TRB Standing Committees

ACS10 – Transportation Safety Management Systems

ACS20 – Safety Performance Analysis

Synthesis Report on Safety-Related Papers

presented at the 103rd TRB Annual Meeting

Prepared by

Alfonso Montella, Mohamed Abdel-Aty, Vamsi Krishna Bandaru, Mohamad Banihashemi, Stefano Coropulis, Joy Davis, Nicholas Fiorentini, Simone Fucito, Francesco Galante, Frank Gross, Md Rakibul Islam, Jaeyoung Lee, Filomena Mauriello, Massimo Losa, Anurag Pande, Vittorio Ranieri, Maria Rella Riccardi, Heesub Rim, Mario Romero, Antonella Scarano, Jiayu Yang, and Samgyu Yang

ACS10 – Standing Committee on Transportation Safety Management Systems

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

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

Membership as of November 2023

Chair

Stephanie Malinoff, University of Minnesota, Twin Cities

TRB Staff Representatives

Bernardo Kleiner, Mary Kissi, Freda Morgan

Secretary

Scott Davis, Washington State Department of Transportation

Committee Communications Coordinator

Wendy Hansen, Penna Powers

Committee Research Coordinator

Brendan Russo, Northern Arizona University

Members

Hillel Bar-Gera, Ben Gurion University of the Negev
Kathryn Belt, Virginia Polytechnic Institute
James Bradford, International Road Assessment Program
Rachel Carpenter, California Department of Transportation
Alicia Chavez, National Study Center for Trauma & EMS
Joy Davis, Institute for Transportation Research and Education
Mark Doctor, Federal Highway Administration (FHWA)
Nathan George, Palm Beach TPA
Offer Grembek, University of California, Berkeley
Frank Gross, VHB
Michael Hanson, Minnesota Department of Public Safety
Kelly Hardy, American Association of State Highway and Transportation Officials
Margaret Herrera, Maricopa Association of Governments
William Horrey, AAA Foundation for Traffic Safety
Seth LaJeunesse, University of North Carolina
Steven Lavrenz, Wayne State University
Jaeyoung Lee, Central South University
Dahianna Lopez, University of Rhode Island
Daniel Magri, Buchart Horn, Inc.
Joseph Marek, Clackamas County
Jennifer Oxley, Monash University
Raul Pineda-Mendez, Kimley-Horn and Associates, Inc.
Bonnie Polin, Massachusetts Department of Transportation
Maria Rella Riccardi, University of Naples Federico II
Kendra Schenk, Burgess and Niple, Inc.
Eric Tang, VHB
Alazar Tesfaye, Colorado Department of Transportation
Shane Turner, Abley Ltd
Essie Wagner, National Highway Traffic Safety Administration (NHTSA)
Nicole Waldheim, Fehr & Peers
Keith Williams, National Highway Traffic Safety Administration (NHTSA)
Robert Wunderlich, Texas A&M Transportation Institute

ACS20 – Standing Committee on Safety Performance and Analysis

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

Website: https://trbacs20.org/

Membership as of November 2023

Chair

Karen Dixon, Texas A&M University

TRB Staff Representatives

Bernardo Kleiner, Mary Kissi, Freda Morgan

Secretary

Derek Troyer, Federal Highway Administration (FHWA)

Members

Mohamed Ahmed, University of Cincinnati
Raul Avelar, Texas A&M Transportation Institute
Kate Bradbury, Jacobs
Daniel Carter, North Carolina Department of Transportation
Cong Chen, University of South Florida
Tim Colling, Michigan Technological University
Deogratias Eustace, University of Dayton
Erin M. Ferguson, Fehr & Peers
Michael Hunter, Georgia Institute of Technology
Khalid Jamil, Texas Department of Transportation
Thomas Jonsson, Norwegian University of Science and Technology
Keith Knapp, Iowa State University
Kim Kolody, Jacobs
Alejandra Medina, Virginia Polytechnic Institute and State University (Virginia Tech)
Juan Medina, University of Utah
Chris Monsere, Portland State University
Alfonso Montella, University of Naples Federico II
David Noyce, University of Wisconsin, Madison
Jennifer Ogle, Clemson University
Bonnie Polin, Massachusetts Department of Transportation
Xiao Qin, University of Wisconsin, Milwaukee
Taha Saleem, UNC Highway Safety Research Center
Peter Savolainen, Michigan State University
Grant Schultz, Brigham Young University
Ida van Schalkwyk, Washington State Department of Transportation
Ward Vanlaar, Traffic Injury Research Foundation
Elizabeth Wemple, HDR
Jonathan Wood, Iowa State University
George Yannis, National Technical University of Athens (NTUA)

Emeritus Members

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

Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ACS10-ACS20 related presentations and events at the 103[3d] Annual Meeting of the Transportation Research Board. With this aim, papers sponsored by the Committees ACS10 – Transportation Safety Management Systems and ACS20 – Safety Performance and Analysis have been split into subthemes and the abstracts reproduced. For each subtheme, a brief comment on the methodological and application perspectives of the presented papers is reported. Further, some papers sponsored by other interacting Committees which are within the scopes of ACS10[1]and ACS20[2] have been identified and classified to promote better interaction between ACS10, ACS20 and these other Committees. Indeed, highway safety is a worldwide major social challenge that requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

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

- three Committee meetings;
- eight Subcommittee meetings;
- four workshops;
- six lectern sessions; and
- nine poster sessions.

The Transportation Safety Management Systems Committee meeting will be held on Wednesday morning, January 10, from 8:00 AM to 12:00 PM, at Marriott Marquis, Salon 12 (M2).

The Safety Performance and Analysis Committee meetings will be held on Wednesday afternoon, January 10, from 1:30 PM to 5:30 PM, at Marriott Marquis, Salon 12 (M2), and on Thursday morning, January 11, from 9:00 AM - 12:00 PM, at Marriott Marquis, Liberty Salon JK (M4).

Sunday, January 7, there are three planned events (Table 1): two workshops in the morning and one workshop in the afternoon. Topics relate to equity integration into safety management systems, relationships between pavement properties and safety, and consideration of emerging micro-mobility needs.

Monday, January 8, there are twelve planned events (Table 2): three subcommittee meetings, seven poster sessions, and two lectern sessions. Lectern sessions are in the format of lectern-

[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.

poster sessions. Each author will present an overview of their research in a rapid-fire, 5-minute pitch followed by one-on-one discussions with the authors in front of their poster.

Tuesday, January 9, there are eight planned events (Table 3): four subcommittee meetings, one poster session, and three lectern sessions.

Wednesday, January 10, there are five planned events (Table 4): the ACS10 Committee meeting in the morning, the first part of the ACS20 Committee meeting in the afternoon, one subcommittee meeting, one poster session, and one lectern session.

Thursday, January 11, there are two planned events (Table 5): the second part of the ACS20 Committee meeting and one workshop on safety of vulnerable road users.

The four hundred seventy-nine safety-related papers identified by the sub-committee address the following topics (some papers are classified in more categories):

a) Crash Data and Safety Analysis (79);
b) Network Screening (39);
c) Safety Performance Functions (22);
d) Crash Severity Prediction (79);
e) Crash Modification Factors and Functions (16);
f) Surrogate Measures of Safety (66);
g) Real-Time Safety Prediction (27);
h) Safety Effects of Connected and Automated Vehicles (60); and
i) Transportation Safety Management (91).

Table 1 ACS10 and ACS20 Events, Sunday, January 7

Schedule	Event type	#	Location	Event name	Details
9:00 AM-12:00 PM	Workshop	1007	CC, Salon A	Integrating Equity into Transportation Safety Management	https://annualmeeting.mytrb.org/OnlineProgram/Details/20755
9:00 AM-12:00 PM	Workshop	1024	CC, 103B	Pavement Friction Management, Continuous Pavement Friction Measurement, and Safety Analysis	https://annualmeeting.mytrb.org/OnlineProgram/Details/20709
1:30 PM-4:30 PM	Workshop	1040	CC, Salon A	Planning for the Infrastructure Needs of Micromobility: Bike Lanes, Parking, and Electrification	https://annualmeeting.mytrb.org/OnlineProgram/Details/20786

Table 2 ACS10 and ACS20 Events, Monday, January 8

Schedule	Event type	#	Location	Event name	Details
8:00 AM-9:45 AM	Lectern	2004	CC, Salon B	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session	https://annualmeeting.mytrb.org/OnlineProgram/Details/21192
8:00 AM-9:45 AM	Poster	2051	CC, Hall A	Emergency Responder Safety, Travel Demand, and Routing	https://annualmeeting.mytrb.org/OnlineProgram/Details/21083
10:15 AM-12:00 PM	Subcommittee		MM, Howard University (M1)	Emergency Response, AMR00(1), AMR00, ACP10, ACS10, ACS30	https://annualmeeting.mytrb.org/OnlineProgram/Details/20401
10:15 AM-12:00 PM	Subcommittee		MM, Salon 13 (M2)	Motorcycle and Moped Safety, ACS10(5), ACS10, ACH60	https://annualmeeting.mytrb.org/OnlineProgram/Details/21345
10:15 AM-12:00 PM	Poster	2096	CC, Hall A	Safety Performance and Analysis	https://annualmeeting.mytrb.org/OnlineProgram/Details/21377
1:30 PM-3:15 PM	Poster	2159	CC, Hall A	Motorcycle Operation and Safety Research	https://annualmeeting.mytrb.org/OnlineProgram/Details/21341
1:30 PM-3:15 PM	Lectern	2124	CC, Salon B	Doctoral Student Research in Transportation Safety: A Lectern-Poster Session	https://annualmeeting.mytrb.org/OnlineProgram/Details/21351
3:45 PM-5:30 PM	Subcommittee		MM, Salon 13 (M2)	Rural Road Safety Policy, Programming, and Implementation, ACS10(4), ACS10, ACS20, AKD30	https://annualmeeting.mytrb.org/OnlineProgram/Details/20522
3:45 PM-5:30 PM	Poster	2212	CC, Hall A	Safety Performance and Analysis of Freeways	https://annualmeeting.mytrb.org/OnlineProgram/Details/21373
3:45 PM-5:30 PM	Poster	2213	CC, Hall A	Safety Performance of Connected Automated Vehicles	https://annualmeeting.mytrb.org/OnlineProgram/Details/21375
6:00 PM-7:30 PM	Poster	2235	CC, Hall A	Transportation Safety Management Systems from Start to Finish	https://annualmeeting.mytrb.org/OnlineProgram/Details/21191
6:00 PM-7:30 PM	Poster	2236	CC, Hall A	School Transportation and Planning Research	https://annualmeeting.mytrb.org/OnlineProgram/Details/21340

Table 3 ACS10 and ACS20 Events, Tuesday, January 9

Schedule	Event type	#	Location	Event name	Details
8:00 AM-9:45 AM	Lectern	3003	CC, 102B	Using Connected and Automated Vehicles to Improve Transportation Safety	https://annualmeeting.mytrb.org/OnlineProgram/Details/21193
10:15 AM-12:00 PM	Subcommittee		MM, Mount Vernon Square (M3)	School Transportation, ACS10(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/20521
10:15 AM-12:00 PM	Subcommittee		MM, Salon 13 (M2)	Safety Analytical Methods, ACS20(1)	https://annualmeeting.mytrb.org/OnlineProgram/Details/20523
10:15 AM-12:00 PM	Lectern	3066	CC, 152B	Safety in a Changing Rural Landscape	https://annualmeeting.mytrb.org/OnlineProgram/Details/21055
1:30 PM-3:15 PM	Subcommittee		MM, Salon 10 (M2)	Surrogate Safety Measures, ACS20(3)	https://annualmeeting.mytrb.org/OnlineProgram/Details/20525
1:30 PM-3:15 PM	Lectern	3146	CC, 146C	Electric Vehicle Incident Response: Strategies and Best Practices	https://annualmeeting.mytrb.org/OnlineProgram/Details/20843
3:45 PM-5:30 PM	Subcommittee		MM, Salon 7&8 (M2)	Pedestrian and Bicycle Safety Analysis, ACS20(4), ACS20, ACH10, ACH20	https://annualmeeting.mytrb.org/OnlineProgram/Details/20526
6:00 PM-7:30 PM	Poster	3231	CC, Hall A	Analytical Methods of Safety Performance	https://annualmeeting.mytrb.org/OnlineProgram/Details/21374

Table 4 ACS10 and ACS20 Events, Wednesday, January 10

Schedule	Event type	#	Location	Event name	Details
8:00 AM-12:00 PM	Committee		MM, Salon 12 (M2)	Transportation Safety Management Systems	https://annualmeeting.mytrb.org/OnlineProgram/Details/20196
8:00 AM-9:45 AM	Lectern	4003	CC, Salon B	Safety Performance and Analysis Research	https://annualmeeting.mytrb.org/OnlineProgram/Details/21372
10:15 AM-12:00 PM	Poster	4070	CC, Hall A	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others	https://annualmeeting.mytrb.org/OnlineProgram/Details/21376
11:15 AM-1:15 PM	Subcommittee		MM, Tulip (Mezz)	Safety Performance and Analysis User Liaison, ACS20(2)	https://annualmeeting.mytrb.org/OnlineProgram/Details/20524
1:30 PM-5:30 PM	Committee		MM, Salon 12 (M2)	Safety Performance and Analysis	https://annualmeeting.mytrb.org/OnlineProgram/Details/20197

Table 5 ACS10 and ACS20 Events, Thursday, January 11

Schedule	Event type	#	Location	Event name	Details
8:00 AM-12:00 PM	Committee		MM, Liberty Salon JK (M4)	Safety Performance and Analysis	https://annualmeeting.mytrb.org/OnlineProgram/Details/20629
9:00 AM-12:00 PM	Workshop	5006	CC, Salon A	Mitigating the Implications of Increasing Vehicle Size and Mass on Pedestrian and Bicyclist Safety	https://annualmeeting.mytrb.org/OnlineProgram/Details/20783

2 Crash Data and Safety Analysis

Mohamad Banihashemi, FHWA
Simone Fucito, University of Naples Federico II

Crash Data and Safety Analysis section contains many papers in wide variety of subjects in highway safety. The subcommittee identified **seventy-nine** papers dealing with this topic.

Most paper dealing with crash data and safety analysis are presented in the following sessions:

- 2096 Safety Performance and Analysis (Monday, January 8, 10:15 AM - 12:00 PM, 13 papers);
- 2235 Transportation Safety Management Systems from Start to Finish (Monday, January 8, 06:00 PM - 07:30 PM, 14 papers);
- 3231 Analytical Methods of Safety Performance (Tuesday, January 9, 06:00 PM – 07:30 PM, 22 papers);
- 2159 Motorcycle Operation and Safety Research (Monday, January 8, 01:30 PM- 03:15 PM, 8 papers);

The subcommittee identified five sub-categories:

- **General data, data analysis and new analytics** (24-00059, 24-00337, 24-00422, 24-00935, 24-01497, 24-01516, 24-02111, 24-02280, 24-02382, 24-02556, 24-02607, 24-02691, 24-02737, 24-02850, 24-02930, 24-02953, 24-03253, 24-03347, 24-03527, 24-03585, 24-03694, 24-03755, 24-03833, 24-03846, 24-04297, 24-04392, 24-04412, 24-04420, 24-04454, 24-05299, 24-05496, 24-05760, 24-05825);
- **Vulnerable road users and first responders** (24-01082, 24-01703, 24-01933, 24-02245, 24-03914, 24-03973, 24-04207, 24-04626, 24-04718, 24-04833, 24-05001, 24-05342, 24-05539, 24-05637, 24-05696, 24-05732, 24-05875, 24-05987, P24-20398);
- **Specific crash types and geometric factors** (24-00017, 24-00476, 24-00647, 24-00854, 24-02292, 24-02750, 24-03729, 24-03816, 24-04338, 24-05493, 24-05716, 24-06143);
- **Human factors and environmental factors** (24-00169, 24-00205, 24-00322, 24-00356, 24-02057, 24-03168, 24-03645, 24-04678, 24-05183, 24-05324);
- **Crash data and data analysis related to connected and autonomous vehicles** (24-00318, 24-01915, 24-02913, 24-03775, 24-05717).

General data, data analysis and new analytics

This sub-category contains 33 papers related to data analysis. Various topics are studied in this sub-category, such as the analysis of the contributory factors in road traffic accidents (24-

01082, 24-02691, 24-02930, 24-03846, 24-00422, 24-05496), estimation of crash type frequency (24-00059, 24-04392), prediction and safety analysis of crashes (24-02607, 24-02953, 24-03253, 24-04454, 24-03585, 24-03694, 24-03833, 24-04420, 24-05760, 24-05825), special analysis of road crashes (24-04297), or identification and analysis of crash hotspots (24-02280). Other examples are paper 24-00935, which studies the optimization for estimating crash data count models by addressing complexity and heterogeneity; or paper 24-01516 that studies the causes of spatial heterogeneity using post-analysis; another one is paper 24-03347, in which a study of freeway crash impacts considering unobserved heterogeneity is presented.

Vulnerable road users and first responders

This sub-category contains 19 papers that focus on vulnerable road users and first responders. Among them, seven papers discuss crash data and safety analysis with particular attention to motorbikes and powered two-wheelers: 24-01082, 24-01703, 24-03914, 24-04626, 24-04833, 24-05539 and P24-20398.

Three papers, on the other hand, are focused on pedestrians: 24-01933, 24-03973, 24-04207.

Other two papers contain studies regarding both pedestrians and cyclists: 24-05987 and 24-05732.

Paper 24-05637 studies the causes of bicycle crashes, while paper 24-05001 contains a macro-level safety assessment and contributing factor analysis of non-motorized vehicles considering traffic crashes and crash-involved riders.

In conclusion, five papers studies crash data related to emergency vehicles and first responders: 24-02245, 24-04718, 24-05342, 24-05696 and P24-20398.

Specific crash types and geometric factors

This sub-category contains 12 papers that focus on specific crash types and geometric factors.

Based on an examination of all road traffic crashes, paper 24-00017 studies the effects of road geometric formation: road cross section, horizontal and vertical alignment, crossings and other elements; paper 24-05493 studies the relationship between lane width and traffic safety; paper 24-00476 focuses its attention on different combinations of slope and curve, while paper 24-00647 enhances the safety prediction for simple and spiral horizontal curves; crash prediction on horizontal curve is the study proposed in the paper 24-02292. Paper 24-04338 describes a safety evaluation of conversion from a conventional signalized intersection to a continuous flow intersection.

Specific crash types studied in these papers are: traffic accidents around intersections (24-06143), rollover crashes (24-05716), crashes involving roadside assistance providers (24-00854), work zone crashes (24-02750) and frontage roadway crashes (24-03729).

Human factors and environmental factors

This sub-category contains 10 papers that focus on crash data and safety analysis with particular attention to human or environmental factors.

With reference to human factors, paper 24-00169 evaluates helmet-wearing of single-vehicle overspeeding motorcycle crashes; paper 24-00205 and 24-04678 analyzes distracted driving: the first through a safety investigation of distracted driving crashes in Kentucky pre and post Covid 19 pandemic, while the second classifies distracted driving crashes using a data fusion-based machine learning approach; driving behaviour is analyzed in paper 24-05183 and incorporates driving behaviour metrics into macroscopic safety modeling; papers 24-03168 and 24-05324 deal with a specific category of users: the first (24-03168) studies crash characteristics and contributory factors to enhance older drivers safety, while paper 24-05324 assesses the crash characteristics associated with female drivers at different life stages.

With reference to environmental factors, paper 24-02057 focuses its attention on reducing wildlife crashes; paper 24-00356 studies road traffic injuries in association with ambient temperatures in Kaohsiung, Taiwan; paper 24-03645 analyzes the causes od road accidents in mining areas.

Crash data and data analysis related to connected and autonomous vehicles

This sub-category contains 5 papers concerning connected and autonomous vehicles.

One paper (24-00318) proposes a method that utilizes in-depth crash data to assess the safety of Avs, focusing on real-world crash scenarios. Another one (24-01915) analyzes how the factor of the crash, by comparing homogeneous cluster-specific patterns of crash-risk factor associations influencing AV-involved crashes in both intersection and non-intersection segments in the USA. Another paper (24-02913) reviews current automated vehicle and baseline human-driven crash databases and evaluates their comparability. Paper 24-3775 analyzes how environmental and road factors impact Automated Vehicle crash results, while paper 24-05717 examines the relationship between connected vehicle driving event data and Police-reported traffic crash data.

Below, for each of the seventy-nine papers involving crash data and safety analysis, ordered by number of paper, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Debela Jima, Budapest University of Technology and Economics Tibor Sipos
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-00017
Paper Title	**Effects of Road Geometric Formation on Traffic Crashes in EU**
Abstract	The proportions and configurations of a roadway's visible elements are referred to as its geometric formation. Road cross sections, horizontal and vertical alignments, crossings, and other elements are included. Poor road design, construction, and maintenance have a substantial impact on the geometric formation of the road as well as the network's operations, safety, and capacity. The goal of this review was to look into the effects of road geometric formation on traffic crashes and their severity levels. This review attempted to combine the most recent academic work and its findings at random. To achieve the review's goal, the evaluation used a mixed-method review approach that included both qualitative and quantitative judgments. Based on an examination of all road traffic crashes and their severity levels. This paper found that the most road geometry formation-oriented factors that encourage the occurrences of road traffic crashes and their severity levels in the EU are straight alignment of the road (70%), daytime with daylight condition (70%), rural roads (60%), dry surfaces, bad roads, motorway road type, two-way road formation, and its carriageways. As a result, relevant agencies must analyze and investigate the aforementioned road geometric formation-related elements, as well as their impact on traffic collisions and severity levels, and take corrective measures to reduce road traffic crashes and their outcomes in the EU.

Authors	Asif Mahmud, Kittelson & Associates, Inc. Vikash Gayah, Pennsylvania State University, University Park Rajesh Paleti, Pennsylvania State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-00059
Paper Title	**Estimation of crash type frequency accounting for misclassification in crash data**
Abstract	Crash misclassification (MC) – e.g., a crash of one type or severity being mistakenly miscategorized as another – is a relatively common problem in transportation safety. Crash frequency models for individual crash categories estimated using datasets with MC errors could result in biased parameter estimates and thus lead to ineffective countermeasure planning. This study proposes a novel methodological formulation to directly account for this MC error and incorporates it into the two most common count data models used for crash frequency prediction: Poisson and Negative Binomial (NB) regression. The proposed framework introduces probabilistic MC rates among different crash types and modifies the likelihood function of the count models accordingly. The capability of the proposed models to estimate true parameters, given the existence MC error, is examined via simulation analysis. Then, the proposed models are applied to empirical data to examine the presence of MC in crash data and further examine the robustness of the proposed models. Although the MC rates are found to be very low in the empirical data, the fit of proposed models are found to be better compared to the models that ignore MC error and thus likely provide more reliable parameter estimates.

Authors	Chenzhu Wang, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Said M Easa Fei Chen, Southeast University Jianchuan Cheng, Southeast University Arshad Jamal
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00169
Paper Title	**Evaluating Helmet-Wearing of Single-Vehicle Overspeeding Motorcycle Crashes: Insights from Temporal Instability in Parsimonious Pooled Framework**
Abstract	A lower helmet-wearing rate and overspeeding in Pakistan are critical risk behaviors of motorcyclists, causing severe injuries. To explore the differences in the determinants affecting the injury severities among helmeted and non-helmeted motorcyclists in motorcycle crashes caused by overspeeding behavior, single-vehicle motorcycle crash data in Rawalpindi city for 2017-2019 is collected. Considering three possible crash injury severity outcomes of motorcyclists: fatal injury, severe injury and minor injury, the rider, roadway, environmental, and temporal characteristics are estimated. Methods: To provide a mathematically simpler framework, the current study introduces parsimonious pooled random parameters logit and ordered probit models. Then, the standard pooled random parameters logit and ordered probit models without considering temporal effects are also simulated for comparison. By comparing the goodness of fit measure and estimation results, the parsimonious pooled random parameters logit model performs better in capturing the temporal instability. Then, the non-transferability among helmeted and non-helmeted overspeeding motorcycle crashes is illustrated by likelihood ratio tests and out-of-sample prediction, and four types of models provide robust results. The marginal effects are also calculated. Results: And several variables, such as age, cloudy and weekday indicators illustrate temporal instability and non-transferability (several variables are only significant in non-helmeted models). More educational campaigns, regulation and enforcement, and management countermeasures should be organized for non-helmeted motorcyclists and overspeeding behavior. Such findings also provide research reference for the risk-compensating behavior and self-selected group issues under overspeeding riding considering the usage of helmets.

