities, crashes, and crash harm. The results indicate that compared to the pre-COVID-19 periods, fatal crashes that occur during the pandemic involved more speeding and more reckless behaviors. Fatal crashes are more likely to happen on interstates and dark-not-lighted roads and involve commercial trucks. These same factors largely contribute to crash harm. As expected, a greater number of trips per person not staying home during COVID-19 is associated with higher crashes, fatalities, and crash harm at the county level. These results can inform policymaking to strengthen traffic law enforcement through appropriate countermeasures, such as the placement of warning signs and the reduction of the speed limit in hotspots.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-03847
Paper Title	COVID-19 Policies and Road Safety: The Case of Nairobi
Abstract	We examine how policies implemented to control the spread of COVID-19--such as curfews and other mobility restrictions--affect road traffic crashes and their severity. We combine unique data on emergency response and severity of crash injuries from Flare, a first response dispatcher and aggregator in Kenya, with crowdsourced data on road traffic crashes from Twitter and mobility data (traffic, congestion and speed) from Google and Waze for the city of Nairobi. Preliminary results indicate that (1) the total number of crashes decreased in the weeks after the closing of schools and bars and the introduction of other policies in line with decreases in mobility, though the percent decrease in crashes is smaller than the decrease in mobility; (2) after a curfew was implemented, crashes and injuries are redistributed around the curfew's starting time; (3) the decrease in crashes is short-lived, with crashes reverting to the pre-policy levels after several weeks. The concentration of crashes around certain times and locations following the introduction of the COVID-19 policies indicates potential policy levers to decrease adverse externalities of these policies on road safety when such policies need to be implemented in the future.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1073
Session Title	The Role of Speed in a Safe System
Paper Number	22-04109
Paper Title	Effectiveness of Vision Zero Initiatives on Cyclists' Safety in New York City
Abstract	In New York City (NYC), safety initiatives under the Vision Zero (VZ) action plan have successfully reduced pedestrian and motorist-involved crashes. However, cyclist-involved crashes have increased since the beginning of VZ initiatives in 2014. This study investigated the significant factors affecting cyclist-involved crash severity in NYC, including VZ initiatives by developing a Ordered Logistic Regression (OLR) model. Model results showed that crash locations, time of day, time of the year/season, driver-related factors, roadway factors, cyclist's error, and five VZ initiatives (i.e., bike priority area, priority corridor, priority zone or area, safe street for seniors, and signal retiming) were significantly associated with cyclist injury severity. Locations within or near a bike priority area and along a signal retimed corridor increased cyclist injury severity by 2.1% and 1.85%, respectively, compared to cyclist crashes in locations without these VZ initiatives. Cyclist crashes within 150 ft of a priority corridor, priority zone, and safe street for seniors decreased cyclist injury severity by 1.73%, 2.35%, and 2.6%, respectively, compared to cyclist crashes in locations without these VZ initiatives. In addition to safety improvement projects, safe streets for seniors and educational outreach to senior centers initiatices effectively reduced cyclist crash severity. Based on the findings of this study, NYC VZ program could emphasize implementation of priority corridor, priority zone or area, and safe street for seniors which wer found to be effective in improving cyclist safety.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1162
Session Title	Translating Safety Research to Real-World Solutions
Paper Number	22-04229
Paper Title	Moving Beyond the Vision Zero Slogan: The Principles of Safe System for Traffic Safety
Abstract	Safe system is a holistic way of managing traffic safety based on the underlying philosophy that road users'behavior is more dependent on the integral road system, rather than on individual ability and choice. The goal is to achieve zero road death by ensuring that the road environment is designed for prioritizing the physical tolerance of human body over the need for efficient movement of vehicles. Safe system was pioneered in the Netherlands and in Sweden in the 1990s and after 20 years, started to influence traffic safety management in other countries, including the U.S. However, there is need for a broader dissemination, understanding, and eventually, adoption of the underlying principles of sustainable safety. Our research shows that since the adoption of safe safety in the Netherlands and in Sweden, the risk of fatality has decreased at a rate far outpaced that in the U.S. The improvements have been particularly impressive when it comes to pedestrian and bicyclists who now has fatality risks that is as low as that of people in cars. In contrast, in U.S., the chance of a traffic fatality for a pedestrian is more than twice that for a person in a car. Given the spike in pedestrian fatality in the U.S. over the last decade there is a need to refocus on improving safety for pedestrians. Our paper outlines details of the Dutch and Swedish approach to safe system that is associated with their tremendous success in reducing traffic fatality – particularly for pedestrians and bicyclists.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-04476
Paper Title	Incorporating Crash Severity to Improve Highway Safety Project Prioritization
Abstract	Released in 2010, the Highway Safety Manual (HSM) provides procedures for evaluating highway safety improvements and prioritizing potential projects. Adopting the HSM guidelines, several states in the US use Excess Expected Crashes (EEC), a parameter dependent on Safety Performance Functions to rank safety projects. However, this method is limited by several methodological disadvantages (e.g., the severity of the observed crashes and the magnitude of the projected crashes by Empirical Bayes method are not considered). This paper describes a new safety scoring method developed for the Kentucky Transportation Cabinet (KYTC) for use in it's Strategic Highway Investment Formula for Tomorrow (SHIFT) project prioritization process. The method addresses crash severity and uses both EB estimates and the EEC metric. Additionally, it introduces a "goal-driven" EEC which represents the potential for reaching targets specified in the State's Strategic Highway Safety Plan and which may be customized for state's use. To demonstrate the use of the methodology, the analysis was performed on KYTC's list of potential projects for the 2020 SHIFT cycle.

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Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	1219
Session Title	Safety Management Systems
Paper Number	22-04687
Paper Title	An Investigation into the Impact of Speeding on Traffic Safety Outcomes during COVID-19 Pandemic Unexpected Trends in Large U.S. Cities
Abstract	As many governments around the world imposed mobility restrictions in order to reduce the spread of COVID pandemic and prevent potential deaths, a considerable reduction in daily traffic also resulted in reduced roadway crashes on roads in all around the world compared to previous years. However, the statistics show that this was not the case in the U.S. and in particular in large urban areas and when measured as fatalities with regards to the total miles driven. This paper aims to investigate the impacts of travel restrictions on traffic safety in selected ten large U.S. cities. We investigated fatalities, injuries and crash severity trends in 2020 and made a comparison with 2018 and 2019. The results show that the fatality number increased in most areas of study. While the national traffic death toll increased by 17% in 2020 compared to 2019, our findings illustrated that the trend was not identical across different areas, and cities showed dramatically different outcomes in terms of traffic safety measures. The highest fatality increases were observed in Philadelphia (69%) and in Chicago (40%). In addition, our results illustrate that the injury numbers were reduced in all studied cities. However, the severity index rose between 23%-71% in the study areas. The study also found that the severity index for pedestrians reached its highest level compared to the other types of users. Our findings suggest that speeding was a significant contributing factor in the increased traffic fatality numbers amid the Pandemic.