Authors	Arunabha Banerjee, Western Kentucky University William Pemberton Tyaha Woodard, Western Kentucky University Benjamin McElroy Bharat Kumar Pathivada and Kirolos Haleem, Western Kentucky University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00205
Paper Title	**Safety Investigation of Distracted Driving Crashes in Kentucky Pre- and Post-COVID-19 Pandemic**
Abstract	This study investigates and compares the pattern of distraction-related crashes pre-COVID-19 pandemic (2018-2019) and post-COVID-19 pandemic (2020-2021) in the state of Kentucky. Comprehensive crash (e.g., manner of collision, at-fault vehicle type, and time of crash), driver (e.g., at-fault driver age), roadway (e.g., roadway condition and type), and environmental (e.g., season and weather) characteristics were investigated and contrasted pre- and post-pandemic. The systemic safety analysis showed that severe distraction-related crashes occurred along urban undivided 1-2 lane roads with 30-40 miles per hour (mph) speed limit and annual average daily traffic (AADT) ≥ 5,000-10,000. However, post-pandemic, severe distraction-related crashes occurred along rural undivided 2-lane roads with 55 mph speed limit and AADT ≤ 5,000. Postpandemic, total distraction-related angle crashes increased by 1.89%, and involvement of light trucks as at-fault vehicle increased by 2.77% (possibly due to the increase in online shopping and on-demand delivery). Off-peak morning crashes increased by 4.53% post-pandemic and involvement of young drivers remained the highest (37.67%), probably due to young drivers being highly distracted by cell phones and in-vehicle music systems. The chi-square test of independence showed that weather was a significant factor impacting severe distraction-related crashes postpandemic. The odds of being involved in severe distraction-related crashes remained the highest for head-on and motorcycle-related collisions pre- and post-pandemic. Implementation of dynamic message signs with more installation of rumble strips to alert inattentive drivers, stronger enforcement of cell phone use, educational campaigns on distracted driving safety challenges, and training young drivers are potential countermeasures to reduce severe distraction-related crashes.

Authors	Rui Zhou Guoqing Zhang Helai Huang, Central South University Jaeyoung Lee, Central South University Yuxuan Dong Jiguang Chen
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2213
Session Title	Safety Performance of Connected Automated Vehicles
Paper Number	TRBAM-24-00318
Paper Title	**Crash-based Assessment of Autonomous Driving: How Do Autonomous Vehicles Behave in Real-World Crash Scenarios?**
Abstract	Autonomous vehicles (AVs) have the potential to revolutionize transportation by enhancing traffic safety, and safety testing is a critical step for enabling large-scale deployment of AVs. Due to the high cost and safety risk associated with public road testing, virtual simulation testing has emerged as a cost-effective and efficient method for safety verification. In this context, high-risk scenarios are particularly important as they pose significant challenges and provide valuable insights into the driving capabilities of AVs. This study proposes a method that utilizes in-depth crash data to assess the safety of AVs, focusing on real-world crash scenarios. First, the 453 real-world crashes involved 596 passenger cars from China In-depth Mobility Safety Study-Traffic Accident (CIMSS-TA) database were reconstructed. Subsequently, 596 testing scenarios were created within the simulation platform. Following this, one of the crash-involved passenger cars was replaced with Baidu Apollo, an advanced black-box automated driving system (ADS), for counterfactual simulation. Finally, the safety performance of the AV was evaluated based on the simulation results. The findings demonstrated that the AV could avoid 363 real-world crashes, accounting for approximately 60.91% of the total, and effectively mitigated injuries in the remaining 233 unavoidable scenarios compared to a human driver. Additionally, seven specific scenarios have been identified wherein the AV is unable to avoid a crash. These findings demonstrate that, compared to human drivers, the AV can avoid crashes that are difficult for humans to avoid, thereby enhancing traffic safety.

Authors	Chunwu Zhu, Texas A&M University, College Station Bahar Dadashova, Texas A&M Transportation Institute Chanam Lee, Texas A&M University, College Station Xinyue Ye, Texas A&M University Charles Brown, Equitable Cities LLC
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00322
Paper Title	**Disparities in Roadway Safety: Exploring Direct and Indirect Pathways Contributing to Disparities in Non-Motorist Crashes in Houston, Texas**
Abstract	Environmental justice is of significant concern in roadway safety research, and an important part of the strategic goals in federal, state, and local level transportation planning. However, existing empirical evidence is limited due to inadequate consideration of intercorrelations between crash-related factors and traffic exposure in most prior studies. In this research, we apply a Structural Equation Model (SEM) approach to explore the underlying mechanism of disparity in non-motorist crashes in Houston, Texas by examining the mediating effect of two transportation modes, motor vehicle and active transportation. The results suggest that disadvantaged neighborhoods tend to have a positive direct and total effect to nonmotorist crashes. We also found a positive mediating effect of motor vehicle mode, suggesting that this disparity is partially due to denser roadway environments and higher vehicular exposure in disadvantaged neighborhoods. On the other hand, inadequate active transportation infrastructure and active transportation exposure showed negative mediating efforts, indicating their roles in mitigating nonmotorist crash risk to some extent. This research offers conceptual insights for urban and transportation planners to better consider environmental justice in roadway safety practices and supporting evidence for providing active transportation infrastructure and mitigating traffic exposure in disadvantaged communities to improve transportation equity.

Authors	Orfeas Karountzos, National Technical University of Athens (NTUA) Alexandros Liazos Konstantinos Kepaptsoglou, National Technical University of Athens (NTUA)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-00337
Paper Title	**Spatial Decision Support System for the Assessment of High-Risk Areas and Contributing Factors in Road Traffic Accidents: Application to the Northern Road Axis of Crete, Greece**
Abstract	This study examines how different variables affect road traffic accidents (RTAs), by analyzing their spatiotemporal characteristics. A comprehensive, easily adaptable and versatile Spatial Decision Support System (SDSS) is developed to provide insights regarding RTA occurrence and its contributing factors on different levels of spatial analysis, and through the use of various GIS-based methods. A case study on the Northern Road Axis of Crete (VOAK) is considered, focusing on identifying blackspots and clusters of RTA occurrence, related injuries, and deaths. The analysis utilizes spatial analysis techniques, such as Kernel Density Estimations (KDE), Spatial Autocorrelation models for the identification of spatial patterns, Univariate and Bivariate Local Indicators of Spatial Association (LISAs) to explore spatiotemporal patterns of RTAs and their correlation with infrastructure related factors. Findings indicate that the most significant blackspots and clusters of RTAs are located in specific parts of the study area which require immediate targeted interventions, mostly due to poor infrastructure. The study highlights the importance of a comprehensive approach to road safety management, considering spatial characteristics and topologyrelated complexities, while providing insights regarding the development of effective strategies for reducing the number of RTAs, related injuries and fatalities caused by them, thus leading to more effective road safety management from policymakers.

Authors	Cheng-Kai Hsu, University of California, Berkeley Daniel Rodriguez, University of California, Berkeley
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00356
Paper Title	**Ambient Temperatures and Road Traffic Injuries in Kaohsiung, a Tropical and Motorcycle-dominant City in Taiwan**
Abstract	Road traffic injuries (RTIs) are a major global health concern, causing around 1.35 million deaths annually. Over 20% of these deaths occur among powered two-wheeler fleets, a transportation mode gaining popularity, especially in Asia, Africa, and Latin America. Despite a growing body of literature on the association between RTIs and ambient exposure factors, including temperatures, there is limited empirical data in tropical, motorcycle-dense locations like Taiwanese cities. This study investigates the effects of ambient exposure factors (temperature, wind speed, atmospheric pressure, and ground-level ozone) on RTIs in Kaohsiung, Taiwan—a city with dense motorcycle usage, high temperatures, and poor air quality—considering seasons and transportation modes of the injured party. Our findings reveal varying effects of ambient exposures on RTI risks. High temperatures, particularly in summer, are associated with increased road risks, while high wind speed in summer exhibits protective effects but is harmful on non-summer days. High atmospheric pressure may adversely impact road safety, possibly due to decreased thermal comfort. Additionally, higher ground-level ozone concentrations are associated with increased RTIs. Compared to car users, motorcycle users have higher susceptibilities to some of these effects. We highlight alarming magnitudes of temperature effects in a tropical and motorcycle-dominant context, exceeding findings in other non-tropical locations. As climate change increases extreme heat events globally, understanding the impact of ambient heat becomes even more critical. As micromobility innovations are emerging, further research is needed to explore how ambient exposures affect road safety of travelers using open transportation modes like electric bicycles and scooters.

Authors	Shuo Liu Liujiang Kang, Beijing Jiaotong University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-00422
Paper Title	**Mining of the Causes of Major Road Traffic Accidents Based on Association Rules**
Abstract	Since the implementation of the strategy to build a transportation power, China's transportation industry has developed rapidly, but the number of road traffic accidents remains high in recent years. Compared with general accidents, the factors influencing major road traffic accidents are more complex. This article focuses on studying the relevant relationships of the factors affecting major road traffic accidents. Firstly, a total of 968 pieces of data on major road traffic accidents from 2012 to 2018 in China are collected and sorted out, sourced from a project conducted by the Ministry of Transport of China. The accident information fields are analyzed to obtain seven attributes, including accident province, accident region, accident quarter, accident time, accident form, accident vehicle and weather condition. Secondly, the Apriori association rule algorithm is developed to mine and solve the strong association rules between accident attribute values. The association between different accident influencing factors and the form of accident results are analyzed, and three-factor and four-factor rules are discussed in more depth. The results show that the causal factors of related accidents will jointly induce the occurrence of major accidents, including the western region represented by Guangxi Province of China, the mainly involved truck models, and rainy and snowy weather in the first quarter. The research conclusions can provide corresponding accident prevention measures for the transportation management department to further improve urban road traffic safety and reduce the occurrence of traffic accidents.

Authors	Jinxiu Fu Peng Cai Zhiqing Zhang, Beijing University of Technology Di Xu Qiang Fu, Beijing University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-00476
Paper Title	**Analysis of traffic safety information transmission law of slope-curve alignment based on the vector autoregressive (VAR) model**
Abstract	Different combinations of slope and curve have a serious impact on driving safety. The coupling factors that increase driving risk have complicated relationships and an abstract dynamic action law. This study applies the quasi-reflective arc information transmission theory to build a three-layer (Road environment, Driver, Vehicle) vector autoregressive model (VAR) for the slope-curve alignment section. The results indicate that there is a significant rule of information transmission about road safety between the three layers. The rules show that slope-curve alignment causes drivers to experience psychological stress, to deliberately reduce their field of vision, to pay more attention to road conditions, and to change their driving behavior more frequently. Finally, it leads to changes in external characteristics, including unsteady vehicle operation and an increase in accidents. The most dangerous part of slope-curve alignment is the connecting segment. The results of the study can support active safety awareness for current road safety design.

Authors	Amir Saman Abdollahzadeh Nasiri Ali Abdi Kordani Omid Rahmani Eazaz Sadeghvaziri, Mercer University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-00647
Paper Title	**Enhancing Safety Prediction for Simple and Spiral Horizontal Curves: A Novel Model Incorporating Road Surface Friction through Genetic Algorithm**
Abstract	The friction coefficient (FC) from road surface conditions directly affects the Margin of Safety in horizontal curves. Evaluation of these factors can introduce the proposed values based on the vehicle's dynamic response to the MoS of the curves against the skidding. This paper evaluates MoS based on the combined effects of the FC of the road surface, vehicle speed, longitudinal grade variables, and vehicle type (sedan, SUV, 3-axle truck) for simple and spiral horizontal curves. Also, the non-linear regression analysis is performed to examine the relationship between the dependent variable (MoS) and independent variables (Speed, FC, weight of vehicles) using a genetic algorithm. The results of this study showed that the values of the Side Friction Demand (SFD) in heavy and light vehicles were higher than AASHTO's suggestions. The value of the SFD of a 3-axle truck was higher than that of the light vehicles. Moreover, the value of the friction supply of the 3-axle truck was lower than that of the light vehicles. The MoS value in the spiral curve was higher than the simple curve in heavy and light vehicles. Furthermore, a comparison of the results of the MoS of the spiral curve and the simple curve showed that the 3-axle truck needed the spiral curve design more than the lighter vehicles. In addition, the reduction in the amount of FC highlighted the fact that using a spiral curve (instead of a simple curve) significantly increased the MoS value of the vehicles.

Authors	Anqi Wei, Georgia Institute of Technology Rebecca Steinbach, AAA Foundation for Traffic Safety Brian Tefft, AAA Foundation for Traffic Safety
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 2051
Session Title	Emergency Responder Safety, Travel Demand, and Routing
Paper Number	TRBAM-24-00854
Paper Title	**Struck-By Fatalities of Motor Vehicle Towing and Roadside Assistance Providers: Identification of Cases and Descriptive**
Abstract	Roadside Assistance Providers (RAP) including motor vehicle towing personnel, mobile mechanics, and safety service patrollers are at risk of being struck by passing vehicles while working. Previous studies of incident responder safety have included some RAP; however, existing crash databases do not reliably identify crash victims as RAP. Thus, no previous research has provided a comprehensive characterization of crashes in which RAP have been struck and killed. The current study identified 127 RAP fatally struck at the roadside in the U.S. in years 2015-2021 using two industry organizations' records of RAP fatalities, successfully linked 123 of these records to the National Highway Traffic Safety Administration's database of fatal crashes using crash and victim information available in both data sources, and used these linked data to perform a descriptive analysis of the circumstances of crashes in which RAP were fatally struck at the roadside. Results show that 86% of these RAP fatalities occurred on Interstates or other high-speed limited-access highways, 63% occurred during darkness, 39% at unlit locations. Half of all striking vehicles reportedly departed their travel lane or departed the road entirely before striking RAP. Although the precise locations of RAP were not reported, data indicate that only the RAP (and no vehicle) was struck in 36% of crashes, and the RAP was struck before any vehicle in another 11%, suggesting, albeit not conclusively, that these workers were likely standing on the traffic-facing side of the vehicle. Relation to previous research, implications for countermeasures, and future research needs are discussed.

Authors	Zeke Ahern, Queensland University of Technology Mohammadali Shirazi, University of Maine Paul Corry, Queensland University of Technology Alexander Paz, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-00935
Paper Title	**An Efficient Optimization Framework for Estimating Crash Data Count Models: Addressing Complexity, Heterogeneity, and Multiple Objectives**
Abstract	Analyzing crash data is a complex process that requires careful consideration of multiple modeling aspects and objectives. However, taking into account these aspects and objectives simultaneously can result in a large number of modeling decisions and hypothesis testing, making the analysis and modeling process susceptible to bias and the neglect of relevant specifications and important insights present in the data. To address these challenges, this paper proposes a mathematical programming formulation and optimization framework that allows for extensive hypothesis testing at a lower computational cost. This framework can assist in estimating crash data count models, helping to ensure the identification of important factors that contribute to crashes and generating insights that can inform policy and decision-making. The data-dependent framework ensures capturing the most appropriate modeling effects and identifying the suitable hierarchical structure of the model, accommodating random parameters, heterogeneity in the means, grouped random parameters, and unique combinations of distributions. To handle complexity and non-convexity, the proposed framework employs diverse metaheuristic solution algorithms, addressing multiple objectives effectively, namely Bayesian Information Criteria (BIC) for model fit and Mean-Square Prediction Error (MSPE) for validation. The effectiveness of the framework was evaluated using synthetic and real datasets, generating efficient results. Overall, the proposed optimization framework provides an efficient and effective approach to developing crash data count models while overcoming many challenges associated with traditional methods. The ability of the framework to identify potential model specifications and provide accurate estimates has the potential to provide valuable information for researchers and practitioners in the field.

Authors	Ta-Yin Hu, National Cheng Kung University Chen-Yang Hsieh Tsai-Yun Liao, National Chiayi University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-01082
Paper Title	**Risk Prediction of Vehicle Collision Involved with Motorbikes: An Application of A Combined Neural Network of CNN and LSTM**
Abstract	Advanced Driver Assistance Systems (ADAS), such as collision mitigation, vehicle control systems, detection, and warning mechanisms, have been implemented to help drivers to avoid accidents. ADAS monitor the vehicle surrounding by data from active sensors. Different data, especially collisions involved with motorbikes, are collected to study the possible benefits of ADAS, and deep learning techniques are applied to examine the data. This motorbike-collision data is provided by the Tainan City Traffic Accident Investigation Committee, including the video recorded by dashcam or closed-circuit television (CCTV) to simulate the sensor of ADAS and train the risk prediction models to avoid vehicle collision. Previous research confirmed that deep learning methods perform better than machine learning or traditional regression methods. A Convolutional Neural Network (CNN) can capture spatiotemporal dependence through distributed and hierarchical feature extraction. A long short-term memory (LSTM) network can capture the temporal features of videos. This study collects two types of data: static data from accident reports and image data from collected video clips. Five models based on CNN or LSTM are constructed to predict vehicle collisions. The ResNet-50 network, a pre-trained CNN, captures image features from each video frame. LSTM captures the temporal features of videos. The results show that integrating CNN and LSTM using vehicle dynamic feature data and video data provides higher performance. Regarding practical applications, if vehicles are equipped with sensors, Models III and V can support ADAS with pre-warning alarms. Drivers or vehicles can respond to these alarms to take appropriate actions to avoid collisions.

Authors	Ou Zheng, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Dongdong Wang Chenzhu Wang Shengxuan Ding
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01497
Paper Title	**TrafficSafetyGPT: Tuning a Pre-trained Large Language Model to a Domain-Specific Expert in Transportation Safety**
Abstract	Large Language Models (LLMs) have shown remarkable effectiveness in various general-domain natural language processing (NLP) tasks. However, their performance in the transportation safety domain tasks has been suboptimal, primarily attributed to the requirement for specialized transportation safety expertise in generating accurate responses. To address this challenge, we introduce TrafficSafetyGPT, a novel LLaMA (Large Language Model Meta AI) -based model, which has undergone supervised fine-tuning using TrafficSafety-2K dataset which has human labels from government produced guiding books and ChatGPT-generated instruction-output pairs. Our proposed TrafficSafetyGPT model and TrafficSafety2K train dataset are accessible at https://github.com/ozheng1993/TrafficSafetyGPT.

Authors	Uibeom Chun, University of Seoul Soobeom Lee Shin Hyoung Park, University of Seoul Joonbum Lim
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-01516
Paper Title	**Identification the Causes of Spatial Heterogeneity in Traffic Accident using Post-Analysis: Developing Accident Prediction Model through Segment-based Spatial Analysis**
Abstract	Spatial heterogeneity is considered one potential factor that occurs accident. Most previous reserachs that have studied spatial heterogeneity in traffic accidents have primarily focused on identifying the factors through spatial analysis at the level of areas or TAZs, even if accidents occurred in a linear space such as a road. Additionally, there has been insufficient analysis of the results obtained from local regressions through considering spatial heterogeneity. In this study, it collected variables that influence on occurence of accidents on the 4-lanes national highways in Korea and conducted spatial analysis at the segment-level. Subsequently, reflecting characteristic of accident such as spatial heterogeneity, overdispersion, and zero-inflated, it developed traffic accident prediction models based on segment unit. Through comparison of indicators, the optimal model, which is geographically weighted poisson regression that derive local regressions by segment, was selected. Post-analysis conducted by grouping road segments based on the coefficient of local regression. As a result, we identified a part of causes of spatial heterogeneity in analysis segment. One of the causes of spatial heterogeneity is attributed to uniform facility installation and road operation methods without considering the geometric structure of roads. Furthermore, it was inferred that frequent improper facility installations in specific areas were another cause. We expect that a post-analysis of localized approach recognizes the importance of considering spatial heterogeneity, which can ultimately lead to more successful outcomes in reducing accidents.

Authors	Bhupali Dutta Ankit Raj Suprag Patel Shubham Yadav Ripunjoy Gogoi
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-01703
Paper Title	**Role of the built environment on vulnerable road users in a developing country: A case study of Jamshedpur, India**
Abstract	This paper investigates the role of the built environment on vulnerable road users (two-wheelers) in India. The study uses simple analytical tools such as the Poisson distribution model, the biserial co-relation coefficient analysis and logistic regression to explore the effect of the built environment factors on vulnerable road user crashes. Three months of accident data for the year 2022 in Jamshedpur, India are used for the analysis. Two-wheeler-vehicle accidents are analyzed for fatal and serious injury collisions. Exploratory variables that are used in the analysis include, type of area (rural or urban), type of road (highway or city road), type of road environment (open or others), type of intersection (junction versus not in junction), and type of road section (straight versus curved). The study suggests that the probability of fatal and serious injury in two-wheeler crashes is more likely to occur in rural areas, on highways, away from junctions, in open areas, and on straight road sections. The findings can raise public awareness of risks associated with riding two-wheelers on certain types of roads and in certain areas, and thus serve to reduce risk of traffic accidents in such areas.

Authors	Reuben Tamakloe, University of Seoul Subasish Das, Texas State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2213
Session Title	Safety Performance of Connected Automated Vehicles
Paper Number	TRBAM-24-01915
Paper Title	**Patterns of Critical Factors Linked to Automated Vehicle-Involved Crashes: A Comparative Analysis of Intersection and Non-Intersection Crash Scenarios**
Abstract	This study aims to comprehensively understand how the factors associated with automated vehicle (AV) crashes differ based on the segment of the crash. The study achieves this objective by comparing homogeneous cluster-specific patterns of crash-risk factor associations influencing AV-involved crashes in both intersection and non-intersection segments in the USA. The Cluster Correspondence Analysis (CCA) was employed for the study. From the analysis, the cluster with the highest prevalence in the intersection-related crash data consisted of observations predominantly associated with dark-lighted conditions. This cluster often involved AVs with multi-point contact areas and collisions with motorists and non-motorists. On the other hand, the most representative cluster for non-intersection crashes mainly comprised AV crashes that occurred during the daytime, frequently involving collisions with parked vehicles. Crashes involving fixed objects were more common in dark unlighted conditions at non-intersections, whereas at intersections, they occurred in the daylight and often resulted in injury. Inclement weather conditions were determined to significantly influence the crashes, irrespective of the segment in which they occurred. The findings of this study provide valuable insights for traffic engineers and AV manufacturers, offering practical suggestions to develop effective countermeasures and policies to reduce the severity of AV crashes. By understanding the specific factors contributing to crashes in different roadway segments, stakeholders can make informed decisions to enhance the safety of AVs.

Authors	Amir Oliaee, Texas A&M University Subasish Das, Texas State University Minh Le, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-01933
Paper Title	**Classifying Imbalanced Crash Typing Data using BERT and RoBERTa**
Abstract	Despite the focus on "Green Transportation," pedestrian deaths in the United States have risen significantly compared to motorist deaths. To accurately analyze and understand the causes of traffic crashes involving pedestrians and bicyclists, the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) was developed. However, manual data entry in the tool is labor intensive thus a more automated method is needed for large datasets. This study developed deep-learning models to automate the classification of crash types. But the PBCAT's classification typology can lead to imbalanced datasets, underscoring the need to actively tackle the issue of imbalanced native classification. By addressing this issue, researchers can significantly enhance their ability to harness the potential of emerging large language models. This endeavor becomes even more crucial as Natural Language Processing tools become increasingly accessible, offering promising opportunities in transportation safety research. This study focused on police reports' text narratives regarding pedestrian crashes in three major cities in Texas from 2018 to 2020 as a case study. It evaluated the effectiveness of classification loss functions, classification typology adjustments, and model pretraining in addressing the adverse effects of dataset imbalance. The tests show that Balanced Categorical Cross Entropy loss and a more robust pertaining of the language model can result in better classification. This effect was noticeable when a large enough sample size per class was present. In the case of smaller datasets, a tiered classification system is recommended with a smaller number of classes and more distinct text sentiment.

Authors	Bridget Donaldson, Virginia Transportation Research Council James Gillespie Rebecca Danese
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-02057
Paper Title	**Valuing Large Animal Crashes and Calculating Benefits and Costs for Safety Improvement Projects**
Abstract	Increased attention to reducing wildlife crashes and restoring habitat connectivity has created new federal funding opportunities for wildlife crossings. Economic evaluations help prioritize candidate countermeasures that can improve driver safety and habitat connectivity. This paper reports how large animal crash valuation methods can inform benefit-cost evaluations through consideration of (1) the scale to which large animal crashes are underrepresented in police reports; (2) cost components used to value a large animal crash; and (3) various means to determine threshold (or break-even) values at which the costs of a wildlife crash countermeasure equal its benefits. Key findings that practitioners can use to support economic evaluations of wildlife crash countermeasures are (1) police crash reports account for one-fifth to one-ninth of actual deer crashes, and (2) there is considerable variability in how wildlife crashes are monetized, in part because of wildlife size and the associated crash severity and in part because of the variability in cost components applied to each method (e.g., emergency response, carcass value, and equivalent crash costs). This paper provides an example of a deer and an elk crash valuation method that resulted in crash values of approximately $41,000 for deer and $81,000 for elk. Further, any countermeasure has some degree of uncertainty with respect to crash reduction values, service life, or ranking against other safety improvements, and the examples of breakeven illustrations in this paper can demonstrate approaches for selecting an appropriate economic method.

Authors	Bowen Cai Léah Camarcat, Imperial College London, South Kensington Mohammed Quddus, Imperial College London
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02111
Paper Title	**A new spatio-temporal causal inference-based CNN model for short-term crash prediction**
Abstract	Short time crash prediction is challenging for having extremely imbalanced dataset of excessive zeros, random crash occurrence, strong correlation with dynamic traffic variables, and being heterogeneity in nature. This paper puts forward a combined method of time series generalized regression neural network and binomial weighted convolutional neural network (TSGRNN-WCNN) model to capture both temporal and spatial features simultaneously in short time crash prediction. The model is trained and tested by employing real-world data that is collected with loop detectors for the M1 motorway in the UK in 2019 and the crash data is extracted from the STATS19 database for the same year with more than 99.99% data is non-crash. The joint TSGRNN-WCNN model conducts crash prediction by updating crash and traffic data in every period of 30 minutes. In the southbound direction, 75.3% crash events are correctly predicted, and 81.6% non-crash events are also identified accurately. In the northbound direction, 78.1% crash event are accurately predicted, and 80.2% non-crash events are predicted. Although GRNN and CNN models have been widely used in crash analysis respectively, the introduction of autocorrelation and seasonality temporal structure to GRNN, the innovative fitting procedure of binomial weighted CNN model to capture crash data distribution, and the combination of both methods to deal with time series and spatially correlated imbalanced crash data are novelties involved in this study. Causal inference is also applied to analyze explanatory variable importance. Results show that speed variances and speed are the most influential factors contributing to crash occurrence.

Authors	Yangming Shi, Colorado School of Mines Ziming Liu, Colorado School of Mines Jun Liu, University of Alabama
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 2051
Session Title	Emergency Responder Safety, Travel Demand, and Routing
Paper Number	TRBAM-24-02245
Paper Title	**Preparing First Responders for Future Electrical Vehicle Emergencies through Multimodality VR Training System**
Abstract	The human society's mobility tool is shifting the paradigm from combustion engine vehicles to electric vehicles (EV). The wide adoption of EVs will benefit the sustainability of society by improving fuel efficiency, lowering fuel and maintenance costs, and reducing carbon emissions. However, the rise of EVs also brings challenges, particularly in EV emergency responses, in which EV fires burn hotter and longer than traditional vehicle fires, and most first responders are not well prepared. This paper introduces a multimodality virtual reality (VR) training system designed to help firefighters understand EV fires. The proposed VR system allows the user to visualize different phases of the thermal runaway process during EV fires. The proposed system has four modules to enhance the fidelity and improve the presence for the user to understand the EV emergency response scenarios. The results from the preliminary evaluation case confirmed the usability and feasibility of the proposed multimodality VR training system.

Authors	Prabal Chandra Bhowmik Md Asif Raihan, Bangladesh University of Engineering and Technology Md. Shamsul Hoque, Bangladesh University of Engineering and Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02280
Paper Title	**Identification and Analysis of Crash Hotspots and Temporal Shifts using Kernel Density Estimation, Getis-Ord Gi*, and Spatial Autocorrelation (Morans I): A Case Study on N1 in Bangladesh**
Abstract	Road safety is a critical concern for transportation authorities worldwide, with Bangladesh being no exception. This study presents a comprehensive analysis of road crash patterns along the N1 in Bangladesh, focusing on identifying temporal shifts in crash hotspots and understanding whether the crashes exhibit dispersed, random, or clustered patterns. Crash data from three distinct time periods (2006–2011, 2012–2017, and 2018–2022) were collected and analyzed using a combination of spatial analysis techniques, including Network Kernel Density Estimation (NKDE), Getis-Ord Gi*, and Spatial Autocorrelation (Moran's I). The temporal analysis of hotspots across three time periods provides insights into the changing patterns of crashes. A comparison of hotspot locations across the three time periods reveals that hotspot locations are evolving over time, which may be attributable to the expansion projects and countermeasures implemented over the year. A random pattern of crashes has been observed between 2006 and 2011, indicating a very even distribution of crashes and signifying that there is no spatial correlation among crash incidents. However, a clustered pattern emerged in the subsequent time frame of 2012–2017, indicating localized areas with higher crash frequencies, forming distinct hotspots along the highway. From 2018 to 2022, however, the pattern switched towards dispersion, indicating an equal distribution of crashes, and shedding light on network-based road safety policies. This temporal perspective allows for an assessment of the effectiveness of implemented interventions and serves as a guide for future road safety strategies.

Authors	Zhongyu Yang, Georgia Institute of Technology Pingzhou (Lucas) Yu, Georgia Institute of Technology Ronit Shah Ron Knezevich, Georgia Department of Transportation Yi-Chang Tsai, Georgia Institute of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02292
Paper Title	**Crash Prediction on Horizontal Curves: Review and Model Performance Comparison**
Abstract	More than 25 percent of all roadway fatalities are associated with a horizontal curve, and the average crash rate for horizontal curves is about three times that of other types of highway segments. A focus on horizontal curves can prove to be a cost-effective approach to reducing safety issues. Accurate Crash Prediction Models (CPMs) on horizontal curves can help roadway safety practitioners assess and prioritize safety improvements. Although many CPMs have been developed, there are no extant studies that compare different CPMs on a singular, real-world, large-scale, and comprehensive dataset to evaluate their capability for horizontal curve crash prediction. This study critically evaluated commonly used CPMs, including multiple linear regression (MLR), Poisson Regression (PR), Negative Binomial Regression (NBR), Support Vector Machine (SVM), Random Forest (RF), and Fully Connected Neural Networks (FCNN) models, on 18,000 centerline miles of Georgia's state-maintained routes and statewide historical crash data set from 2013 to 2021. Results show PR and NBR models outperform the MLR by around 6%. Moreover, the FCNN and RF models further improved this performance by around an additional 6% over the PR and NBR models. Overall, machine learning (ML)-based models outperform generalized linear regression models. The results prove ML-based models can be recommended to transportation agencies to forecast horizontal curve crashes more accurately.

Authors	Caitlin Northcutt, University of Kentucky Nikiforos Stamatiadis, University of Kentucky Tony Fields, Kentucky Transportation Cabinet Reginald Souleyrette, Kentucky Transportation Cabinet
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02382
Paper Title	**Data Linkage and Text Mining to Estimate Occupational Crashes for Small and Medium Size Vehicles**
Abstract	Occupational motor vehicle crashes (OMVCs) are the most prevalent cause of injury-related fatalities of workers in the US (24%). Statewide crash databases are a good source for identifying crashes involving large commercial vehicles but have limited ability to identify occupation-related injuries involving passenger cars or light trucks. This could lead to underestimation of the OMVC counts and an incomplete picture of the magnitude of the problem. The Kentucky Occupational Motor Vehicle Injury Surveillance (OMVIS) system was conceived to build a more complete database of OMVCs and establish surveillance trends. The first step in the development of the OMVIS database was to identify OMVCs for light and medium vehicles, i.e., passenger cars, pickup trucks, sport utility vehicles, and vans. A two-step process was developed utilizing 1) a machine learning approach for mining crash narratives and 2) a data linkage effort between crash data and workers compensation (WC) claims records. Crash narrative data mining process resulted in the identification of approximately 5 percent of Kentucky's crashes as occupationrelated in 2019. A series of validation efforts were conducted to ensure the quality and accuracy of the crash classification. Manual linkage of motor vehicle crash-related WC claims to crash records further identified more than 300 additional OMVCs that were otherwise missing from the traditional counting method based solely on vehicle types within the statewide crash database. Minimal overlap of the two surveillance methods supports additional efforts to utilize text narrative mining in combination with linkage methodology across surveillance databases.

Authors	Yang Li, University of Wisconsin, Milwaukee Xiao Qin, University of Wisconsin, Milwaukee Md Sayed, University of Wisconsin, Milwaukee Md Hossain, University of Wisconsin, Milwaukee Mohammad Amer, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02556
Paper Title	**A Systematic Review of Machine Learning Methods for Traffic Crash Modeling**
Abstract	Although conventional statistical methods have been widely applied with some successes in traffic crash modeling and analysis, they have well-acknowledged limitations such as pre-assuming linear or nonlinear relationships between the exploratory variables and the response variable. With the rapid advancement of artificial intelligence (AI) and increasing availability of safety data, machine learning (ML) techniques have quickly gained popularity in safety analysis. Compared to conventional statistical methods, ML has fewer pre-defined assumptions. The objective of this review is to summarize, characterize, and evaluate studies that used ML techniques for traffic crash modeling and analysis; and to identify unresolved research issues regarding their uses in safety analysis. A systematic review of studies in the last decade (2012-2021) that use ML techniques for crash modeling and analysis was performed, with a focus on their modeling performance. The observations based on approximately 200 papers have been provided from various perspectives, including research topics, focus areas, and methods. The relationships between research topics, focus areas, and methods, as well as the research trends, were examined followed by a discussion on research issues, proposed solutions, and limitations in existing works.

Authors	Saumik Sakib Bin Masud, University of Kansas Kirti Mahajan, University of Kansas Kondyli Alexandra, University of Kansas Katerina Deliali, National Technical University of Athens (NTUA) George Yannis, National Technical University of Athens (NTUA)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02607
Paper Title	**Leveraging Machine Learning Algorithms to Predict and Analyze Single-Vehicle and Multi-Vehicle Crash Occurrences on Motorways**
Abstract	Road crashes are a common occurrence in many parts of the world, causing significant loss of life, injury, and economic damage. Crashes can be broadly classified into single-vehicle crashes (SV) and multivehicle crashes (MV). Various statistical approaches have been implemented to identify the key factors behind these two types of crashes and it has been concluded that these factors need to be analyzed separately. The dataset for this research included various types of roadway design parameters and traffic conditions. Combinations of three feature-selection techniques such as ANOVA, correlation matrix, and ExtraTreesClassifier algorithm were utilized to separately select the appropriate variables for SV and MV crash analysis. Various Machine Learning (ML) models (e.g., LightGBM, XGBoost, etc.) along with a statistical method (binary logistic regression) have been adopted to predict SV and MV crash occurrences. The results show that gradient-boosting type ML algorithms outperform the remaining prediction models and the LightGBM was found to be the most powerful in prediction. The LightGBM classifier produced accuracy, ROC_AUC, and avg. F-1 score of 0.75, 0.83, and 0.76 respectively for MV crashes and 0.76, 0.82, and 0.76 respectively for SV crashes. The SHapley Additive exPlanations (SHAP) analysis was used to explain how each variable impacted the models' output. The results confirmed that the crash factors associated with SV and MV crashes are different and that some variables have inverse impact. Artificial intelligence and ML can assist transportation professionals in better understanding the causes of SV and MV crashes and advance the process toward Vision Zero.

Authors	Mahsa Jafari, Ryerson University: Toronto Metropolitan University Bhagwant Persaud
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02691
Paper Title	**Structural Equation Modeling: A Viable Tool for Investigating Behavioral Factors Contributing to Road Crashes?**
Abstract	Among the methodologies used in research for investigating the effect of different behavioral characteristics on traffic crashes, Structural Equation Modeling (SEM) is prominent due to its ability to analyze different data types. With this in mind and given the importance of understanding the contribution of human behaviour in traffic crashes, the objective of this study was to investigate the usefulness of SEM for providing this understanding. In this paper, we present a systematic review of 19 articles relevant to this objective. These were found from available digital libraries through keyword search, title screening, and screening for developed models. Based on the defined categories regarding the independent variables, sleep, and risky driving were found to have the greatest influence on crash involvement. This and other results of this study highlight the viability of SEM as a tool for ultimately mitigating the undesirable effects of behavioral characteristics on road safety by providing the means for understanding those characteristics.

Authors	Brian Porter, Florida Department of Transportation Joseph Post, University of South Florida Achilleas Kourtellis, University of South Florida Yu Zhang, University of South Florida
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 2051
Session Title	Emergency Responder Safety, Travel Demand, and Routing
Paper Number	TRBAM-24-02737
Paper Title	**INCORPORATING UAS INTO STATE TRAFFIC INCIDENT MANAGEMENT PROGRAMS**
Abstract	All states in the US have a Traffic Incident Management (TIM) Program funded by state tax revenue. The state DOTs are responsible for hosting this program to timely clear roadway incidents. The federal government provides research and other resources to aid states in creating their TIM program and to keep it updated. Closed Circuit Television (CCTV) cameras are the main technology currently used by Traffic Management Centers to gather information about an incident. Unmanned Aerial Systems (UASs) are a new technology that can play the role of stationed or mobile sensors to provide video feed but are currently underutilized in TIM due to their novelty. A survey was developed and sent to state DOTs to understand common challenges faced during the TIM Process and to investigate if UASs could help alleviate any of these challenges. Keywords: Congestion Reduction; Incident Detection; Incident Response; Incident Clearance; Unmanned Aerial Systems.

Authors	Hongyue Wu Xingzhou Guo, University of Minnesota, Duluth Chi Tian, Purdue University Yunfeng (Cindy) Chen, Purdue University Jiansong Zhang, Purdue University James Jenkins
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02750
Paper Title	**Understanding the Causes of Work Zone Crashes from the Color-related Perspective: Indiana Crash Data Analysis using Natural Language Processing (NLP)**
Abstract	Color is a key factor impacting work zone safety. Existing studies explored the causes of work zone crashes without considering color-related factors or only discussed one or two color-related factors regarding single work zone elements based on small-scale experiments. To address the gaps, this study aims to explore the causes of work zone crashes by integrating the color-related factors and considering different work zone elements relying on the large-scale Indiana crash data and literature review. Natural Language Processing (NLP) approach was applied to extract the key information from crash data by generating top n-grams, correlation heatmaps, and network graphs. The findings were also compared with the causes of work zone crashes from the literature. By connecting NLP results with color-related factors from literature, three causes of work zone crashes from the color-related perspective were summarized: insufficient color contrast between work zone elements and the overall environment, poor visibility and brightness of color for work zone elements, and lack of changes in color for work zone elements in dangerous areas. Examples of work zone elements and dangerous areas in work zones were summarized based on NLP results. The study contributes to a new understanding of the causes of work zone crashes from the color-related perspective and provides color-related recommendations to help reduce work zone crashes in practice.

Authors	Kazi Redwan Shabab Tanmoy Bhowmik, Portland State University Naveen Eluru, University of Central Florida Mohamed Zaki, University of Western Ontario
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lectern Session 4003
Session Title	Safety Performance and Analysis Research
Paper Number	TRBAM-24-02850
Paper Title	**A Systematic Unified Approach for Addressing Temporal Instability in Road Safety Analysis**
Abstract	Multivariate models are widely employed for crash frequency analysis in traffic safety literature. In the context of analyzing data for multiple instances (such as years), it becomes essential to evaluate the stability of parameters over time. The current research proposes a novel approach, labelled the mixed spline indicator pooled model, that offers significant enhancement of current approaches to capture temporal instability. The proposed entails carefully creating additional independent variables that allow us to measure parameter slope changes over time and can be easily integrated into existing methodological frameworks. The current research effort compares four multivariate model systems: year specific negative binomial model, year indicator pooled model, spline indicator pooled model, and mixed spline indicator pooled model. The model performance is compared using log-likelihood and Bayesian Information Criterion. The empirical analysis is conducted using the Traffic Analysis Zone (TAZ) level crash severity records from Central Florida for the years from 2011 to 2019. The comparison results indicate that the proposed mixed spline indicator pooled model outperforms the other models providing superior data fit with significantly fewer parameters. The proposed mixed spline model can allow a piece-wise linear functional form for the parameter and is suitable to forecast crashes for future years as illustrated in our predictive performance analysis.

Authors	Noah Goodall, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-02913
Paper Title	**Comparability of Automated Vehicle Crash Databases**
Abstract	Advanced driving assistance systems are available on many late-model vehicles, and automated driving systems are testing on public roads. Regulators and developers continue to assess the safety of these vehicles by comparing automated vehicle crash rates to baseline, human-driven crash rates. While there are several widely-cited automated vehicle and conventional vehicle crash databases, these databases have different underlying assumptions and inclusion criteria. Crash rates among databases may be directly comparable only with significant filtering and normalization, if at all. This paper reviews current automated vehicle and baseline human-driven crash databases and evaluates their comparability. Recommendations are presented to improve their comparability, both in terms of normalization and contextualization, as well as additional data fields that can be incorporated into existing databases. These findings may assist researchers, regulators, and automated vehicle developers attempting to evaluate the safety of driving automation systems.

Authors	Mahanaz Faiza Sadia Sama Chowdhury Jemeem Jaanvi Ashrar Washi Moinul Hossain, Islamic University of Technology Md Asif Raihan, Bangladesh University of Engineering and Technology Mohammed Quddus, Imperial College London
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-02930
Paper Title	**Analyzing the relationship between built environment, road encroachment and road safety: a comparative study**
Abstract	In developing countries, road encroachment is an overlooked risk factor behind many road crashes. Existing literature has, therefore, evaluated the impact of encroachment on traffic characteristics. However, several crucial factors that influence encroachment and are influenced by it have not been thoroughly investigated yet. This study examines the reciprocal relationship between the built environment and different levels of encroachment from a road safety perspective. For that, 249 four-legged national and regional intersections of Bangladesh were selected as the study area. From those intersections, data on the intersections' dimensions of permitted traffic movement, land use, road furniture, pedestrian facility, traffic control mechanisms, right-of-way, public transport, goods vehicle, and visibility were extracted and represented as factors of encroachment in a fishbone diagram. Next, a decision tree algorithm was employed to detect the most important clusters of these variables. Furthermore, multinomial probit model was produced to mathematically explain the relationship between the built environment and encroachment from a safety perspective. The findings revealed a strong association between highly encroached intersections and utility-based land use patterns. It also underscored that high encroachment due to illegally parked vehicles creates visibility obstruction and discontinuity in pedestrian movement. Pavements and shoulders having effective lane markings and traffic signs can minimize the encroachment level and therefore, ensure safe movements.

Authors	S. Madeh Piryonesi, University of Toronto
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02953
Paper Title	**Incident Prediction on Urban Roads Using Data Fusion: The Case of Toronto**
Abstract	This paper presents a case study about using both SQL and non-SQL data for predicting road incidents at the City of Toronto. Road incidents can adversely affect the traffic and exacerbate road congestion. Using machine learning for predicting the probability of incidents, their severity and areas more prone to incident can help municipalities and departments of transportation (DOTs) improve road level of service while allocating their resources more effectively. In this paper, data of incidents in the City of Toronto was used to demonstrate how data analytics can help predict road incidents and their severity. The dataset included both SQL and non-SQL (written comments) data. A data fusion approach was used to merge these two types of data. Machine learning tree-based models were used to predict when and where major incidents occur on two major roads in the city: Gardiner Expressway and Don Valley Park (DVP). The developed models predicted the occurrence of major incidents, using solely SQL data, with an accuracy of 93%. After combing the SQL and non-SQL data for prediction, the model accuracy increased to 97%. Next, models were trained to predict the required time for incident scene clearance on the road. The accuracy of this model for predicting three classes was around 60%. After including the attributes extracted from the textual data, the accuracy increased to 81%. Several recommendations, related to standardized data collection, were made to improve the city's procedures. These recommendations can be useful to any municipality or DOT.

Authors	Thomas Cabe Yi-Chang Tsai, Georgia Institute of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-03168
Paper Title	**Studying Crash Characteristics and Contributing Factors Using Historical Crash Data to Enhance Senior Driver Safety**
Abstract	With the rapidly growing senior population, ensuring the safety of older drivers has become a critical concern in transportation research. However, there are limited studies utilizing large datasets to analyze crash characteristics in senior driver related collisions. To address this gap, this paper proposes the following methodology: 1. Prepare a comprehensive crash data set (3.37 million records from 2013 to 2021), 2. Select senior driver related collisions based on age (468,000 records), 3. Analyze crash characteristics using Numetric, 4. Compare senior and non-senior driver crash characteristics to identify concerns for seniors, and 5. Identify the contributing factors by analyzing crash narrative data and reviewing psychological and physiological studies on seniors. Our study of 3.37 million crash records reveals most fatal senior driver related crashes involve angle collisions with another vehicle, whereas most non-senior driver related fatal crashes are not due to a collision with another motor vehicle. Angle collisions are a common type of crash at intersections because of failures to yield. Additionally, senior driver related crashes were found to be 44% more likely to be fatal and 47% more likely to be attributable to a failure to yield. Intersections are particularly difficult for seniors; subsequently, 55% of senior driver related crashes are intersection related, compared to 46% for non-senior driver related crashes. The disparity in crash characteristics presented above is likely related to age related ailments based on our literature review. However, further investigation is required such as a comprehensive study of seniors' behavior while driving using sensing technologies.

Authors	Pengfei Gao, Southwest Jiaotong University Bin Shuai Rui Zhang, Southwest Jiaotong University Bao Wang, Southwest Jiaotong University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03253
Paper Title	**STCM-GCN: A Spatio-Temporal Prediction Method for Urban Road Traffic Accidents under Road Network Constraints**
Abstract	To further enhance the fusion and coordination of multi-source data for more accurate spatio-temporal prediction of urban road traffic accidents, this paper proposes a new method called Spatio-Temporal Composite Multi-Graph Convolutional Neural Network (STCM-GCN). The method integrates heterogeneous data with three attributes, i.e., spatial, temporal and spatio-temporal data. The spatial module utilizes residual-connected GCN blocks to capture spatial features based on road network topology and traffic pattern similarity. The temporal module employs a combination of multilayer bi-directional GRUs and self-attention mechanisms to extract temporal features. The spatio-temporal module combines residual-connected GCN blocks with GRUs to capture dynamic spatio-temporal information and incorporates spatio-temporal distribution information of traffic violations for the first time. The feature fusion module utilizes an attention mechanism to adjust the weights of the three feature components before fusion to obtain the final output. In addition, in order to reduce the sparsity of accident data, this paper also introduces accident police data as official data expansion. Experiments utilizing real-world data collected from Shenzhen, China, show that our model outperforms other baseline models in terms of overall prediction performance, robustness under various spatio-temporal conditions, and ability to capture positive instances. The ablation experiments further validate the rationality and necessity of our model design and structure.

Authors	Chang Liu Xiaohua Zhao, Beijing University of Technology Ying Yao, Beijing University of Technology Jushang Ou Hang Qi, Beijing University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-03347
Paper Title	**A Study of Freeway Crash Impacts Considering Unobserved Heterogeneity: Introduction of Driving Behavior Data and Traffic Flow Data**
Abstract	Freeway crashes are influenced by various factors, including road alignment, traffic flow, environmental characteristics, and aggressive driving behavior. This study aims to analyze the causal effects of these factors on freeway crashes and examine the role of unobserved heterogeneity. We employ the random parameter logit model (RPL) and the random parameter logit model based on mean and variance heterogeneity (RPL_HMV) to investigate the underlying causes of freeway crashes. The results indicate that the RPL_HMV model is superior in addressing the problem of unobserved heterogeneity. The coefficient of variation of speed, horizontal curvature, and the number of vehicles were found to have random effects on freeway crashes. Furthermore, the frequency of sharp deceleration behavior, length of road section, and rain were observed to influence the degree and randomness of the impact of these random parameters on crash outcomes. Additionally, we estimate the elasticity to quantify the safety impact of explanatory variables on highway crashes. The length of the road section, horizontal curvature, downhill slope, coefficient of variation of speed, number of vehicles, rain, frequency of sharp acceleration behavior, and frequency of sharp deceleration behavior were found to significantly affect freeway crashes. This study introduces a novel perspective on the analysis of freeway crash causation by integrating data on aggressive driving behavior and considering the role of unobserved heterogeneity in crash impacts, building upon existing freeway safety research.

Authors	Monik Gupta, Indian Institute of Technology, Bombay Rajesh Meena Nagendra Velaga, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03527
Paper Title	**The Validation of Motorized Two-Wheeler Simulator: Evaluation of Relative Validity Considering Distraction, Road Infrastructure, and Individual Characteristics**
Abstract	The driving simulators provide the flexibility to perform experiments in better controlled conditions without compromising the safety of the drivers. However, before inferring the concluding evidence from simulator-based studies it is required to evaluate the limitations and validity of the driving simulator. In this study a comparison of motorized two-wheeler simulator with naturalistic field data is performed to analyze the validity of the simulator. This study considered distracted driving condition, road geometry variation, and individual characteristics as the control factor for evaluating the relative validity of the simulator. The mixed linear models were developed to analyze the impact of control factors on riders' speed by considering the simulator or field driving as grouping variable. This study showed that riders generally maintained a higher speed in the riding simulator compared to real-world driving. However, the developed models revealed that relative variation across various road sections, distracted driving conditions are similar in both riding simulator and actual field conditions. This study also evaluated the impact of perceived realism and exposure of electronic devices on the riders' performance in simulator. The results suggested that riders' realistic performance can be improved if the roadside infrastructure is replicated adequately while designing the simulator experiment. The findings also suggested that older drivers have more variability in their performance on simulator since they tend to experience higher simulator sickness than younger drivers. Overall, this study found an overall relative validity for the riding simulator and suggested insights to be considered while conducting and analyzing the simulator-based studies.

Authors	Ruru Tang Haicheng Liao Zhenning Li, University of Macau Cong Chen, University of South Florida Ziyuan Pu Kai Zhang, Tsinghua University Wenyu Li Shengbo Li Chengzhong Xu, University of Macau
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03585
Paper Title	**Robust Bayesian Regression for Outlier Mitigation in Traffic Crash Analysis**
Abstract	Traffic crash analysis is critical for improving road safety; however, it is often challenged by the presence of outliers in crash datasets, which can significantly affect the accuracy and reliability of traditional methods. In this study, we propose a novel approach to address this issue through a robust Bayesian regression model, known as the "robit" model. The robit model uses a heavy-tailed Student's t distribution as the link function, which effectively reduces the influence of outliers and improves the robustness of the analysis. To further improve the estimation efficiency of the posteriors, we introduce a sandwich algorithm based on data augmentation. The proposed model is rigorously evaluated on a dataset of tunnel accidents, demonstrating its superior performance compared to conventional methods. The results show that the proposed model provides greater efficiency and robustness in dealing with outliers, thus providing more accurate estimates of crash data. In addition, the study uncovers several significant factors, such as night driving and speeding, which significantly affect the severity of injuries in tunnel crashes. This research contributes to a comprehensive understanding of outlier treatment methods in road safety studies and provides valuable recommendations for developing effective countermeasures to prevent severe injuries in tunnel crashes.

Authors	Saroj Rajwar Prasanta Bhuyan, National Institute of Technology, Rourkela Mahabir Panda, National Institute of Technology, Rourkela
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03645
Paper Title	**Analyzing and Ranking Causes of Road Accidents in Mining Areas: Insights from Road Safety Experts**
Abstract	This study investigates various causes of road accidents around mines area and derived their ranking with a reference to mines area of Jharkhand State, India. The basic causes of road accidents were identified through literature survey and subsequently a paper-based face to face interview questionnaire was prepared and responses in the numerical scale of seven points were collected from nine road safety experts of different field. The nine experts were from different areas of expertise as Motor Vehicle Inspector, Road Safety Engineer, District Road Safety Manager, Police officers, and Road safety researchers. The collected expert opinion survey data were analysed by using five established methods namely Multi criteria Decision Making model -Weight Summation Model (WSM), Weight Product Model (WPM), Grey Relation Analysis (GRA), Technique for order preference by similarity to ideal solution (TOPSIS) and Combined Compromise Solution (CoCoSo) to evaluate the variation in the derived attributes rankings determined from these methods. Spearman rank correlation coefficient was used to compare the ranks obtained from these methods, and it indicate all the five ranking methods have a strongly positive rank order relationship exist among themselves. The consistency of the results indicates the causes of road accidents in mines area roadways associated with human characteristics.

Authors	Younghoon Seo Jihyeok Park, Ajou University Gyungtaek Oh Hyungjoo Kim, Advanced Institute of Convergence Technology Chiwoo Roh Jia Hu, Tongji University Jaehyun So, Ajou University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-03694
Paper Title	**Extracting Traffic Crash Information from Imbalanced-Unstructured Traffic Crash Description Texts Using a Text Classification Modeling Technique**
Abstract	Most data-driven traffic safety studies rely on structured data recorded in a standardized format, whereas unstructured data recorded by police officers in the form of textual descriptions are ignored, despite the fact that such texts include detailed information on traffic situations. This is primarily owing to difficulties in text analysis because such traffic crash descriptions vary significantly in the word choice, format, and length, depending on the person who recorded them. To overcome this issue, this study developed a methodology to classify important words in unstructured data describing traffic crash situations into standardized data. The proposed bidirectional encoder representation from transformer (BERT)-based crash description text classification model provides a practical method for enabling the interpretation of text-based traffic crash descriptions and demonstrates better performance than other natural language processing models. Furthermore, the additional information extracted from traffic crash descriptions using this method can facilitate an improved understanding of the specific nature of traffic crashes and ultimately help prevent traffic crashes by providing appropriate countermeasures.

Authors	Subasish Das, Texas State University Ahmed Hossain, University of Louisiana, Lafayette M. Rahman Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-03729
Paper Title	**Exploring Factors Contributing to Frontage Roadway Crashes Using a Probabilistic Graphical Model**
Abstract	Frontage roads play a crucial role in providing access and connectivity between freeways, principal arterial roadways, and adjacent commercial and non-commercial areas in the U.S. Specifically in Texas, frontage roads are a key design solution to facilitate access along rural freeways and principal arterial routes. These roads typically function as two-way roads in less developed urban and rural regions, while in urban and city-centered areas, they predominantly operate as one-way roadways. Despite their importance in enhancing accessibility, frontage roads also pose significant safety concerns, which have not been thoroughly investigated until now. To address this gap in knowledge, this study examined safety issues related to frontage roads by analyzing six years (2014-2019) of frontage road crash data (235,522 crashes) collected in Texas. The primary objective is to develop conditional probability models that shed light on the causal patterns of crash occurrences on these roadways. The results can provide valuable evidence for policymakers, traffic engineers, and transportation agencies to develop evidence-based safety strategies and policies. The findings will be instrumental in guiding safety improvements and traffic engineering interventions tailored to frontage roads, ensuring safer travel experiences for road users, including pedestrians and cyclists, and reducing the potential for traffic conflicts and collisions.

Authors	Hou Xuerui Xuerui Hou Meiling Su Chenhui Liu, Hunan University Ying Li, Chang'an University Qinglu Ma, Chongqing Jiaotong University Chaoru Lu
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-03755
Paper Title	**Examination of Electric Vehicle Traffic Safety: A Case Study in Norway**
Abstract	With the great increase of electric vehicles (EVs) in the past decade, the EV-involved traffic accidents have also been increasing quickly, brining many new traffic safety challenges. Norway has the largest EV penetration rate in the world. Using the crash data of Norway in 2020 and 2021, this study aims to completely investigate the characteristics of EV accidents. During this period, there were 930 EV accidents occurring in Norway. It is found that rear-end collision is the major collision type, and EVs are more likely to collide with pedestrians/cyclists. Besides, EV accidents are found to occur mainly during weekday peak hours, and road segments with medium and low speeds, good visibility, and dry road surface conditions. Then, an ordered logistic regression model is established to identify the key factors affecting the EV accident size, a surrogate of accident severity. It finds that time of day, speed limit, and presence of medians, have statistically significant impacts on the EV accident size. Finally, countermeasures are proposed based on the research results.

Authors	Shi Dong Zhiwei Cui, Chang'an University Daniel(Jian) Sun, Chang'an University Liming Ye Shengxuan Ding
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-03775
Paper Title	**How Does Environmental and Road Factors Impact Automated Vehicle (SAE Level 2) Crash Results? A Network and Coupling Analysis**
Abstract	In recent years, extensive on-road testing has been conducted to monitor the safety of automated vehicles (AVs) in real-world conditions. Environmental and road (ER) factors notably contribute to AV crashes. However, the effects of ER factors on AV crash events remain unclear due to the limited number of studies conducted in this area. This study aims to explore their influence mechanisms through investigating AV at SAE Level 2. First, empirical data from the Autonomous Vehicle Operation Incident Dataset (AVOID) were obtained to cleansing and processing, resulting in a refined dataset comprising 709 crashes. Five categories of ER factors were extracted, along with two types of crash results. Next, a combination of two-mode social network analysis and N-K model was employed to analyze the relationships and coupling interactions. The results indicate that: snow and traffic incident/work zone are exclusively associated with collisions involving fixed object and vehicle, respectively. Dark-lighted, rain and wet road surface have a stronger impact on crash results. Ten ER core factors and three core crash results were revealed, which the ER core risk factors includes rain, wet, dark-lighted and intersection. The risk associated with coupling modes involving rain and wet conditions is higher than that of other. The four high-risk combinations can be addressed through improvements in sensors, target recognition algorithms and the promotion of dedicated AV lanes. Finally, safety recommendations for AV based on ER factors were proposed based on the findings, which may be improved as AV safety guidelines and applied in high-level scenarios.

Authors	Xiyang Chen Meiling Su Chenhui Liu, Hunan University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-03816
Paper Title	**Exploration of Characteristics of Road Closures Caused by Bridge Traffic Accidents: A Case Study in Pennsylvania, USA**
Abstract	When crashes occur, roadways often need to be closed for emergency response, which would greatly interrupt traffic operations. Many studies have discussed the road closure issue caused by crashes, but few of them have focused on road closure events on bridges. However, bridges are the critical components of roadways. Their unique geometry determines that road closures on bridges could impair traffic operations more seriously. Using traffic accident data from 2001 to 2020 in Pennsylvania, this study aims to identify the characteristics and trends of roadway closure events due to bridge traffic accidents. First, bridge traffic accidents and non-bridge ones were compared in terms of collision, environment, driver, and vehicle features. Bridge traffic accidents are confirmed to be more likely to result in lane closures than non-bridge ones, and they also have the longer average road closure time. Compared with non-bridge ones, bridge traffic accidents occur more in winter. Then, a zero-inflated Poisson regression model is built to identify the factors influencing the road closure time. The modeling results show that bridge traffic accidents occurring on wet pavements, urban areas, and interstate or local roads have the significantly shorter lane closure time, whereas bridge traffic accidents involving hit-fixed-object collisions, DUI, speeding, and heavy trucks would result in the longer lane closure time. The findings are expected to provide new insights for agencies to develop effective measures to reduce durations of road closures caused by bridge traffic accidents. Keywords: Bridge traffic accidents, road closure, the zero-inflated Poisson regression model

Authors	Steve Jackson, Toxcel, LLC
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03833
Paper Title	**Introducing rfars, an R Package to Quickly Download and Analyze Crash Data from FARS, GES and CRSS**
Abstract	The National Highway Traffic Safety Administration (NHTSA) has established two important crash databases: the Fatality Analysis Reporting System (FARS) and the Crash Report Sampling System (CRSS), both of which are accessible via the Fatality and Injury Reporting System Tool (FIRST). However, extracting comprehensive data from these databases often entails cumbersome procedures involving annual ZIP files and extensive data dictionaries. The rfars R package was designed to expedite and enrich transportation safety analysis. rfars significantly simplifies the data extraction process by enabling users to retrieve FARS and CRSS data with a single line of code, producing a complete dataset ready for analysis. This paper introduces rfars and demonstrates how it facilitates data extraction and visualization in transportation safety analysis.

Authors	Joonho Park, Ajou University Juyeong Kim Haneul Park, Ajou University Jinsu Yoon Juneyoung Park, Hanyang University, Ansan Tiantian CHEN Changju Lee, Virginia Transportation Research Council Jaehyun So, Ajou University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-03846
Paper Title	**Assuring the Main Factors of Traffic Crashes: A Bibliometric Review of Literature from 2010 to 2022**
Abstract	What is the main factor of traffic crashes? Many studies have classified the factors of traffic crashes into three categories: human, vehicle and environment. However, with the advancement of vehicle technology and the establishment of strict standards for road facilities, there is a need to redefine factors that contribute to traffic crashes. Therefore, this study aims to collect factors that cause traffic crashes and create a taxonomy. A bibliometric search was conducted to collect relevant literature. 62 literature were finally selected for the study. Factors found to be significantly associated with traffic crashes in the selected literature were collected. A total of 78 factors were identified as contributing to traffic crashes. The collected factors were grouped according to their characteristics. Through two steps of grouping, the taxonomy of factors causing traffic crashes was finally completed. As a result of the grouping, the factors were classified into six categories: general information and demographics, human factor, vehicle factor, environment factor, road environment factor (time static) and road environment factor (time dynamic). Road type/shape, weather, and road surface were the most used factors. weather, road type/shape, and road surface were the factors with the highest number of significant relationships with traffic crashes, while speed, traffic volume, and drunk driving had the highest number of significant relationships relative to the number of uses. The results of this study are expected to identify the main factors of traffic crashes and contribute to reducing traffic crashes in the future.

Authors	Maroa Mumtarin Ye Dong, Iowa State University Sudesh Bhagat, Iowa State University Jonathan Wood, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03914
Paper Title	**At-Fault or At-Bias: Evaluation of Equity Towards Motorcyclists on Accident Accountability**
Abstract	Motorcyclists face a unique set of challenges on the roadways. Firstly, they are exposed to a higher fatality rate in the event of a crash. On top of that, they are perceived as exhibiting higher risk-taking propensities compared to drivers of other vehicles and are more likely to get assigned the “at-fault” status if involved in a crash. This raises a pertinent question of whether there is any bias towards motorcyclists being assigned the at-fault status. Exploring this aspect of motorcycle crashes is germane to ensure equity in traffic safety. Hence, this study attempts to examine if there is any potential bias towards the motorcyclists in assigning at-fault in a traffic accident. This paper also delves into different driver, vehicle and crash-related attributes to understand their influence on at-fault assignment. For this purpose, the binary logistic regression model has been employed to investigate the California and Ohio data from the HSIS database. The results show that if the driver is a motorcyclist, there is a 19.7% and 7.79% higher chance of being assigned as at fault in California and Ohio, respectively. This percentage combines the actual likelihood of causing a crash and bias together. Additionally, significant difference for Ohio and California is reported. Results of this research contribute towards evidence of potential biases towards the motorcyclists in at-fault assignment.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette Md. Rabbi Shahrin Islam
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-03973
Paper Title	**Investigating the Complexity of Pedestrian Crashes at Non-intersection Locations: Applying Association Rules Mining to Reveal the Crash Patterns**
Abstract	Pedestrians are over-represented in crashes at non-intersection locations thus making it a serious traffic safety concern. This study investigates non-intersection crashes involving pedestrians using a crash database (2017-2021) collected from Louisiana State. As the risk of pedestrian crashes tends to vary with distance from the intersection, the research team utilized a unique framework 'distance to intersection' to capture the differences in crash patterns at nonintersection locations. The study identified that around 50% of non-intersection pedestrian crashes occurred within 198 ft. of the intersection. In the next step, the collected 3,135 pedestrian crashes at non-intersection locations during the study period were subdivided into three zones: D1 zone designates crashes occurring within 150 ft. of an intersection (1,277 crashes), D2 zone designates crashes occurring within 151 ft. to 435 ft. of an intersection (1,060 crashes) and D3 zone designates crashes occurring at 435 ft. or higher from an intersection (798 crashes). To explore the complex interaction of multiple factors, an intuitive data mining technique, Association Rules Mining was used. A total of the top 60 interesting association rules (20 for each zone) were identified by the algorithm (based on lift and support measures). The findings provide some critical insights into pedestrian crash involvement at non-intersection locations and how complex interaction of multiple factors variables according to 'distance to intersection'. The broader impact of this research can be the identification of problem-specific crash countermeasures customized according to distance to the intersection.

Authors	A. Latif Patwary, University of Tennessee Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 2051
Session Title	Emergency Responder Safety, Travel Demand, and Routing
Paper Number	TRBAM-24-04207
Paper Title	**Endogeneity of Pedestrian Survival Time and Emergency Medical Service Response Time: Variations Across Disadvantaged and Non-Disadvantaged Communities**
Abstract	The vision zero-safe systems approach prioritizes fast access to Emergency Medical Services (EMS) to improve the survivability of road users in transportation crashes, especially concerning the recent increase in pedestrian-involved crashes. Pedestrian crashes resulting in immediate or early death are considerably more severe than those taking longer. The time gap between injury and fatality is known as survival time, and it heavily relies on EMS response time. The characteristics of the crash location may be associated with EMS response and survival time. The US Department of Transportation Justice40 initiative identifies communities often facing challenges. Six disadvantaged community (DAC) indicators, including economy, environment, equity, health, resilience, and transportation access, enable an analysis of how survival and EMS response times vary across DACs and non-DACs. To this end, this study created a unique and comprehensive database by linking Justice40 DACs data with 2017-2021 pedestrian-involved fatal crashes. This study utilizes two-stage residual inclusion models with segmentation for DACs and non-DACs accounting for the endogenous relationship between EMS response and pedestrian survival time. The results indicate that EMS response time is higher and pedestrian survival time is lower in DACs than non-DACs. A delayed EMS response time is associated with a greater reduction in survival time in DACs compared to non-DACs. Factors, e.g., nighttime, and interstate crashes, contribute to higher EMS response time, while pedestrian drugs, driver speeding, and hit-and-run behaviors are associated with a greater reduction in survival time in DACs than non-DACs. The implications of the findings are discussed in the paper.

Authors	Maria Valencia-Cardenas, University of California, Davis Juan López, University of California, Davis Miguel Jaller, University of California, Davis
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	TRBAM-24-04297
Paper Title	**Spatial analysis of road crashes: A case study in Medellin, Colombia**
Abstract	The transportation and safety sectors aim to reduce road crashes and their societal and economic effects. By studying these events and examining related variables and their location and patterns, local authorities can identify critical zones to establish successful road safety initiatives and mitigate the negative consequences of their occurrence. This study aims to analyze traffic crashes' spatial and temporal patterns in Medellin, Colombia, to identify the characteristics of the high-risk areas and provide helpful information to authorities for having rapid response systems. To this end, spatial, temporal, and traffic variables provide vital information for predicting the number of crashes in various city areas. The study proposes a methodology integrating point pattern analysis, descriptive statistics, statistical characterization, and clustering analysis using a k-prototype model to capture a simple representation of similarities among crash data. The study also estimated a negative binomial (NB) model to identify the spatial and traffic parameters that help explain crash occurrences. The results show a concentration of crashes in Downtown Medellin, the area with the highest trip generation in the city. Road hierarchy, land use, and traffic variables correlate highly with crashes and influence spatial patterns. The clustering process found two main clusters with significant differences in the hierarchy and traffic conditions, and the NB unveiled a high correlation between the crash count and the large vehicle flow.

Authors	Taha Saleem, UNC Highway Safety Research Center Chris Cunningham, North Carolina State University Raghavan Srinivasan, University of North Carolina, Chapel Hill
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-04338
Paper Title	**Safety Evaluation of Conversion from a Conventional Signalized Intersection to a Continuous Flow Intersection (CFI)**
Abstract	This paper describes the efforts to evaluate the safety impacts of conversion from a conventional signalized intersection to a continuous flow intersection (CFI), with an aim of building on the current knowledgebase of CFIs by answering “Are these intersections expected to reduce crashes compared to other design alternatives?” An empirical Bayes (EB) before-after analysis was conducted on 16 typical CFIs. Overall, CFIs were found to significantly reduce total crashes by 12.2%. The most significant feature impacting safety at CFIs was the use of parallel vs. standard right turns, with parallel right turns having significant safety benefits (29.6% reduction) across the board and standard right turns increasing crashes (15.6% increase) in nearly all categories. Rural locations were significantly safer overall compared to urban/suburban designs (40.3% vs. 26.0% reduction). Although both site types showed improvement in safety, 4-legged sites provide the best overall results for all crash category types and 3-legged sites were only significant in one of the categories. While comparing CFIs with 1-lane and 2-lane crossovers, 2-lane crossovers were found to significantly decrease crashes (34.9% reduction), indicating that moving dual lane left turns upstream from a standard intersection has the greatest benefit.

Authors	Angela Haddad, University of Texas, Austin Aupal Mondal, University of Texas, Austin Naveen Eluru, University of Central Florida Chandra Bhat, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-04392
Paper Title	**A Novel Integrated Approach to Modeling and Predicting Crash Frequency by Crash Event State**
Abstract	In this study, we propose a novel integrated parametric framework for analyzing multivariate crash count data based on linking a univariate count model for the total count of motor vehicle crashes across all possible crash states with a discrete choice model for crash event state given a crash. In doing so, we are able to use information at the disaggregate crash-level from an unordered model structure in analyzing the aggregate level crash count. To our knowledge, this is the first such model proposed in the econometric literature. We apply this approach in a demonstration exercise to examine the number of motor vehicle crashes in Census Block Groups (CBGs) in Austin, Texas, considering four injury severity levels. Our model estimation results indicate a significant and positive linkage between the disaggregate crash event state dimensions and the total crash count. Through the use of elasticity measures, our results also clearly highlight the improved policy sensitivity of the integrated model framework.

Authors	Md Nasim Khan, Texas State University Subasish Das, Texas State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-04412
Paper Title	**A Systematic Review on Safe System Approach and its Applications in Highway Safety**
Abstract	The Safe System Approach (SSA) has gained prominence as a comprehensive framework for enhancing traffic safety by prioritizing system-wide interventions. This systematic review examines the implementation and impact of the SSA on overall traffic safety. Through an exhaustive search and critical analysis of relevant studies, this review provides insights into the effectiveness of the approach in reducing road traffic fatalities and injuries. Additionally, it explores the challenges and opportunities associated with its implementation, including policy initiatives, institutional frameworks, and stakeholder collaborations. The findings highlight the potential for the SSA to create a more forgiving and resilient transportation system, offering valuable guidance for policy decisions, future research, and interventions aimed at promoting safer road environments. This review contributes to the ongoing efforts to prioritize safety and transform the transportation landscape in the United States and other countries.

Authors	Hanchu Zhou, Central South University Fangrong Chang, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-04420
Paper Title	**What Should We Notice During the Crash Occurrence? An Investigation from Crash Narratives by Interpretive Machine Learning Method**
Abstract	The mainstream police-reported crash data used for injury analysis are mainly composed of static forced-choice variables. However, dynamic and detailed information on crash occurrence is important for a comprehensive understanding of crash-related injury mechanisms. To fill this research gap, crash narrative data are collected from Crash Investigation Sampling System (CISS) and used for injury analysis. A herein challenge with the narrative data is the processing of unstructured textual information. The study thus introduces a Local Interpretable Model-Agnostic Explanations (LIME) method to integrate useful information extraction from crash narrative data and quantitative injury analysis. The LIME is developed based on random forest approach and the results revealed a series of important factors associated with severely injured consequences, including verbs and nouns, such as depart, tree, and intersect. Based on the obtained important factors contributing to injury levels, a network-topology-based approach is used for identifying pairwise relationships that indicate high-risk traffic scenarios. A term community resulting in a higher probability of being severely injured result is identified as a high-risk scenario. A total of three high-risk scenarios are centered on tree, curve, and ramp terms and encompass verbs and nouns. The important verbs and the high-risk scenarios can describe the dynamic procedures of crash occurrence. In this way, crash narrative analysis can be a supplement or substitute to conventional injury studies, especially when the tabulated crash data suffer from incompleteness issues. The findings add to the knowledge of motor vehicle crashes obtained based on the tabulated policereported crash data.

Authors	wen cheng, California State Polytechnic University, Pomona Kirill Rogovoy, California State Polytechnic University, Pomona Seyedbamdad Sharifiilierdy, California State Polytechnic University, Pomona Omar Mora, California State Polytechnic University, Pomona Rosalyn Lu Yichi Cheng
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-04454
Paper Title	**Enhancing Daily Crash Count Prediction using Deep Learning: Window Size Selection and Seasonality Predictor Integration**
Abstract	The escalating need for proactive safety measures, coupled with advancements in data collection and analytical techniques, has significantly refined the accuracy of crash count predictions, shifting from annual scales to finer daily or hourly estimates. This research places emphasis on Recurrent Neural Networks (RNNs), specifically the Long Short-Term Memory (LSTM) model, acknowledged for effectively managing sequential data in time series predictions. Paramount considerations encompass the treatment of input data, including the decision to incorporate temporal features alongside endogenous historical target values, and the establishment of an optimal window size for data input. Despite the critical nature of these facets, exhaustive studies concurrently investigating both under controlled conditions are scarce. This research addresses this gap, assessing diverse scenarios featuring distinct temporal treatments and window sizes, employing an LSTM model with uniform fine-tuned parameters to ensure a fair comparison. With eleven years of daily crash count data, the study measures performance based on the correlation and differences between actual and predicted crash counts, setting the stage for superior future interventions. Findings indicate a significant variation in performance among models employing different window sizes and month predictor integration, under identical RNN structures and LSTM configurations. The embedding model displayed superior learning efficiency, requiring fewer epochs to achieve comparable prediction accuracy. Unlike seasonality predictor treatment, diverse window size selections did not lead to statistically significant differences in model performance.

Authors	Md Nasim Khan, Texas State University Subasish Das, Texas State University Jinli Liu
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-04626
Paper Title	**Investigating Seasonal Variability Patterns in Motorcycle Crash Injury Types Using Association Rules Mining**
Abstract	This study investigates the contributing factors and temporal variation in motorcycle crashes, with a particular focus on the differing severity levels: fatal, injury, and property damage only (PDO). Using five years of Massachusetts Department of Transportation (MassDOT) motorcycle crash severity data from 2016 to 2020, a comprehensive dataset was constructed comprising variables related to roadway geometry, crash characteristics, environmental conditions, and driver characteristics. Motorcycle-related crashes were grouped into four temporal clusters, namely summer, fall, winter, and spring, based on seasons. A comparative analysis approach was employed using association rules mining to uncover patterns and identify crash-contributing factors. By generating, evaluating, and visualizing association rules for each severity level within each cluster, significant findings were unearthed. Significant associations are observed between fatal crashes in summer and factors such as aggressive driver behavior, dark unlit conditions, and clear weather. Similarly, factors including collisions with other motor vehicles and driving on roadways without a right shoulder are linked to PDO crashes in summer. In winter, fatal crashes are associated with conditions such as driving on two-way undivided roadways and angle collision types, with young riders identified as particularly vulnerable. Spring fatal crashes demonstrate frequent connections with high traffic volumes, aggressive driving behavior, and high-speed roadways. This study provides valuable insights for stakeholders, aiding the development of strategies for motorcycle safety improvements like roadway enhancements, safety campaigns, and better lighting and traffic management.

Authors	Md Sayed, University of Wisconsin, Milwaukee Xiao Qin, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-04678
Paper Title	**A Structure and Narrative Data Fusion-based Machine Learning Approach to Classifying Distracted Driving Crashes**
Abstract	datasets and more efficient identification of misclassified crashes. In this study, Machine learning based Logistic Regression (LGR) with structure and narrative data fusion was utilized to achieve three primary objectives: identifying misclassified crash features, detecting potential false negatives during manual review, and retrieving crashes misclassified by police officers in the crash reports. The model was evaluated using distracted driving (DD) crashes in Wisconsin and its performance was compared with base models from three test datasets: the dataset of reported DD containing solely police-reported flags, the dataset of augmented DD including both police reported DD and manually retrieved crashes that are not reported as DD, and the dataset of recovered DD comprising manually retrieved flags from police-reported non-distracted crashes. The proposed LGR model consistently demonstrated the most balanced and effective results of identifying distracted driving crashes across different datasets. The study compared predictors present in the structured data of crashes (true positives) that were not detectable through narrative review and crashes (false negatives) that were retrieved through manual review. The comparison revealed distinct patterns, with true positives showing predictors unrelated to vehicle or driver behavior, while false negatives were predominantly associated with in-vehicle activities.

Authors	Nicholas Ferenchak, University of New Mexico
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 2051
Session Title	Emergency Responder Safety, Travel Demand, and Routing
Paper Number	TRBAM-24-04718
Paper Title	**Someone Call 911! The Impact of Communication Advances on Emergency Notification and Response Times for Fatal Rural/Urban Motor Vehicle Collisions**
Abstract	Past research has identified an approximately 50% reduction in the response time (RT) of emergency medical responders for fatal U.S. motor vehicle collisions over the last four decades. To further improve safety outcomes, we seek to better understand where, when, and how these improvements were realized. What proportion of the improvement has come from communication enhancements versus reduced travel times? Which technological developments have coincided with advances, and where is there potential for further development? How have RT improvements varied between rural and urban areas? To answer these research questions, we collected Fatality Analysis Reporting System (FARS) data on fatal motor vehicle collisions that occurred in the U.S. between 1975 and 2017. We use t-tests to explore rural versus urban and communication versus transport outcome differences and linear regressions to analyze longitudinal trends, specifically focusing on notable improvements in the early 1980s and late 2000s. Findings suggest that RT improvements have been driven by communication improvements, with two technological advancements – the 911 system and cell phones – coinciding with periods of substantially decreasing RT. These communication improvements have most significantly impacted rural areas, thereby lessening the rural/urban RT gap. Activation and travel times had no significant improvements over the study period. Results suggest that continued optimization of communication systems – particularly automated localization of notifications – may be an effective way to continue to improve RT.

Authors	Muhammad Adeel, The University of Tennessee Knoxville Numan Ahmad Behram Wali, Urban Design 4 Health, Inc. Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-04833
Paper Title	**Exploring the Associations of Rider Age and Experience on Motorcycle Injury Crash Risk: Evidence from A Case-Control Study**
Abstract	Motorcycle riding offers travel options, freedom, and thrill to road users. However, motorcyclists are more vulnerable to a substantially higher risk of crashes and severe injuries than motorized users. Understanding the factors contributing to motorcycle crash risk, especially rider age, experience, and training, is essential for developing effective safety measures. This study explores the relationships between these variables and motorcycle crash risk to identify potential safety interventions. Rider age, experience, and training can account for a substantial portion of the risk. Using a unique and comprehensive matched case-control database of the Motorcycle Crash Causation Study, this study analyzes the dependencies of injury crash risk on riders' age, inexperience, and training levels while controlling for other factors, such as alcohol use by the rider. The data consists of 350 cases (injury crash-involved riders) vis-à-vis 700 controls (similarly-at-risk non-crash-involved riders). Based on a conditional logit analysis accounting for the matched case-control structure of the data, "risk curves" are created to understand the relationships between rider age and injury crash risk. Results suggest that younger riders have a heightened injury crash risk, which reduces with increasing age. Each additional year is associated with a 3.31% reduction in the odds of an injury crash - although a non-linear specification is also tested. Each year of rider experience is associated with a 2.69% reduction in the odds of an injury crash, and participation in training programs during recent years is associated with lower crash risks.

Authors	Xueyu Zhang, Tongji University Xuesong Wang, Tongji University Mohamed Abdel-Aty, University of Central Florida Zhicheng Dai, Tongji University Lixia Lei
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05001
Paper Title	**Macro-Level Safety Assessment and Contributing Factors Analysis of Non-motorized Vehicles Considering Traffic Crashes and Crash-involved Riders**
Abstract	During rapid growth in non-motorized vehicle (NMV) ownership, crash-oriented assessment methods make biased identification of key traffic safety management areas, leading to unclear analysis of safety problems and limited improvement. To improve NMV regional safety, this study developed a systematic approach to identify crash and rider hazardous areas and explore the mechanisms of primary macro-level contributing factors, jointly modeling crashes and crash-involved riders. Socio-economic, road network, traffic enforcement, and land use intensity data were collected as independent variables. A Poisson lognormal bivariate conditional autoregressive model (PLN-BCAR) and the four-quadrant assessment method based on the potential for safety improvement (PSI) density were developed to identify crashprone and rider-prone towns. XGBoost and SHAP were applied to examine the importance and effects of contributing factors. Results showed that 49.6% of NMV crashes occurred outside the crash-involved riders' residence areas. The four-quadrant assessment method could accurately identify crash-prone and rider-prone areas compared to crash-determined hot zone identification methods. There were nonlinear relationships between primary contributing factors and key areas. Differences of importance and effects for the contributing factors in different areas provided important insights into reducing crashes and crash-involved riders; for example, areas with high GDP and low population density reduced NMV crashes and riders and should be selected to make safety improvements in the macro-level like traffic safety education. The proposed approach can help traffic administrators identify the key areas and contributing factors and provide guidelines for improvement.

Authors	Juan Medina, University of Utah Raghavan Srinivasan, University of North Carolina, Chapel Hill Taha Saleem, UNC Highway Safety Research Center Bo Lan, UNC Highway Safety Research Center
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05183
Paper Title	**Incorporating Driving Behavior Metrics Derived from Naturalistic Driving Data into Macroscopic Safety Modeling**
Abstract	This research leveraged datasets from the Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS) to explore the potential benefits of incorporating macroscopic measures derived from NDS into traditional safety modeling. Large datasets with traversals from more than 1,700 unique drivers were used to extract driving behavior on freeway segments. New sets of time series totaling over 1,600 hours of driving were developed, including vehicle dynamics exclusively during car-following, while also tracking the spacing between the instrumented vehicle and the vehicle being followed. This paper focuses on the statistical modeling of crash frequency incorporating macroscopic metrics derived from the new time-series datasets in terms of the mean, median, variance, and 85th percentile of vehicle spacing, vehicle speed, and traffic density. Results of this exploration indicate that an increase in the traffic density variance, an increase in the speed variance, and a decrease in the mean vehicle spacing had significant effects associated with increases in multi-vehicle crash frequencies. These results can be used to estimate the safety effect of countermeasures that may change speed, density, and or spacing, along with changes in AADT.

Authors	Chuang CUI Bocheng An, Southeast University Linheng Li, Southeast University Xu Qu, Southeast University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	TRBAM-24-05299
Paper Title	**A Vehicle Safety Early Warning Method Based on Risk Map**
Abstract	Traffic safety has always been a focal point of concern, especially on highways where vehicles travel at high speeds, and the harm caused by traffic accidents is more severe. To evaluate the driving risks of highway vehicles and reduce the accident rate on highways, this study proposes a highway vehicle safety warning method based on a risk map. Firstly, a two-dimensional feature indicator MTTC (Modified Time to Collision) is selected to describe the driving risk between vehicles, and it is subjected to probabilistic processing. Then, the probabilistic risk values are mapped onto road segments. The risk map is obtained by overlaying them, which is used to depict the driving risks around vehicles. After that, highway vehicle warning is performed based on the risk map. When the risk value is higher than the warning threshold, high-risk vehicles are given a warning alert. Finally, the effectiveness and timeliness of the proposed method are verified through simulation in VISSIM. The experimental results show that the proposed method is effective and timely. This study constructs a vehicle warning risk map in the connected vehicle environment and provides a research foundation for enhancing highway driving safety, which is not only suitable for the current stage of manual driving and assisted driving but can also be applied to future autonomous driving.

Authors	Olga Bredikhina, Alabama Transportation Institute Riffat Islam, University of Alabama Emmanuel Adanu, Alabama Transportation Institute Steven Jones, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-05324
Paper Title	**Assessing the Crash Characteristics Associated with Female Drivers at Different Life Stages**
Abstract	The share of female drivers on U.S. roads has been growing steadily over the last decades resulting into female drivers' increasing exposure to crashes. Past research suggests that at various life stages, female drivers may drive differently and may be involved in different types of road crashes: for instance, the driving style and types of crashes associated with younger female drivers are likely to be different from those of older drivers. Although multiple studies have examined the relationship between driving behavior, age, and gender, most studies focused on the comparison of crash rates and types between young, adult, and elderly drivers, and between males and females. This study focuses on female drivers only and explores how various crash factors correlate with different stages of female life cycle: adolescence, reproductive, climacteric, and post-climacteric. To perform the analysis, historical at-fault female crash data for the state of Alabama were obtained from the Critical Analysis Reporting Environment (CARE) at the Center of Public Safety (CAPS) at The University of Alabama. Only single-vehicle crashes were considered for this study. After data cleaning efforts, a total of 50,143 crash observations were available for analysis. A random parameter multinomial logit model was estimated using the NLOGIT statistical software to examine the crash characteristics that are significantly associated with female drivers at four life stages: adolescence, reproductive, climacteric, and post-climacteric. The study's findings may be useful to transportation planners, policymakers, researchers, and other stakeholders working to improve the safety and efficiency of transportation systems.

Authors	Sumon Mojumder Steven Schrock, University of Kansas
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-05342
Paper Title	**Factors Determining a Traffic Crash to be Within or Outside of the 'Golden Hour'**
Abstract	The 'golden hour' has been used as an ideal measure of patients' access to trauma centers. It is the one hour after any traumatic accident, including a traffic crash. It was shown that if patients can arrive at the hospital within the 'golden hour' after a traumatic injury, the chances for survival increase. Therefore, this study aimed to identify the determining factors for patients involved in a traffic crash to arrive at the trauma center within the 'golden hour.' For this, four years (2018-2021) of Kansas traffic crash data were investigated. Among the eight factors analyzed in the study, the time of the crash and lighting conditions were found to be the most important factors. The result showed that crashes that occurred during lighting conditions dark with no streetlights experienced the highest total transport time (TTT), which was 61.3 minutes. TTT did not exceed the 'golden hour' for any other factor. This study also showed that the distance between the crash location and the trauma center was not the only factor for increased total transport time (TTT). For example, crashes occurring within 5 miles of trauma centers can experience TTT higher than 60 minutes. This could happen if a crash goes unnoticed for a long period of time or if time is needed to extricate the patients.

Authors	Shima Hamidi, Johns Hopkins University Ebrahim Azimi
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05493
Paper Title	**Are Wider Lanes Safer? Evidence From New York City**
Abstract	Lane width reduction is a traffic safety treatment that is been rarely studied and implemented, much less than other more popular interventions. The few existing studies on the relationship between lane width and traffic safety show conflicting findings. This study seeks to address the gaps in the literature by investigating the relationship between lane width and non-intersection crash frequencies in a sample of 266 homogenous roadway sections in New York City representing a diverse range of road classes from principal arterials to major collectors while accounting for more than 23 street-level built environmental determinants of traffic safety from sidewalk to bike lane, on-street parking, tree coverage, traffic calming measure and more. Overall, we found no statistically significant difference between streets with 10-ft lanes and streets with 11-, 12-, and 13-ft lanes in terms of crash frequencies. Our results indicate that if considered in isolation, wider lanes are associated with lower crash frequencies. However, the addition of functional and microscale design characteristics overpower the effect size of lane width and it becomes statistically insignificant.

Authors	Subasish Das, Texas State University M. Ashifur Rahman, Louisiana Transportation Research Center (LTRC)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05496
Paper Title	**Examining Encroachment related Work Zone Crash Contributing Factors using Probabilistic Graphical Method**
Abstract	Ensuring work zone safety is a paramount objective for transportation agencies given the risks associated with vehicles changing travel paths and lanes within these areas. Recent statistics underscore the severity of the issue, revealing a staggering 46 percent increase in fatal collisions within work zones in 2019 compared to 2011. The high frequency of roadway departures at work zones, the elevated risks of fatalities resulting from these encroachments, and the paucity of insights into the types of encroachment occurring in work zones all underscore the pressing need for a comprehensive investigation. Therefore, this study investigated encroachment-related crashes in the work zone environment to understand the hidden mechanism. Focusing on a span of four years (2016-2019) of crash data obtained from the Texas Department of Transportation (TxDOT), this study applied a probabilistic graphical method to identify the critical factors, their associations, and potential counterfactual scenarios. The findings from this study will offer valuable guidance to safety engineers in their efforts to reduce encroachment-related work zone crashes. Armed with a deeper understanding of the critical factors and their impact, transportation agencies can implement effective measures to mitigate the risks associated with work zone encroachments, ultimately fostering a safer environment for both drivers and roadway workers.

Authors	Siwon Jang, USF Center for Urban Transportation Research Victoria Salow, USF Center for Urban Transportation Research Chanyoung Lee, USF Center for Urban Transportation Research Lisette Koessick
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-05539
Paper Title	**Motorcycling in Middle-age & Beyond: A Review of the Characteristics, Behaviors, and Crash Outcomes of Riders Ages 40 and Older**
Abstract	There has been a sharp, well-documented increase in crash-related fatalities among motorcycle riders ages 40 and older throughout Australia, Europe, and the United States since 1997. Pre-crash information about this population, however, has received much less attention. The purpose of this paper was to locate and synthesize what is currently known about riders ages 40 and older, including not only information about older riders' crashes and crash outcomes, but also information about the general characteristics, behaviors, and beliefs of older riders. A comprehensive review of Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE, and Transportation Research International Documentation (TRID) revealed 75 articles and reports for inclusion. As was expected, the majority of research on older riders (45%) focuses on post-crash outcomes including crash-related fatality rates, injury patterns and measures of resiliency. While there is markedly less literature on the pre-crash risk factors of older riders, several salient findings emerged. Older riders are significantly more likely to ride motorcycles with large engine capacities and many are new motorcyclists or have recently returned after a substantial break from riding. Middle age riders (40 - 59 years of age) appear to be the least likely to wear helmets and the most likely to ride while under the influence of drugs or alcohol. Crash-prevention recommendations, including the development of training courses specifically for older riders, and areas for further study, including the physical and cognitive differences between rider age cohorts, are discussed.

Authors	Subasish Das, Texas State University Anandi Dutta, University of Texas, San Antonio David Mills
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-05637
Paper Title	**Assessing Causation of Bicycle Crashes through Bayesian Network Modeling**
Abstract	Cycling offers numerous benefits to individuals and society; however, cyclists remain vulnerable road users, necessitating advanced analytical methods to understand counterfactual scenarios that may arise. Despite the environmental and societal advantages associated with cycling, bicyclists face significant risks on urban roads. Understanding the factors contributing to bicycle-related crashes is crucial for effective allocation of treatment resources. A concerning increase in the number of fatal bicycle crashes (52% increase) in 2021 compared to 2017 emphasizes the urgency of implementing effective safety measures to protect vulnerable road users. This study examines crash data from over 4,098 bicyclists in Louisiana between 2017 and 2021, aiming to investigate the underlying factors influencing bicycle crashes. Using Bayesian Network analysis, the study provides valuable insights into the complex relationships and dependencies among various contributing factors, offering a foundation for targeted interventions and measures to enhance bicycle safety. Additionally, the study highlights a concerning increase in the number of fatal bicycle crashes in 2021 compared to 2017, emphasizing the urgency of implementing effective safety measures to protect vulnerable road users.

Authors	Subasish Das, Texas State University Valerie Vierkant, Texas A&M University
Sponsoring Committee	Section - Transportation Systems Resilience (AMR00) Standing Committee on Regional Transportation Systems Management and Operations (ACP10) Standing Committee on Transportation Safety Management Systems (ACS10) Standing Committee on Traffic Law Enforcement (ACS30) Section - Transportation Systems Resilience (AMR00)
Session Number	Poster Session 2051
Session Title	Emergency Responder Safety, Travel Demand, and Routing
Paper Number	TRBAM-24-05696
Paper Title	**Exploring Special Case Investigation Reports Associated with Ambulances**
Abstract	Ambulance crashes constitute a matter of utmost concern within the realm of public health, posing potential risks to both patients and emergency responders. Despite this critical importance, our understanding of the underlying causes contributing to these collisions remains hindered due to the scarcity of comprehensive and relevant datasets. To bridge this research gap and gain valuable insights, the present study embarked on a mission to shed light on the causative factors behind ambulance-related crashes. To achieve this objective, this study adopted a meticulous approach, focusing on collecting narrative descriptions from ten special investigation reports published by the National Highway Traffic Safety Administration (NHTSA). These reports were selected as they offered in-depth accounts of real-life ambulance crashes, rendering them an invaluable resource for analyzing the multifaceted aspects leading to such incidents. Central to this investigation was the utilization of the Perceptual Cycle Model (PCM), a well-established and comprehensive framework that facilitates a systematic examination of the various stages leading to a crash. By employing the PCM, the study examined the key influential factors associated with ambulance crashes. The outcomes of this study will bolster the safety of ambulance operations, safeguard patients and personnel, and ensure the efficient delivery of life-saving emergency services to those in need.

Authors	Subasish Das, Texas State University Juan Cruz-Gonzalez Catalina Gonzalez
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05716
Paper Title	**Examining the Interplay of Factors in Rollover Crashes**
Abstract	Rollover crashes on roadways are a significant concern for transportation authorities due to their potential devastating consequences. However, the causes of serious and fatal injuries resulting from these crashes are not well understood. This study takes a focused and comprehensive approach, individually examining different phases of rollover crash scenarios using the Perceptual Cycle Model (PCM). By analyzing ten special investigation reports from the NHTSA, the study uncovers insights into the factors leading to vehicle overturning and causing thoracic injuries. The results show that rollover crashes involve diverse factors, including high speeds, seatbelt use, and collisions with larger vehicles, necessitating suitable safety measures. Moreover, leveraging the power of natural language processing (NLP), the study employed a sophisticated NLP tool to identify and analyze the associations between top keywords. This NLP-driven analysis effectively established connections among the various factors, providing a holistic view of their interplay in rollover crashes. The findings aim to contribute to evidence-based strategies for preventing rollover crashes and enhancing road safety.

Authors	**Examining the Relationship between Connected Vehicle Driving Event Data and Police-Reported Traffic Crash Data at the Segment- and Event-Level**
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 3003
Session Title	Using Connected and Automated Vehicles to Improve Transportation Safety
Paper Number	TRBAM-24-05717
Paper Title	**Examining the Relationship between Connected Vehicle Driving Event Data and Police-Reported Traffic Crash Data at the Segment- and Event-Level**
Abstract	Police-reported crash data have been the de-facto element used by the transportation agencies in developing and implementing traffic safety projects. This approach is reactive in nature and can lead to suboptimal investment decisions due to inherent challenges in crash data analysis. Due to their large-scale and near real-time availability, the connected vehicle (CV) driving event data have emerged as a promising means to address these challenges. This study utilized CV event data for three different event types, namely, acceleration, braking, and cornering at three severity levels- easy, normal, and harsh, to examine the viability of using these data in traffic safety analysis. The results showed a strong correlation between crash frequency and CV driving event frequency. CV event data also improved the goodness-of-fit of crash frequency models. The results also showed that the relationship between CV driving events and traffic volume and roadway geometry data are generally consistent with the trends that crash data usually exhibit with the same predictors. This was true at both segment-level and individual event-level, as well as when the data were subsetted based on type. Overall, the results showed a strong case for these data to be used in traffic safety analysis in complement to or in-lieu to police-reported crash data.

Authors	Majeed Algomaiah, VHB Sahal Alzahrani Turkey Arbaein
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-05732
Paper Title	**Investigating the Spatiotemporal Characteristics of Vulnerable Road User (VRU) Crashes at Signalized Intersections**
Abstract	The aim of this paper is to investigate the spatiotemporal characteristics of VRU crashes at signalized intersections. The first objective of this paper is to understand the effect of signalized intersection surrounding on VRU crashes from big data using a statistical method. The second objective is to enhance the understanding by utilizing image processing technique in graphing the data. Since the crash severity was based on KABCO score of severity ordinal logistic regression model was utilized. For pedestrian crashes and bike crashes, logistic regression model was applied to the data. The results revealed that although 9% of crashes occurred from 10pm to 6am, severe crashes are 22% higher at that period compared to morning (6am to 2pm). The analysis also revealed that higher pedestrian and bike crashes occurred when posted speed from 20 mph to 50 mph and when the major road classification is collector and arterial. Another important finding is that higher pedestrian and bike crashes occurred when there is a sidewalk on the two sides regardless of the existence of median. Moreover, when the road is divided, higher pedestrian and bike crashes occurred when there is no sidewalk. Thus, engineering solution for reducing pedestrian and bike crashes should consider the significant variables.

Authors	Fahmida Rahman, Rowan University Cidambi Srinivasan, University of Kentucky Xu Zhang, Kentucky Transportation Center Mei Chen, Kentucky Transportation Center
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-05760
Paper Title	**Utilizing Random Forest Regression in Crash Prediction of Rural Two-Lane Highways**
Abstract	During the early planning stage of roadway safety, it is essential to use a robust crash prediction model for quantitative analysis. Despite the fact that practitioners and researchers have extensively explored traditional statistical methods for this purpose, they often have limitations due to assumptions on functional forms, leading to biased results. To address this, researchers have explored Machine Learning (ML) techniques, especially for higher functional class roads. However, ML models for predicting crashes on rural two-lane highways remain relatively unexplored. This study aims to develop a crash prediction model using the Random Forest (RF) technique and examines the impact of various factors on crashes, such as traffic, geometric, and operating conditions. Comparing the RF model with the traditional approach shows that the RF model significantly improves crash prediction accuracy by up to 25%. A closer look at contributing factors reveals that AADT, segment length, and average speed are among the top three important variables. Interestingly, the effect of average speed varies with different road segments, where it can either increase or decrease crashes based on road characteristics like shoulder and lane width. This finding highlights the potential of average speed as an indicator of overall geometric and traffic conditions on rural two-lane highways, helping analyze safety and reduce crashes.

Authors	Jia Li, Beijing University of Technology Guan jie Li
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-05825
Paper Title	**Fusing crash data and risking dirving behaviors for freeway safety assessment: Developing dynamic structural equation model to examine the relationships among traffic operation characteristics, risky driving behaviors, and traffic crashes**
Abstract	Crash data is an important index to evaluate road traffic safety, however, it needs a long sampling time and there are often under-reporting issues. Risky driving behaviors can capture more frequent “near-crash” situations, which can be integrated with crash data to assess road safety. Dynamic traffic flow is a critical influencing variable for both crashes and risky driving behaviors. There is a lack of research on the complex relationships among traffic operation characteristics, risky driving behaviors, and crashes. Using traffic flow, risky driving behavior, and crash data with statistical unit of 5 minutes for 22 road segments on Yongtaiwen freeway, this study developed a dynamic structural equation model (DSEM) to provide an in-depth analysis of contemporaneous relationships and cross-lagged interactions among these three characteristics. DSEM decomposes the total variance of all parameters into a within-segment part and a between-segment part. A within-segment level model was developed to determine cross-lagged and contemporaneous effects, and a between-segment level model was developed to examine the influences of road geometric design covariates. In terms of the cross-lagged effects, there was a lagged negative impact of sharp deceleration frequency on crash frequency for freeway segment, higher crash frequency leads to a decrease in segment average speed and an increase in sharp deceleration frequency subsequently, the effects between average speed and risky driving behavior frequency vary across different behavior types. Additionally, average speed, sharp acceleration and deceleration frequency all have positive contemporaneous effects on crash frequency. The findings are expected to assist active traffic safety management.

Authors	TEJAS SHARMA SNEHIL VIJAYVARGIYA AAYUSH VERMA BALASAHEB MULE Madhumita Paul, Indian Institute of Technology, Kharagpur
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-05875
Paper Title	**Assessment of Motorized Two-Wheeler Riders' Perceptions of Road Safety and Infrastructure Demands in Mixed Traffic Conditions Using Machine Learning Technique**
Abstract	Indian residents primarily commute on urban roads using motorized two-wheelers (MTWs), even though MTW fatality rates are significantly high in India. Identifying riders' views of road safety under mixed traffic conditions is therefore crucial. This study conducted an online questionnaire survey that contained MTW rider’s socio-demography, travel information, driving styles, insight into safety-perception and infrastructural demands. K-Means clustering and Principal Component Analysis (PCA) were done to categorize respondents as per socio-demography and investigate their driving characteristics and riding preferences on urban roads. Five Principal Components were generated from each dataset after dimension reduction using PCA. These are component 1 (Traffic Laws Enforcement), component 2 (Risk Taking Behaviour), component3 (Erratic Manoeuvres’),component 4 (Safety Measures) and component 5 (Driving under Influence).Multinomial Logistic Regression was done to relate PCA components with sociodemographic clusters. This study also used socio-demographic data and machine learning algorithms (Decision Tree, Random Forest, K-Nearest Neighbor and Logistic Regression) to predict preferences for two-wheeler infrastructural demands. Evaluation metrics were applied to assess model performance. Results showed that MTW riders lack knowledge of wearing helmets or stopping at red signals. Around 40% male riders commute under stress, involved in overtaking, riding between other vehicles in congested areas, and using footpaths to avoid traffic. Regarding infrastructural need, 82% of riders recommend mandating dedicated motorcycle lanes. The study outcome provides a comprehensive understanding of motorcyclists' safety perceptions, behaviour, and infrastructure demands, which will help policymakers choose the best future infrastructure for improving motorists’ safety in urban settings.

Authors	Saki Rezwana, University of Connecticut Manmohan Joshi, University of Connecticut Mohammad Shaon, University of Connecticut Eric Jackson, Connecticut Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-05987
Paper Title	**Unveiling the Dynamics of Pedestrian and Bicycle Crashes in Connecticut: A Comprehensive Data Exploration**
Abstract	This research delves into the critical issue of pedestrian and bicycle crashes in Connecticut, aiming to identify the underlying factors contributing to these incidents and propose targeted measures for enhanced safety. Analyzing comprehensive data spanning eight years, this study examines the frequency, distribution, and trends of pedestrian and bicycle crashes, assessing the severity of outcomes and exploring the influence of temporal factors. Additionally, the research evaluates crash data from a demographic perspective to pinpoint vulnerable groups and significant contributors to crashes, ultimately proposing tailored safety interventions. The findings reveal that aggressive driving, distracted driving and driving under the influence are significant contributors to crash incidents, demanding strict enforcement measures and educational campaigns to modify driver behavior. Young and male pedestrians emerge as particularly vulnerable demographics, necessitating age and gender-specific interventions. Time-specific safety measures are suggested to address peak crash periods, and the unexpected association between level roads, dry conditions, and increased crash rates calls for reevaluating existing road safety measures. The study's comprehensive data exploration provides crucial insights into pedestrian and bicycle crashes, highlighting key determinants and risk factors. These insights inform evidence-based road safety strategies, with the ultimate goal of reducing crash rates and enhancing overall road safety in Connecticut.

Authors	Satoshi Nakao, Kyoto University Koshi Sawada Andreas Keler Jan-Dirk Schmoecker, Kyoto University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-06143
Paper Title	**Analysis of Land-use and POIs Contributing to Traffic Accidents around Intersections**
Abstract	In Japan more than half of all traffic accidents occur at or near intersections and many at small intersections where only minor roads cross. A database of all intersections in the built-up area of Kyoto, Japan was created using Open Street Map data, including spatial characteristics such as the presence and types of surrounding facilities. This data was used as explanatory variables to analyze the relation to traffic accidents reported over a period of three years. Presence of traffic signals, pedestrian infrastructure and traffic flow was used as control variable. The results of the analysis suggest that traffic accidents are less likely to occur at intersections where parks are nearby. More accidents occur at medium and small intersections where facilities such as restaurants, supermarkets and convenience stores are nearby. We discuss that the results suggest that visibility but also attention when “briefly hopping into a store” as well as general business of junctions are determinants of accident risks. These results highlight that to reduce the occurrence of traffic accidents at intersections a broader understanding of who passes the junction at what times and the wider land-use characteristics of the vicinity is important.

Authors Josie Gray, HNTB Corporation
Scott Parr, Embry Riddle Aeronautical University
Sean Parr, Miami-Dade Fire Rescue Department

Sponsoring Committee Section - Transportation Systems Resilience (AMR00)
Standing Committee on Regional Transportation Systems Management and Operations (ACP10)
Standing Committee on Transportation Safety Management Systems (ACS10)
Standing Committee on Traffic Law Enforcement (ACS30)
Section - Transportation Systems Resilience (AMR00)
Session Number Poster Session 2051
Session Title Emergency Responder Safety, Travel Demand, and Routing
Paper Number P24-20398

Paper Title **Analysis of Crashes Involving First Responder Vehicles**

Abstract First responders face many hazards that put their lives at risk while on duty. A review of the National Law Enforcement Officers Memorial Fund statistics shows that 553 police officers died in the line-of-duty between 2008 and 2017 as a direct result of a traffic related incidents. Sadly, the nation's first responders are exposed to factors which make them uniquely vulnerable to traffic related injuries and deaths. The goal of this research is to investigate and analyze crashes involving first responder vehicles and struck-by crashes. This project concludes that approximately 1.2% of the crashes in the state of Florida involve a first responder vehicles. The findings also highlight characteristics of interest to target for more research or revise traffic scene and management practices. Some of these highlighted characteristics include: sideswipes to emergency vehicles and dark settings with ambient lighting. The data found from this research should be implemented to protect the lives of emergency responders. Every bit of research that helps to discover safer techniques or situations can better lead to all responders going to home after their shift. These individuals are extremely thankful for focused efforts on helping the emergency responder community.

3 Network Screening

Nicholas Fiorentini and Massimo Losa
University of Pisa

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 **nineteen papers** strictly related to network screening and **twenty papers** discussing methods with suggestions on the possibility of using these methods for network screening. Both groups of studies are included in this review.

Several papers dealt with network screening aiming at enhancing the Highway Safety Manual procedures. Indeed, novel safety performance functions and crash modification factors are proposed, both for road segments and road intersections.

Moreover, the Empirical Bayes has been frequently used to rank hotspots, as well as Kernel Density Estimation and Spatial Autocorrelation methods. Novel methods exploiting machine and deep learning algorithms are frequently used to assess the road safety level of a road site. Finally, novel data sources coming from both connected vehicles and traffic conflicts are used for network screening.

Considering the **aim**, below the paper number and the leading aim of the study of the 19 papers strictly related to network screening are reported.

Paper Number	Title	Aim of the Study
TRBAM-24-04373	Developing A Comprehensive Vulnerable Road User Safety Screening Method Using Multi-Level Data	To provide a framework for combining site level and area level analysis to generate an aggregate network screening result
TRBAM-24-04297	Spatial analysis of road crashes: A case study in Medellin, Colombia	To analyze traffic crashes' spatial and temporal patterns for identifying the characteristics of the high-risk areas and provide helpful information to authorities for having rapid response systems
TRBAM-24-00900	A Pilot Application of the Sliding Window Screening Method on Virginia Roadways	To evaluate the practicality and efficacy of implementing the Highway Safety Manual recommended sliding window method for systemically identifying high-risk segments
TRBAM-24-05198	Evaluating the Capability of a Short Segment Peak Search Approach to Detect High Crash Locations	To compare the short segment peak search approach to other HSM network screening methods
TRBAM-24-05001	Macro-Level Safety Assessment and Contributing Factors Analysis of Non-motorized Vehicles Considering Traffic Crashes and Crash-involved Riders	To develop a systematic approach for identifying crash and rider hazardous areas and explore the mechanisms of primary macro-level contributing factors for non-motorized vehicles
TRBAM-24-04985	Enhancing Urban Traffic Safety Estimations and Spatial Pattern Analysis Using Extensive NearMiss Data: A New York City Case Study	To identify specific grid areas with unexpectedly high or low crash frequencies using near-miss data
TRBAM-24-02057	Valuing Large Animal Crashes and Calculating Benefits and Costs for Safety Improvement Projects	To perform Economic evaluations on large animal crashes for prioritizing candidate countermeasures that can improve driver safety and habitat connectivity
TRBAM-24-00532	Developing Motorcycle Crash-Specific Safety Performance Functions along Rural Two-Lane Undivided Road Segments in Kentucky Pre- and Post-COVID-19 Pandemic	To develop safety performance functions for motorcycle crashes
TRBAM-24-05700	Network Screening of National Highways for Fatal Crashes in India	To define blackspot separately for each studied highway and identify blackspots using the Empirical Bayes method.
TRBAM-24-06151	Intersection Safety Risk Scoring using Connected Vehicle Data and Machine Learning: A Case Study in Atlanta Region	To perform safety analyses by using connected vehicle data and rank the intersections based on safety performance
TRBAM-24-00048	Identifying Corridor-Level Safety Improvements for Urban and Suburban Arterials in Florida Within a Safe System Framework	To develop a corridor-level methodology for holistically looking at corridors made of consecutive intersections and roadway segments, identifying safety improvements which align with the Safe System approach while requiring less data than HSM methods
TRBAM-24-02502	Drawing the Lines on Safety Priorities: The How and Why of Developing Washington, D.C.'s High Injury Network	To provide a sturdier framework for jurisdictions to consider when developing their own High Injury Networks (HINs) so that HINs match with agency goal
TRBAM-24-04412	A Systematic Review on Safe System Approach and its Applications in Highway Safety	This systematic review examines the implementation and impact of the Safe System Approach on overall traffic safety
TRBAM-24-01057	Comprehensive Investigation of Severe Distraction-Related Crashes along Kentucky's Rural Two-Lane Roads	To develops safety performance functions (SPFs) for severe distraction-related crashes
TRBAM-24-02363	A Data-Driven Approach to Develop Master Plan to Prioritize Schools for Safe Routes to School (SRTS) Program	To identify site-specific infrastructure improvements that have the potential to positively impact student safety and mobility
TRBAM-24-00337	Spatial Decision Support System for the Assessment of High-Risk Areas and Contributing Factors in Road Traffic Accidents: Application to the Northern Road Axis of Crete, Greece	To examine how different variables affect road traffic accidents (RTAs), by analyzing their spatiotemporal characteristics, focusing on identifying blackspots and clusters of RTA occurrence, related injuries, and deaths
TRBAM-24-02280	Identification and Analysis of Crash Hotspots and Temporal Shifts using Kernel Density Estimation, Getis-Ord Gi*, and Spatial Autocorrelation (Morans I): A Case Study on N1 in Bangladesh	To identify temporal shifts in crash hotspots and understanding whether the crashes exhibit dispersed, random, or clustered patterns
TRBAM-24-03693	Risk Hotspot Identification from Massive Driving Behavior Data Considering Driver Style Classification: A Bayesian Network Approach	To identify risk hotspots from massive driving behavior data, taking into account both traffic situations and driver styles
TRBAM-24-03981	Identify High-risk Road Segments of Traffic Accidents Using Street Map Segmentation and Machine Learning	To identify high-risk road segments without relying on accident and surveillance indexes trough segment street view images

Below the paper number, the **methodological perspective** and the **application perspective** of the 19 papers strictly related to network screening are reported.

Paper Number	Methodological Perspective	Application Perspective
TRBAM-24-04373	Bayesian Thurstonian model and a mean score ranking method	State-maintained signalized intersections in Connecticut
TRBAM-24-04297	K-prototype model and negative binomial model	Various city areas of Medellin, Colombia
TRBAM-24-00900	Sliding Window method	Virginia roadway network
TRBAM-24-05198	State-specific SPFs, Driveway SPFs (using only AADT), and driveway SPFs with adjusted CMFs	Short road segments of South Carolina
TRBAM-24-05001	Poisson lognormal bivariate conditional autoregressive model and the four-quadrant assessment method	Not specified
TRBAM-24-04985	Combination of grid-based aggregation methods with the Empirical Bayes (EB) approach, and spatial analysis using global Moran's I and local Moran's I	Midtown Manhattan, NYC
TRBAM-24-02057	Cost-Benefit analysis based on economic valuation	deer and an elk crash valuation
TRBAM-24-00532	Conway-Maxwell-Poisson and heterogeneous ConwayMaxwell-Poisson models. Empirical Bayes method was then used to rank the top ten high-crash roadway segments	Rural two-lane undivided roadway segments in Kentucky
TRBAM-24-05700	Negative binomial models, kernel density, and Empirical Bayes method	National Highways of India
TRBAM-24-06151	Negative Binomial Regression, Random Forest, and Extreme Gradient Boosting	3,853 signalized in Atlanta Region, GA
TRBAM-24-00048	Negative Binomial Regression and Empirical Bayes method	549 corridors on urban and suburban arterials across Florida
TRBAM-24-02502	Not specificied	Washington, D.C.'s High Injury Network
TRBAM-24-04412	This is a review paper	United States and other countries
TRBAM-24-01057	Conway-Maxwell-Poisson model, Conway-Maxwell-Poisson, zero-inflated Conway-Maxwell-Poisson, and zero-inflated heterogeneous Conway-Maxwell-Poisson	Rural two-lane undivided roadway segments in Kentucky
TRBAM-24-02363	Safety Performance Functions	3,000 schools in the State of Florida
TRBAM-24-00337	Kernel Density Estimations, Spatial Autocorrelation models, Univariate and Bivariate Local Indicators of Spatial Association	Northern Road Axis of Crete, Greece
TRBAM-24-02280	Kernel Density Estimation, Getis-Ord Gi*, and Spatial Autocorrelation Moran's I	N1 Road in Bangladesh
TRBAM-24-03693	Bayesian Network	6,698 probe vehicles in the Wangjing area in Beijing
TRBAM-24-03981	DeepLabv3+ algorithm, Random Forest, XGBOOST, and LightGBM	Not specified

Below, for each of the **thirty-nine papers** involving network screening or related activities, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Manmohan Joshi, University of Connecticut Mohammad Shaon, University of Connecticut Saki Rezwana, University of Connecticut Kai Wang, University of Connecticut Shanshan Zhao, University of Connecticut John Ivan, University of Connecticut Eric Jackson
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2004
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	TRBAM-24-04373
Paper Title	**Developing A Comprehensive Vulnerable Road User Safety Screening Method Using Multi-Level Data**
Abstract	Despite significant advancements in motor vehicle safety, the number of fatalities resulting from road crashes has been increasing in recent years. The resultant injuries from roadway crashes are more severe for vulnerable road users (VRU), i.e., pedestrians and bicyclists. High disparity is observed in the distribution of the burden of these crashes across areas, ethnic and race groups and hence FHWA requires states to incorporate equity-related variables in the analysis of vulnerable road user safety. Conventionally, Highway Safety Manual (HSM) provides methodologies for identifying high crash risk locations, but those methods are not enough to prioritize low volume sites with a higher crash rate, as is the case of vulnerable road users. This study first explores a wide range of equity level variables in addition to site characteristics of state-maintained signalized intersections in Connecticut and then provides a framework to combine site level and area level analysis to generate an aggregate network screening result, using Bayesian Thurstonian model and a mean score ranking method. The exploration and combining framework is a novel practice in transportation safety analysis and shows promising results for network screening based on systemic safety principles.

Authors	Maria Valencia-Cardenas, University of California, Davis Juan López, University of California, Davis Miguel Jaller, University of California, Davis
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2004
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	TRBAM-24-04297
Paper Title	**Spatial analysis of road crashes: A case study in Medellin, Colombia**
Abstract	The transportation and safety sectors aim to reduce road crashes and their societal and economic effects. By studying these events and examining related variables and their location and patterns, local authorities can identify critical zones to establish successful road safety initiatives and mitigate the negative consequences of their occurrence. This study aims to analyze traffic crashes' spatial and temporal patterns in Medellin, Colombia, to identify the characteristics of the high-risk areas and provide helpful information to authorities for having rapid response systems. To this end, spatial, temporal, and traffic variables provide vital information for predicting the number of crashes in various city areas. The study proposes a methodology integrating point pattern analysis, descriptive statistics, statistical characterization, and clustering analysis using a k-prototype model to capture a simple representation of similarities among crash data. The study also estimated a negative binomial (NB) model to identify the spatial and traffic parameters that help explain crash occurrences. The results show a concentration of crashes in Downtown Medellin, the area with the highest trip generation in the city. Road hierarchy, land use, and traffic variables correlate highly with crashes and influence spatial patterns. The clustering process found two main clusters with significant differences in the hierarchy and traffic conditions, and the NB unveiled a high correlation between the crash count and the large vehicle flow

Authors	Chien-Lun Lan, Virginia Transportation Research Council Hyun Cho, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-00900
Paper Title	**A Pilot Application of the Sliding Window Screening Method on Virginia Roadways**
Abstract	This study evaluates the practicality and efficacy of implementing the Highway Safety Manual recommended sliding window method for systemically identifying high-risk segments in the Virginia roadway network. The research proposes a homogeneous segmentation network that maintains consistency in segment characteristics, based on annual average daily traffic and safety performance function types. The sliding window method, executed in Python, was applied to the newly generated homogeneous segments. The evaluation of this method's performance encompassed multiple aspects, including assessment of potential for safety improvement (PSI) values, segment rankings, and comparison with the current VDOT PSI list. Further, this study investigated the sensitivity of window size selection to crash occurrences' inherent stochastic nature. Specifically, smaller window sizes proved to be more effective in identifying localized crash hotspots, while larger window sizes delivered a more general overview of the entire segment. The research also advises against the use of a single year's ranking for determining high-risk PSI segments, owing to this stochastic variation. The research found that the sliding window method does not exhibit inherent bias toward two roadway attributes: segment length and median presence. The finding that bias does not exist with respect to roadway length and geometry mitigates the existing segment length variation problem that is present in the current approach. Building on these results, the study concludes that the sliding window method holds promise in enhancing current practices employing the simple ranking method.

Authors	Adika Iqbal, Clemson University Wayne Sarasua, Clemson University Afshin Famili, City of Richmond jennifer ogle, Clemson University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-05198
Paper Title	**Evaluating the Capability of a Short Segment Peak Search Approach to Detect High Crash Locations**
Abstract	South Carolina crash geocoding has improved over the years and this enhanced spatial accuracy of crashes can potentially lead to a new paradigm for midblock crash safety analysis. This paper focuses on a short segment peak search analysis using segment lengths less than the Highway Safety Manual (HSM) recommended minimum of 0.1 miles for statewide screening of midblock crash locations. The main objective of this research was to compare the short segment peak search approach to other HSM network screening methods. State-specific SPFs, Driveway SPFs (using only AADT), and driveway SPFs with adjusted CMFs were used to evaluate the short segment screening method. Frequency-based identification of short segments stratified by six different roadway geometry types (R2U, R4D, U2U, U4D, U3T, and U5T) were compared with three SPF based screening methods to determine segments with the highest excess predicted average crash frequency. For short segment sites with highest crash frequencies (three crashes for U3T, U4D, and U2U; four crashes for U5T and two crashes for R4D and R2U), the comparison showed similar results (Top 90% agreement). Thus, should insufficient data be available to conclude SPFs, a frequency-based approach will likely identify the highest ranked crash sites. While this method works relatively well with highest ranked crash sites, the reliability of this method will wane with lower-ranked sites.

Authors	Xueyu Zhang, Tongji University Xuesong Wang, Tongji University Mohamed Abdel-Aty, University of Central Florida Zhicheng Dai, Tongji University Lixia Lei
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-05001
Paper Title	**Macro-Level Safety Assessment and Contributing Factors Analysis of Non-motorized Vehicles Considering Traffic Crashes and Crash-involved Riders**
Abstract	During rapid growth in non-motorized vehicle (NMV) ownership, crash-oriented assessment methods make biased identification of key traffic safety management areas, leading to unclear analysis of safety problems and limited improvement. To improve NMV regional safety, this study developed a systematic approach to identify crash and rider hazardous areas and explore the mechanisms of primary macro-level contributing factors, jointly modeling crashes and crash-involved riders. Socio-economic, road network, traffic enforcement, and land use intensity data were collected as independent variables. A Poisson lognormal bivariate conditional autoregressive model (PLN-BCAR) and the four-quadrant assessment method based on the potential for safety improvement (PSI) density were developed to identify crashprone and rider-prone towns. XGBoost and SHAP were applied to examine the importance and effects of contributing factors. Results showed that 49.6% of NMV crashes occurred outside the crash-involved riders' residence areas. The four-quadrant assessment method could accurately identify crash-prone and rider-prone areas compared to crash-determined hot zone identification methods. There were nonlinear relationships between primary contributing factors and key areas. Differences of importance and effects for the contributing factors in different areas provided important insights into reducing crashes and crash-involved riders; for example, areas with high GDP and low population density reduced NMV crashes and riders and should be selected to make safety improvements in the macro-level like traffic safety education. The proposed approach can help traffic administrators identify the key areas and contributing factors and provide guidelines for improvement.

Authors	Chuan Xu, New York University Jingqin Gao, New York University Fan Zuo, New York University Kaan Ozbay, New York University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-04985
Paper Title	**Enhancing Urban Traffic Safety Estimations and Spatial Pattern Analysis Using Extensive NearMiss Data: A New York City Case Study**
Abstract	City-wide near-miss data can provide potential insights to traffic safety estimation, especially since crashes are often rare. In this study, we evaluate urban traffic safety in Midtown Manhattan, NYC, and examine spatial patterns by incorporating 6-month near-miss data (59,277 near misses). Our methodology employs a combination of grid-based aggregation methods with the Empirical Bayes (EB) approach, and spatial analysis using global Moran's I and local Moran's I. The study findings reveal that among all the variables studied, near misses have the strongest positive correlation with observed crash frequency . The ratio of near-misses to crashes is approximately estimated to be 1957:1, providing a potentially useful benchmark for urban areas. For other variables, an increased number of intersections and bus stops, along with a greater road length, are found to contribute to a higher crash frequency. Conversely, residential and open-space land use rates show a negative correlation with crash frequency. Through spatial analysis, potential risk hotspots including roads linking bridges and tunnels, and avenues with high pedestrian activity, are highlighted. By mapping the differences between observed and predicted crash frequencies, we identified specific grid areas with unexpectedly high or low crash frequencies. These findings highlight the potential of using near-miss data in urban traffic safety policy and planning, particularly with the imminent rise of autonomous and connected vehicles. By integrating near-miss data into safety estimations, we can develop a more comprehensive understanding of traffic safety and, thus, more effectively address urban traffic risks.

Authors	Md Rakibul Islam Mohamed Abdel-Aty, University of Central Florida Dongdong Wang Zubayer Islam, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-01380
Paper Title	**Developing Safety Performance Functions and Crash Modification Factors for Skid Resistance**
Abstract	Pavement friction is a critical factor in determining road safety, especially in adverse weather conditions. This study investigates the relationship between pavement friction, measured as Skid Number (SN), and crash frequency on Utah highways. Utilizing four years of data (2016–2019) from an interstate (I-15) and a non-interstate (US-89) highway, negative binomial models were employed to establish safety performance functions (SPFs) and crash modification factors (CMFs). The models controlled for traffic volume and segment length while examining various crash types, including dry and wet weather, property damage only, and injury-related crashes. Results indicate a significant negative association between SN and crash frequency for all crash types on both highway types. Higher SN values (more friction) were associated with fewer crashes, with a 10-point increase in SN leading to a 12–13% decrease in total crashes. The impact of friction on wet weather crashes and injury crashes on non-interstate highways was even more pronounced. These findings suggest that increasing pavement friction through measures like high friction surface treatments could lead to substantial traffic safety improvements. Overall, the results support the continued collection of skid data by transportation agencies, such as the Utah Department of Transportation (UDOT), to identify high-risk locations and prioritize friction improvement efforts to enhance roadway safety.

Authors	LIU Xingwei, University of Yamanashi Jian XING, Nippon Expressway Research Institute Kuniaki SASAKI, Waseda University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-06465
Paper Title	**Exploring Contributory Factors to Accident Severity Based on XGBoost Approach: An Application Case Analysis in Tomei Expressway, Japan**
Abstract	Traffic accidents have grave implications in terms of human life and property. Efficient traffic management requires a profound comprehension of the underlying causes of accidents and the ability to predict their severity partially. In this study, we investigated the factors contributing to accident severity by utilizing accident data collected from the Gotenba to Tokyo section of the Tomei Expressway in Japan during 2019. We employed a random forest model on the cleansed dataset to predict traffic accident severity, encompassing a total of 701 cases. Additionally, a grid search was conducted to identify the optimal hyper parameters for XGBoost model. To gain the independent performance and impact of each factor on traffic accident severity, we employed SHAP (SHapley Additive exPlanations) to show the visualization results. This effective tool facilitated the identification of high-risk routes and individuals. Notably, our analysis revealed remarkable findings that variables of geometric design were more prone to accident severity, and vehicles located at the end of congestion also have a high risk of severity when accidents occurred. These compelling findings provide valuable insights for the development of strategies aimed at enhancing expressway management.

Authors	Bridget Donaldson, Virginia Transportation Research Council James Gillespie Rebecca Danese
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-02057
Paper Title	**Valuing Large Animal Crashes and Calculating Benefits and Costs for Safety Improvement Projects**
Abstract	Increased attention to reducing wildlife crashes and restoring habitat connectivity has created new federal funding opportunities for wildlife crossings. Economic evaluations help prioritize candidate countermeasures that can improve driver safety and habitat connectivity. This paper reports how large animal crash valuation methods can inform benefit-cost evaluations through consideration of (1) the scale to which large animal crashes are underrepresented in police reports; (2) cost components used to value a large animal crash; and (3) various means to determine threshold (or break-even) values at which the costs of a wildlife crash countermeasure equal its benefits. Key findings that practitioners can use to support economic evaluations of wildlife crash countermeasures are (1) police crash reports account for one-fifth to one-ninth of actual deer crashes, and (2) there is considerable variability in how wildlife crashes are monetized, in part because of wildlife size and the associated crash severity and in part because of the variability in cost components applied to each method (e.g., emergency response, carcass value, and equivalent crash costs). This paper provides an example of a deer and an elk crash valuation method that resulted in crash values of approximately $41,000 for deer and $81,000 for elk. Further, any countermeasure has some degree of uncertainty with respect to crash reduction values, service life, or ranking against other safety improvements, and the examples of breakeven illustrations in this paper can demonstrate approaches for selecting an appropriate economic method.

Authors	Huiqing Lyu, University of South Florida, Tampa Zhenyu Wang, University of South Florida Pei-Sung Lin, University of South Florida Qing Lu, University of South Florida Ping Hsu, Florida Department of Transportation Emmeth Duran, Florida Department of Transportation
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-03697
Paper Title	**Implementing High Friction Surface Treatment (HFST) to Improve Intersection Safety**
Abstract	Maintaining adequate pavement friction is essential to prevent or reduce roadway vehicle crashes and injuries effectively. High Friction Surface Treatment (HFST) is an innovative pavement material that dramatically enhances the road surface's frictional characteristics with a long-lasting service life (10 years). HFST has been implemented to improve traffic safety on various roadway facilities, such as curves and ramps. The Florida Department of Transportation (FDOT) District 7 is extending the application of HFST at intersections along high-traffic corridors to reduce intersection crashes, especially for pedestrians. To evaluate the safety impacts of HFST, a pilot study was conducted at selected signalized intersections in the Tampa Bay area, Florida. Vehicles' stopping behaviors with and without HFST were compared in before-after studies. The comparison results indicate that HFST significantly reduced improper stopping rates and crosswalk-intrusion behaviors for all scenarios (daytime, nighttime, dry surface, and rainy weather). It implies that implementing HFST allows transportation agencies to allocate resources wisely to reduce intersection crashes for multimodal road users.

Authors	Md Nasim Khan, Texas State University Subasish Das, Texas State University Ryan Benton Mohammad Jalayer, Rowan University Ahmed Hasan, Rowan University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	TRBAM-24-05047
Paper Title	**Uncovering Motorcycle Crash Severity Patterns through Association Rules Mining**
Abstract	Motorcycle crashes have raised significant concerns due to their disproportionate impact on overall vehicle fatalities in the U.S., necessitating in-depth analyses into the complex factors influencing their likelihood. Thus, the primary aim of this study was to employ association rules mining, a robust data mining approach, to examine the contributing factors leading to motorcycle crashes and unveil patterns related to crash severity levels, namely fatal, injury, and property damage only (PDO). To accomplish this objective, a five-year dataset (2016-2020) of motorcycle crash severity data obtained from the Massachusetts Department of Transportation (MassDOT) was utilized. Subsequently, comprehensive rule generation, evaluation, and visualization were conducted for the three crash severity levels, with crash severity levels considered as consequents and other variables as antecedents. The generated rules highlighted aggressive driving as the predominant attribute associated with fatal crashes, along with factors including nighttime riding in unlighted conditions, summer season driving, collisions with barriers, and urban driving. Likewise, the rules identified associations between injury crashes and single motorcycle incidents, daytime riding in the summer, rollover crashes, two-way undivided roadways, middle-aged drivers, and specific road types. Additionally, rules for PDO crashes indicated high associations with adverse weather conditions, winter season driving, collisions with roadside fixed objects, angle crashes, and the absence of traffic control devices on roadways. The study's findings provide valuable insights for policy development, resource allocation, and interventions aimed at mitigating the risks associated with motorcycle crashes.

Authors	Bharat Kumar Pathivada, Western Kentucky University Arunabha Banerjee, Western Kentucky University Kirolos Haleem, Western Kentucky University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	TRBAM-24-00532
Paper Title	**Developing Motorcycle Crash-Specific Safety Performance Functions along Rural Two-Lane Undivided Road Segments in Kentucky Pre- and Post-COVID-19 Pandemic**
Abstract	This study develops safety performance functions (SPFs) for motorcycle crashes along rural twolane undivided roadway segments in Kentucky, separately in each of the pre-COVID-19 pandemic (2015-2019) and post-COVID-19 pandemic (2020-2022) periods. Motorcycle crash records and various road-specific features (e.g., shoulder width, speed limit, and annual average daily traffic “AADT”) were used. The systemic safety analysis using crash tree diagrams revealed that motorcycle crashes were frequently occurring on rural two-lane undivided roadways; hence, SPFs were fitted on this facility type. Conway-Maxwell-Poisson (CMP) and heterogeneous Conway-Maxwell-Poisson (HTCMP) models were applied and compared (since both models account for under-dispersed motorcycle crashes, i.e., with variance being less than the mean). For both pre- and post-pandemic period, the HTCMP model (with a varying dispersion parameter) outperformed its CMP counterpart using various goodness-of-fit measures (e.g., Akaike information criterion “AIC”, Bayesian information criterion “BIC”, and McFadden pseudo R2). The empirical Bayes (EB) method was then used to rank the top ten high-crash roadway segments pre- and postpandemic. From the developed SPFs, for both pre- and post-pandemic, presence of horizontal curves, mountainous terrain, and AADT were significantly associated with increased motorcycle crash frequencies. For the pre-pandemic period, presence of roadside guardrails, posted speed limit (50-55 mph), and wider right shoulders were associated with reduced motorcycle crash frequency, whereas post-pandemic, only the presence of roadside guardrails significantly reduced motorcycle crash frequency. Several motorcycle safety countermeasures were proposed, such as installing chevrons on curved road sections along with grooved rumble strips on the edge of the road.

Authors	Saif Alarifi, King Saud University Khalid Alkahtani
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-03284
Paper Title	**Developing Safety Performance Functions for Diamond Interchanges on Rural Freeways in Saudi Arabia**
Abstract	This paper aims to develop full safety performance functions (SPFs) for diamond interchanges on rural freeways in Saudi Arabia. The data for this study was obtained from different sources for the period of 2017 to 2019 (3 years) before COVID-19 pandemic for the development of SPFs. Diamond interchanges represent about 55% of all rural interchanges in KSA and have the highest crash frequency during the study period. Data for 32 diamond interchanges were collected, and simple and full SPF models were developed in this study. Goodness-of-fit measure indicated that full SPF models provide better fit of the data compared to simple SPF models. Also, it was found that Poisson regression models were able to explain FI crashes better than NB models. Volume exposure was not found as a statistically significant explanatory variable for FI crashes. Center-to-Center Distance, number of through lanes on crossroad, presence of junctions in buffer, presence of new jersey median, and presence of painted median variables were significant in the Poisson model. Those variables had negative coefficient in the SPF, therefore, they tend to decrease crash occurrence. This study is very useful to enhance the methodology used in identifying hotspots at interchanges on rural freeway. It will also help to develop local crash modification factors using more accurate methods, which include SPF. Lastly, this study covers only the most common design of interchanges on rural freeways, and it is recommended to develop SPFs for the other popular designs, such as cloverleaf and partial cloverleaf interchanges.

Authors	Jimoku Salum, SRF Consulting Cecilia Kadeha, World Bank Priyanka Alluri, Florida International University Srinivas Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-01476
Paper Title	**Quantitative Safety Measures for Managed Lanes on Freeway Facilities with Reversible Flow**
Abstract	Managed lanes have emerged as an effective solution for alleviating freeway congestion in the United States. This study focuses on reversible flow managed lanes and aims to develop quantitative measures, including safety performance functions (SPFs) and crash modification factors (CMFs), to enhance safety and guide targeted interventions. Data from Florida, Georgia, and Texas facilities were analyzed, including roadway characteristics, average annual daily traffic (AADT), and crash data from 2015 to 2019. The results revealed that higher AADT was associated with increased crash frequency, while having more managed lanes and wider separation widths between managed and general-purpose lanes, with a concrete barrier, led to fewer crashes. The developed SPFs provide insights into crash patterns and expected crash rates based on specific roadway conditions and variables. By applying CMFs to predicted crash rates derived from SPFs, agencies can estimate the potential crash reduction achievable through specific design modifications or countermeasures. This facilitates informed decision-making and prioritization of strategies to enhance roadway safety. It is important to note that the findings are based on specific datasets and focused on priced managed lanes during a particular time period. Therefore, their generalizability to other contexts may be limited. Nevertheless, these findings provide valuable information for agencies involved in managed lane operations and the selection of separation treatments, contributing to the enhancement of safety in reversible flow managed lanes.

Authors	Hasan Naqvi, National Highways Authority of India Geetam Tiwari, Indian Institute of Technology, Delhi
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-05700
Paper Title	**Network Screening of National Highways for Fatal Crashes in India**
Abstract	This paper presents network screening of National Highways (NHs) in three states using only fatal crash data, to define blackspot separately for each studied NH and identify blackspots using the empirical Bayes (EB) method. The results are compared with negative binomial approach and GIS technique. Data for fatal crash, traffic volume and highway inventory have been collected for NHs having varying lane configurations: two-lane NH-8, four-lane NH-24, and six-lane NH-1. Blackspot is defined for each studied NH employing the EB method. The NH segments, which had expected a number of fatal crashes for a segment that is, four times for two-lane NH-8, three times for four-lane NH-24, and two times for six-lane NH-1 than their population average, are defined as blackspot based on the plotted graphs. The screening results revealed that for two-lane NH-8, of the total five segments caught in the fatal crash count ⩾ 10, three segments are expected to be ‘true positives’. For four-lane NH-24, no segment is found to be ‘true positive’. For six-lane NH-1, of the total nine segments caught in the fatal crash count ⩾ 16, five segments are expected to be ‘true positives’. Moreover, a comparison of the identified NHs segments with ‘true positives’ obtained through the EB method and the corresponding NHs segments obtained through kernel density estimation (KDE) using GIS is done to compare the EB results. The comparison of the results showed that segments identified through the EB method as blackspots were also identified as hot spots through KDE.

Authors	Alican Karaer, Iteris Masoud Hamedi, Iteris
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-06151
Paper Title	**Intersection Safety Risk Scoring using Connected Vehicle Data and Machine Learning: A Case Study in Atlanta Region**
Abstract	Signalized intersections are often considered critical crash hotspots due to the presence of multiple conflicting movements. Traditional intersection safety studies have been conducted using historical crash data which is a reactive approach as it requires multiple years of crash records. The advancements in connected vehicle (CV) technology introduced a wealth of vehicle motion data, such as hard acceleration/braking events, highly granular trajectories, and segment-wise speeding proportions. This study proposes a framework utilizing these emerging data sources to demonstrate their viability on network screening for signalized intersection safety assessment even in the absence of up-to-date crash data. As proof of concept, CV event data and intersection characteristics are linked and compared with two years of crash data in the metropolitan area of Atlanta, GA covering 3,853 intersections. Exploratory analysis revealed that hard acceleration is the most significant factor followed by hard braking and traffic volume. To predict the number of crashes using this emerging dataset at each intersection, Negative Binomial Regression (NBR) and two Machine Learning (ML)-based models, namely Random Forest (RF) and Extreme Gradient Boosting (XGBoost), are employed. All models ranked the intersections with a relatively high ranking-order correlation coefficient, While ML models outperformed the NBR model. The XGBoost model predicted the number of crashes with an error margin of ±22 per intersection. By reducing reliance on historical crash data, the proposed methodology empowers stakeholders to efficiently rank signalized intersections based on safety performance and prioritize critical locations for future investments or policy development.

Authors	John McCombs, University of Central Florida Haitham Al-Deek, University of Central Florida Adrian Sandt, University of Central Florida Nizam Uddin, University of Central Florida Grady Carrick, Enforcement Engineering, Inc.
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-00048
Paper Title	**Identifying Corridor-Level Safety Improvements for Urban and Suburban Arterials in Florida Within a Safe System Framework**
Abstract	Many agencies have adopted a Safe System approach to improving roadway safety. The Highway Safety Manual (HSM) provides methods for assessing safety, but these models are site-specific and require extensive data, making them difficult to use at large scales. This paper develops a corridor-level methodology for holistically looking at corridors made of consecutive intersections and roadway segments to identify safety improvements which align with the Safe System approach while requiring less data than HSM methods. Using a standardized definition, 549 corridors on urban and suburban arterials across Florida were identified which experienced over 10,000 fatal and serious injury (FSI) crashes from 2017 through 2021. A negative binomial regression model was developed to predict mean FSI (MFSI) crashes at the corridor level (using corridor length as exposure), with the predicted values adjusted using the Empirical Bayes method to provide more accurate results. The significant factors in the model were traffic volume, intersection densities and sizing, area type, bus stop presence, citation rate, and corridor lighting presence. Increasing citation rates (citations/year/mile) for unsafe driving behaviors by one unit was predicted to reduce MFSI crash frequency in corridors by 2%, and corridors without lighting were predicted to experience 2.85 times more MFSI crashes compared to corridors with lighting. Two sister corridors in South Florida with similar roadway characteristics but different crash frequencies were also analyzed. Improvements to lighting and access control in the identified high-risk corridor could help reduce FSI crashes. Overall, this corridor approach can help agencies proactively improve roadway safety.

Authors	Sangjae Lee, Hanyang University Young Jo, Hanyang University, Ansan Juneyoung Park, Hanyang University, Ansan Cheol Oh, Hanyang University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-00694
Paper Title	**Prioritizing Safety-Vulnerable Interrupted Road Facilities for Mixed Car-Following Situations: Methodology and Application**
Abstract	With the advancement of autonomous driving technology, it is expected that autonomous vehicles (AVs) and manually driven vehicles (MVs) will coexist and operate soon. The different driving behaviors of AVs and MVs can potentially impact the driving safety on existing road infrastructure. This study tries to evaluate the driving safety of AVs and MVs in the context of following events on urban roads and determine priority for evaluation and improvement. The multi agent driving simulator (MADS) was utilized to simulate AV manuevering control algorithms and urban road, enabling the derivation of longitudinal, lateral, and inter-vehicle driving safety indicators. To provide a relative comparison of driving safety, the change rate in safety indicators for each road section was compared against the tangent section on a level road. The analysis revealed that longitudinal safety decreased by 11 times and inter-vehicle safety decreased by 150 times compared to the tangent section on a level road, particularly in signalized and unsignalized intersections that require frequent acceleration and deceleration. Furthermore, the lateral driving safety in roundabout and U-turn sections, which necessitate significant steering controls, was found to be 17 times lower. Additionally, by applying the developed safety evaluation methodology to a real-world mobility testbed to find urban road sections requiring safety improvement. The analysis results indicated that sections with a high number of signalized intersections showed lower driving safety. Based on the prioritization of urban road sections derived from this analysis, vulnerable sections for AV mixed traffic can be identified in terms of driving safety.

Authors	Alexander Garbier, Kittelson & Associates, Inc. Caitlin Mildner, Kittelson & Associates, Inc. Alek Pochowski, Kittelson & Associates, Inc. Christine Mayeur, District Department of Transportation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-02502
Paper Title	**Drawing the Lines on Safety Priorities: The How and Why of Developing Washington, D.C.'s High Injury Network**
Abstract	In 2015, the District of Columbia made a Vision Zero commitment to reach zero traffic-related deaths and severe injuries. As part of the effort, the District in partnership with District Department of Transportation (DDOT), pursued a data-driven approach to target safety projects. One aspect of the District's Vision Zero work is the identification and maintenance of a High Injury Network (HIN). In 2022, DDOT attempted to create an improved methodology for identifying the District's HIN. As part of the effort, DDOT reviewed the crash screening approach recommended by the Highway Safety Manual (HSM) and methods used by other jurisdictions. While DDOT found useful information and examples of jurisdictions who documented their processes, the information was in disparate locations and often failed to provide context for choices and trade-offs inherent in those decisions. This paper attempts to fill this gap in the state of the practice by organizing DDOT's findings into a holistic resource for other jurisdictions. In addition to summarizing findings, the paper lays out in detail DDOTs experience updating the District HIN to illustrate how to develop a methodology incorporating standard practices while responding to local goals and context. HINs are an increasingly popular communication tool for identifying agency priorities. The goal of this paper is to provide a sturdier framework for jurisdictions to consider when developing their own HINs so that HINs match with agency goal

Authors	Md Nasim Khan, Texas State University Subasish Das, Texas State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-04412
Paper Title	**A Systematic Review on Safe System Approach and its Applications in Highway Safety**
Abstract	The Safe System Approach (SSA) has gained prominence as a comprehensive framework for enhancing traffic safety by prioritizing system-wide interventions. This systematic review examines the implementation and impact of the SSA on overall traffic safety. Through an exhaustive search and critical analysis of relevant studies, this review provides insights into the effectiveness of the approach in reducing road traffic fatalities and injuries. Additionally, it explores the challenges and opportunities associated with its implementation, including policy initiatives, institutional frameworks, and stakeholder collaborations. The findings highlight the potential for the SSA to create a more forgiving and resilient transportation system, offering valuable guidance for policy decisions, future research, and interventions aimed at promoting safer road environments. This review contributes to the ongoing efforts to prioritize safety and transform the transportation landscape in the United States and other countries.

Authors	A. Latif Patwary, University of Tennessee Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-04785
Paper Title	**Exploring How Urban Form, Demographics, and Disadvantaged Communities are Linked with Pedestrian and Bicycle Safety**
Abstract	With pedestrian and bicycle safety as the main focus, this study investigates the role of urban form, disadvantaged communities (DACs), and demographics at the national level. All three are closely related, e.g., the urban form can lead to segregation and concentration of DACs with limited access to resources such as safe infrastructure, services, and economic opportunities. The study uses the recently released US Department of Transportation data on DACs. This information is available at the census tract level through the Justice40 initiative and aims to address transportation equity issues. Specifically, six comprehensive indicators identify DACs based on economy, environment, equity, health, resilience, and transportation. This study uses these DAC indicators, urban form (e.g., developed area and alternative modes), and demographics (race or gender) to explore their association with pedestrian and bicycle fatal crashes. The study creates a unique database combining ten years of pedestrian-bicycle-involved fatal crashes with data for the 71,729 census tracts. The data are analyzed using descriptives and rigorous zero-hurdle negative binomial models, which account for excessive zeros. The inference-based analysis results reveal that all the disadvantaged indicators are positively associated with pedestrian-bicycle-involved fatal crashes. Furthermore, fatal-crash rates are positively associated with high-intensity development in census tracts. Higher Black, American Indian, or Alaska Native populations are associated with more fatal crashes. The study creates new knowledge about safety in different contexts characterized by urban forms, DACs, and demographics. The information can assist policymakers in allocating resources to improve DACs on a priority basis, promoting transport social justice.

Authors	Arunabha Banerjee, Western Kentucky University Bharat Kumar Pathivada, Western Kentucky University Dylan Justice Kirolos Haleem, Western Kentucky University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-01057
Paper Title	**Comprehensive Investigation of Severe Distraction-Related Crashes along Kentucky's Rural Two-Lane Roads**
Abstract	This study develops safety performance functions (SPFs) for severe ("KA" or "fatal & suspected serious injury") distraction-related crashes along Kentucky's rural two-lane undivided road segments. Recent four-year (2018-2021) of distraction-related crash records and police narratives were carefully reviewed. The systemic safety analysis revealed that severe distraction-related crashes frequently occurred along rural two-lane roadways; thus, SPFs were fitted for this facility. To account for under-dispersion when the crash variance is less than its mean, Conway-Maxwell-Poisson (CMP) model and CMP-based models, including the heterogeneous Conway-Maxwell-Poisson (HTCMP), zero-inflated Conway-Maxwell-Poisson (ZI-CMP), and zero-inflated heterogeneous Conway-Maxwell-Poisson (ZI-HTCMP), were fitted and compared. The ZI-HTCMP model outperformed the other comparative models in terms of goodness-of-fit measures (e.g., Akaike information criterion "AIC", Bayesian information criterion "BIC", and pseudo R2). From the developed SPFs, presence of horizontal curves, wider shoulder widths, posted speed limit (55 mph), and lower annual average daily traffic (AADT) were associated with increased severe distraction-related crash frequency, whereas mountainous terrain was associated with reduced severe distraction-related crashes. The empirical Bayes (EB) method was then used to rank the top ten high distraction-related crash locations (HCLs). The HCL in-depth investigation revealed that single-vehicle distraction-related crashes were the most frequent crash type. Furthermore, "using cell phones", "falling asleep", and "driving under the influence" were the common forms of distraction. Countermeasures were proposed to help reduce severe distraction-related crashes on rural two-lane segments, including installation of chevron signs before sharp curves, installation of edge rumble strips, and use of high visibility dynamic message signs on overhead digital billboards.

Authors	SAMUEL TAKYI, Florida A&M University-Florida State University Richard Antwi Mohammadreza Koloushani, FAMU-FSU College of Engineering Eren Ozguven, Florida A&M University-Florida State University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-05521
Paper Title	**A Spatial Analysis of Traffic, Speeding, and Proximity to Critical Facilities: A Case Study in the State of Florida.**
Abstract	One of the most crucial facets of transportation management is improving accessibility and safety on the roads. To identify possible areas of concern and enhance road safety and accessibility, this study focuses on completing a spatial analysis of traffic patterns, speed limits, and the proximity of telemetered traffic monitoring stations to critical facilities in urban environments. As such, the aim of this research is to offer useful insights for transportation agencies by merging spatial data analysis approaches, and Geographic Information Systems (GIS). The analysis starts with the collection and integration of a variety of data, such as the volume of traffic, the posted speed limits, and the locations of critical facilities like schools, hospitals, and shelters. To find possible hotspots or areas where accessibility and safety are at risk, spatial analysis techniques are used to evaluate relationships between traffic patterns, speed limits, and proximity to critical facilities. The research also seeks to identify traffic impacts on important areas and prospects for improving urban planning and transportation infrastructure by utilizing spatial analytic tools. Findings of this study can help drive decision-making by identifying places where improvements to infrastructure, traffic-calming strategies, or adjusted speed limits can improve roadway safety.

Authors	Yu Wu Hao Yang, McMaster University Harith Abdulsattar
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-05833
Paper Title	**Development of A Novel Real-time road safety evaluation system**
Abstract	This research aims to develop a real-time, comprehensive, practical, and reliable safety performance evaluation system for road segments, taking into account various types of potential collisions. The system considers potential rear-end collisions on straight roads and side-impact collisions within intersections. The probability and severity of potential collisions are estimated using real-time vehicle trajectories, and a real-time risk score is defined to assess the safety performance of road segments. In this paper, we propose a predicted PET based on the anticipated trajectories of vehicles at intersections. Simultaneously, this research also takes into account near-side and far-side impact collisions. Furthermore, model justifications based on simulation data are conducted to demonstrate the system's effectiveness in identifying potential conflicts near intersections. An empirical analysis of two real-world intersection datasets is performed to evaluate the system's performance with actual data. The developed system lays the groundwork for municipalities and government agencies to adopt a safety-based road management approach and identify vulnerable locations within specific areas.

Authors	Zihe Zhang, University of Alabama Chenxuan Yang, University of Alabama Jun Liu, University of Alabama Cong Chen, University of South Florida Steven Jones, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-02956
Paper Title	**Revisiting the Roles of Speeds in Traffic Crashes: A Geographically Weighted Neural Network Approach**
Abstract	Improper speed behavior is a major contributing factor in traffic fatalities and injuries, especially on rural roads. Extensive research has been conducted to investigate factors related to speeding behavior and its impact on injury severity. However, previous studies have neglected the distinction between two types of improper speed behaviors: exceeding the posted speed limit (EPSL) and driving too fast for conditions (DTFFC). Crashes involving these two types of behaviors may exhibit different contributing factors and crash injury outcomes. This study utilizes a statewide crash database to develop separate models and compare the correlates of injury severity in crashes involving EPSL and DTFFC, respectively. Considering the complex relationships inherent in crashes, such as spatial unobserved heterogeneity, variable interaction, and non-linear patterns, besides the traditional logit regression (LR), this study adopts Geographically Weighted Logistic Regression (GWLR), Neural Network model (NN), and Geographically Weighted Neural Network (GWNN) to model injury severity. The relationship between explanatory variables and injury severity is quantified using marginal effects (ME) to explain the machine learning models. The findings indicate that: 1) GWLR and NN models exhibit better goodness-of-fit compared to LR; 2) the ME of injury severities differs between the two types of crashes in all models; 3) both GWLR and GWNN show substantial variation in ME across different spatial regions. This study contributes by incorporating NN into the spatial modeling framework and is expected to help identify high-risk regions for specific speeding behavior-related crashes, allowing for localized countermeasures to be implemented.

Authors	Tumlumbe Juliana Chengula, South Carolina State University Judith Mwakalonge, South Carolina State University Gurcan Comert, Benedict College Saidi Siuhi, South Carolina State University Judy Perkins
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-04693
Paper Title	**Using Empirical Bayes Estimation Approach to Quantify the Abnormality of Traffic Conditions During the COVID-19 Pandemic**
Abstract	The COVID-19 pandemic caused unprecedented disruptions in transportation worldwide, leading to significant reductions in traffic volume. However, this reduction in traffic was surprisingly accompanied by a notable surge in traffic fatalities, raising alarm for public safety. Using traffic volume data from respective State Departments of Transportation (DOT) and Fatality Analysis Reporting System (FARS) data, traffic abnormalities during the pandemic were examined. The I-95 interstate highway was segmented based on roadway characteristics to understand the impact in various segments. Considering both confounding variables, our analysis showed an estimation accuracy of 88.59%, indicating that accounting for traffic volumes and regression to the mean was important to make accurate predictions. However, when regression to the mean was removed from the model, the estimation accuracy significantly improved to 99.62%. This suggests that pre-pandemic fatalities might not have been higher than expected due to random fluctuations, contributing to a more accurate prediction. Surprisingly, scenario three, where we assumed no confounding variables, yielded an estimation accuracy of 50.19%. This indicates that ignoring the influence of confounding variables could lead to less accurate predictions of the pandemic's impact on fatal crashes. Policymakers can use this information to identify vulnerable segments along various highways and allocate resources for targeted safety interventions Bayesian analysis provided critical insights into the disproportionate compromise to road safety during the COVID-19 pandemic, even with reduced traffic volume. The predictive analysis produced accurate predictions, shedding light on the complexity of the pandemic's impact on traffic operations and safety along the roadways.

Authors	In Je Lee, University of Florida Shraddha Sagar, University of Florida Nithin Agarwal, University of Florida Sivaramakrishnan Srinivasan, University of Florida Ruth Steiner, University of Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2236
Session Title	**School Transportation and Planning Research**
Paper Number	TRBAM-24-02363
Paper Title	**A Data-Driven Approach to Develop Master Plan to Prioritize Schools for Safe Routes to School (SRTS) Program**
Abstract	Safe Routes to School (SRTS) programs initiated by the U.S. Department of Transportation aim to promote active modes of transportation (walking and biking) among students commuting to school through several means, including infrastructure improvements and educational programs. A review of SRTS programs at the state level reveals that there is lack of standard framework to quantify and prioritize the needs of school districts and/ or communities. The primary objective of the study is to develop a systematic and data-driven framework to identify site-specific infrastructure improvements that have the potential to positively impact student safety and mobility. There is limited literature on risk factors associated with bike and pedestrian crashes around schools. This study investigates roadway infrastructure, socioeconomic and demographic conditions and land use characteristics to identify risk factors impacting the safety of bicyclists and pedestrians around schools. The study encompassed the analysis of around 3,000 schools in the State of Florida and tests over 20 potential independent variables to develop safety performance functions (SPFs) assessing the safety of bicyclists and pedestrians near schools. The research reveals significant factors influencing the risk of school-related bike and pedestrian crashes, including school location, the number of schools in the service area, intersections with stop signs, retail land uses, median age of population in the service area, median household income, and the proportion of the white population. Practitioners can adopt the models to prioritize the schools for the SRTS infrastructure investments.

Authors	Orfeas Karountzos, National Technical University of Athens (NTUA) Alexandros Liazos Konstantinos Kepaptsoglou, National Technical University of Athens (NTUA)
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-00337
Paper Title	**Spatial Decision Support System for the Assessment of High-Risk Areas and Contributing Factors in Road Traffic Accidents: Application to the Northern Road Axis of Crete, Greece**
Abstract	This study examines how different variables affect road traffic accidents (RTAs), by analyzing their spatiotemporal characteristics. A comprehensive, easily adaptable and versatile Spatial Decision Support System (SDSS) is developed to provide insights regarding RTA occurrence and its contributing factors on different levels of spatial analysis, and through the use of various GIS-based methods. A case study on the Northern Road Axis of Crete (VOAK) is considered, focusing on identifying blackspots and clusters of RTA occurrence, related injuries, and deaths. The analysis utilizes spatial analysis techniques, such as Kernel Density Estimations (KDE), Spatial Autocorrelation models for the identification of spatial patterns, Univariate and Bivariate Local Indicators of Spatial Association (LISAs) to explore spatiotemporal patterns of RTAs and their correlation with infrastructure related factors. Findings indicate that the most significant blackspots and clusters of RTAs are located in specific parts of the study area which require immediate targeted interventions, mostly due to poor infrastructure. The study highlights the importance of a comprehensive approach to road safety management, considering spatial characteristics and topologyrelated complexities, while providing insights regarding the development of effective strategies for reducing the number of RTAs, related injuries and fatalities caused by them, thus leading to more effective road safety management from policymakers.

Authors	Raja Daoud Matthew Vechione, University of Texas, Tyler Okan Gurbuz, Texas A&M Transportation Institute Prabha Sundaravadivel
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-00293
Paper Title	**Development of an Illumination Data Collection Tool and Nighttime Crash Severity Prediction Models Using Machine Learning**
Abstract	Past research has shown that driving at night is riskier in terms of crash involvement than during the day. Fortunately, it is clearly established that illumination on roadways can reduce the number of nighttime crashes. However, state and municipal departments of transportation (DOTs) lack the available illumination data. Therefore, the objective of this research is threefold: (i) to develop machine learning models that use readily available roadway characteristic data to predict the crash severity of nighttime crashes; (ii) determine the effect illumination has on crash severity; and (iii) develop a tool to assist DOT decision-makers in collecting illumination data. To accomplish this objective, we have extracted data from the Texas Department of Transportation (TxDOT) Crash Record Information System (CRIS) database, which was then further split into a training and a test data set. Then, five machine learning techniques, namely binary logistic regression, k-nearest neighbors, naïve Bayes, random forest, and an artificial neural network, were all applied to the unseen test data. The random forest model produced the most promising results by predicting severe crashes with 97.6% accuracy. In addition, we conducted a pilot study to test the collection of illumiation data using a light meter. In the future, we aim to complete the development of a smartphone application, which can be used in conjunction with the random forest model presented in this paper, to collect crowdsourced illumination data and predict nighttime crash hotspots. This may assist DOT decision-makers to prioritize funding for illumination at the hot spots.

Authors	Zhongyu Yang, Georgia Institute of Technology Pingzhou (Lucas) Yu, Georgia Institute of Technology Ronit Shah Ron Knezevich, Georgia Department of Transportation Yi-Chang Tsai, Georgia Institute of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-02292
Paper Title	**Crash Prediction on Horizontal Curves: Review and Model Performance Comparison**
Abstract	More than 25 percent of all roadway fatalities are associated with a horizontal curve, and the average crash rate for horizontal curves is about three times that of other types of highway segments. A focus on horizontal curves can prove to be a cost-effective approach to reducing safety issues. Accurate Crash Prediction Models (CPMs) on horizontal curves can help roadway safety practitioners assess and prioritize safety improvements. Although many CPMs have been developed, there are no extant studies that compare different CPMs on a singular, real-world, large-scale, and comprehensive dataset to evaluate their capability for horizontal curve crash prediction. This study critically evaluated commonly used CPMs, including multiple linear regression (MLR), Poisson Regression (PR), Negative Binomial Regression (NBR), Support Vector Machine (SVM), Random Forest (RF), and Fully Connected Neural Networks (FCNN) models, on 18,000 centerline miles of Georgia's state-maintained routes and statewide historical crash data set from 2013 to 2021. Results show PR and NBR models outperform the MLR by around 6%. Moreover, the FCNN and RF models further improved this performance by around an additional 6% over the PR and NBR models. Overall, machine learning (ML)-based models outperform generalized linear regression models. The results prove ML-based models can be recommended to transportation agencies to forecast horizontal curve crashes more accurately.

Authors	Prabal Chandra Bhowmik Md Asif Raihan, Bangladesh University of Engineering and Technology Md. Shamsul Hoque, Bangladesh University of Engineering and Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-02280
Paper Title	**Identification and Analysis of Crash Hotspots and Temporal Shifts using Kernel Density Estimation, Getis-Ord Gi*, and Spatial Autocorrelation (Morans I): A Case Study on N1 in Bangladesh**
Abstract	Road safety is a critical concern for transportation authorities worldwide, with Bangladesh being no exception. This study presents a comprehensive analysis of road crash patterns along the N1 in Bangladesh, focusing on identifying temporal shifts in crash hotspots and understanding whether the crashes exhibit dispersed, random, or clustered patterns. Crash data from three distinct time periods (2006–2011, 2012–2017, and 2018–2022) were collected and analyzed using a combination of spatial analysis techniques, including Network Kernel Density Estimation (NKDE), Getis-Ord Gi*, and Spatial Autocorrelation (Moran's I). The temporal analysis of hotspots across three time periods provides insights into the changing patterns of crashes. A comparison of hotspot locations across the three time periods reveals that hotspot locations are evolving over time, which may be attributable to the expansion projects and countermeasures implemented over the year. A random pattern of crashes has been observed between 2006 and 2011, indicating a very even distribution of crashes and signifying that there is no spatial correlation among crash incidents. However, a clustered pattern emerged in the subsequent time frame of 2012–2017, indicating localized areas with higher crash frequencies, forming distinct hotspots along the highway. From 2018 to 2022, however, the pattern switched towards dispersion, indicating an equal distribution of crashes, and shedding light on network-based road safety policies. This temporal perspective allows for an assessment of the effectiveness of implemented interventions and serves as a guide for future road safety strategies.

Authors	Xiao Hu, Tsinghua University Yu Qi Ke Zhang, Tsinghua University Huiping Li Meng Li, Tsinghua University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03693
Paper Title	**Risk Hotspot Identification from Massive Driving Behavior Data Considering Driver Style Classification: A Bayesian Network Approach**
Abstract	Aggressive driving behavior data from probe vehicles, as a novel type of spatial-temporal information, demonstrates significant potential in risk hotspot identification. In this work, we propose a Bayesian Network (BN) framework to identify risk hotspots from massive driving behavior data, taking into account both traffic situations and driver styles. Through an illustrative example, we demonstrate how BNs can effectively detect risk hotspots, even when faced with limited data sampling and varying driver styles. Subsequently, we apply the BN framework to analyze the massive driving behavior data collected from 6,698 probe vehicles in the Wangjing area in Beijing. To identify aggressive drivers, we employ a novel fractional model that considers frequent travel paths and the frequency of risky behaviors. The BN's parameters are inferred from real-world data, and the results are visualized and compared with traditional methods. Results indicate that: (a) The proposed BN method outperforms the KDE method in identifying hotspots with fewer recorded data points and provides better interpretability; (b) Aggressive drivers tend to exhibit risky behavior more frequently than calm drivers on both safe and hazardous road links; (c) Frequent drivers are more prone to engage in risky behavior than rare drivers, especially on hazardous road links. Finally, we offer several policy implications for improving traffic safety management based on the study's findings.

Authors	Yi Zhang Mouxing Lai Jun Li Xiwen Yang Siyu Shi Sai Tian Tong Zhu, Chang'an University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03981
Paper Title	**Identify High-risk Road Segments of Traffic Accidents Using Street Map Segmentation and Machine Learning**
Abstract	To identify high-risk road segments without relying on accident and surveillance indexes, we collect and segment street view images to extract visual environment data. We then investigate the correlation between drivers' visual environment data and the occurrence of fatal traffic accidents. In this study, we (1) collect road data and traffic fatality accident records in the study area, locate latitude and longitude, and extract street view images as driver's visual environmental data; (2) use the DeepLabv3+ algorithm for semantic segmentation of the visual images, identifying 20 environmental elements, and calculate the mean and standard deviation of pixel proportions for each class; (3) encode the feature variables and use three tree-based ensemble models (Random Forest, XGBOOST, and LightGBM) to estimate accident frequencies, comparing the models to find that the XGBOOST-based risk segment identification model provides the best data fit. We then interpret the significant factors affecting accident frequencies using SHAP values; (4) utilize the XGBOOST model to identify accident-prone locations for a specific transportation route instance. Using extraction and recognition methods based on street-level maps, we can rapidly identify hazardous road segments and ensure transportation route safety. Additionally, the proportion of fences stands out as the most significant factor for road segments with accidents, followed by other important factors such as the proportion of roads, vehicles, background, sidewalks, poles, walls, and terrain for road segments with accidents.

Authors	Pengfei CUI, Beijing Jiaotong University Manli YANG Zhengqi HUO Xiaobao YANG, Beijing Jiaotong University Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-01795
Paper Title	**Modelling Urban Traffic Crash Causation Considering Spatio-Temporal Instability in Big Cities**
Abstract	Traffic crashes have become one of key public health issues, triggering significant apprehension among citizens and urban authorities. Quantifying the spatiotemporal variability and underlying factors on urban traffic crashes can guide proactive policymaking, fostering public safety trust. In this study, we elucidate the complexities underlying urban traffic crashes, revealing the spatiotemporal heterogeneity and the distinct influences of real-time weather conditions and geographical features on the severity of traffic crashes across three major U.S. cities—New York, Los Angeles, and Houston. We employ a novel methodology that merges an Integrated Nested Laplace Approximation based Stochastic Partial Differential Equation model with spatially adaptive graph structures, enabling efficient analysis of vast geospatial data. Our findings unveil city-specific disparities in the impact of various factors on severe traffic crashes. Despite some universal trends, such as the risk-enhancing effect of cold weather and pedestrian crossings, we find marked differences across cities in relation to factors like temperature, precipitation, and the presence of certain traffic facilities. This work has important policy implications, suggesting a need for tailored, location-specific strategies to improve traffic safety, thereby aiding authorities in better resource allocation and strategic planning.

Authors	S. Madeh Piryonesi, University of Toronto
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-02953
Paper Title	**Incident Prediction on Urban Roads Using Data Fusion: The Case of Toronto**
Abstract	This paper presents a case study about using both SQL and non-SQL data for predicting road incidents at the City of Toronto. Road incidents can adversely affect the traffic and exacerbate road congestion. Using machine learning for predicting the probability of incidents, their severity and areas more prone to incident can help municipalities and departments of transportation (DOTs) improve road level of service while allocating their resources more effectively. In this paper, data of incidents in the City of Toronto was used to demonstrate how data analytics can help predict road incidents and their severity. The dataset included both SQL and non-SQL (written comments) data. A data fusion approach was used to merge these two types of data. Machine learning tree-based models were used to predict when and where major incidents occur on two major roads in the city: Gardiner Expressway and Don Valley Park (DVP). The developed models predicted the occurrence of major incidents, using solely SQL data, with an accuracy of 93%. After combing the SQL and non-SQL data for prediction, the model accuracy increased to 97%. Next, models were trained to predict the required time for incident scene clearance on the road. The accuracy of this model for predicting three classes was around 60%. After including the attributes extracted from the textual data, the accuracy increased to 81%. Several recommendations, related to standardized data collection, were made to improve the city's procedures. These recommendations can be useful to any municipality or DOT.

Authors	Ayushi Shah Gaurang Joshi, Sardar Vallabhbhai National Institute of Technology Manoranjan Parida, Indian Institute of Technology, Roorkee
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-24-04634
Paper Title	**Prioritization of Strategies for Non-Motorized Transportation: A Multi-Criteria Intuitionistic Fuzzy TOPSIS Method**
Abstract	Achieving a zero-carbon city requires a long-term strategic perspective. India has committed to achieve net zero emissions by the year 2070. However, India requires a prioritization framework that considers the effectiveness of sustainable urban transport and the adaptability of both the system and users for the policies and strategies. This study proposes a novel extension of Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), Intuitionistic fuzzy TOPSIS to prioritize strategies for non-motorized transport. The findings revealed that strategies like upgradation the quality of bicycle infrastructure ranked highest, followed by the promotion of a public bicycle system, according to decision-makers' opinions. A comparative analysis was also conducted, comparing the proposed method with the fuzzy TOPSIS method across six scenarios to assess sensitivity. The proposed method used in this study can be transferred to other cities which aim to achieve a means of sustainable urban transport. This study contributes to the field by addressing the challenge of prioritizing strategies for non-motorized transport, considering their uncertainties. The study's insights have broader implications for cities worldwide seeking to enhance their sustainability and combat climate change through well-informed and effective policy prioritization.

Authors	Ramina Javid, Morgan State University Eazaz Sadeghvaziri, Mercer University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-24-02780
Paper Title	**Predicting Bicycle-Involved Crashes in SCAG Region: A Machine Learning Analysis Using HSIS Data from California State**
Abstract	Bicycling is one of the popular modes of transportation in the U.S. However, crashes involving bicycles continue to be a significant safety issue. This study used Health and Safety Information System (HSIS) data to examine the factors influencing the severity of bicycle-involved crashes in the Southern California Association of Governments (SCAG) region between 2013 and 2017. The study developed a Bayesian network model with strong consistency validation and low error rate, indicating the effectiveness of the model in analyzing crash data and providing valuable insight into improving rider safety. The study also created two scenarios to understand the impact of different variables on the probability of having a fatal crash. The first scenario showed that having proper lighting and reflective clothing could increase visibility and reduce the probability of a fatal crash. The second scenario showed the need for designing roads and infrastructure that can handle wet conditions and provide adequate drainage to reduce the probability of a fatal crash. The study's results demonstrate the importance of designing effective infrastructure and highlighting the significance of proper lighting and visibility on bicycles to reduce the probability of a fatal crash. The findings can help policymakers and transportation engineers prioritize measures to improve rider safety. Furthermore, the study highlights the effectiveness of Bayesian network models in identifying the most significant factors contributing to bicycle-involved crashes. Overall, the study provides valuable insight into improving the safety of riders and demonstrates the effectiveness of Bayesian network models in analyzing and predicting bicycle-involved crashes.

Authors	Faria Raha, Northern Arizona University Brendan Russo, Northern Arizona University Steven Gehrke, Northern Arizona University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-24-05020
Paper Title	**Assessing the Impact of Vehicle Type on Pedestrian and Bicyclsit Crash Injury Severity**
Abstract	Light-duty vehicles, such as sport utility vehicles (SUVs) and pickup trucks, have become increasingly commonplace on US roads. The size of these vehicles has also increased significantly with time. Given this trend, an improved understanding of the potential safety implications of large vehicles on other road users, especially pedestrians and bicyclists, has become increasingly necessary for informing responsive policies. This study examines the impact of vehicle type and other crash-related indicators of pedestrian and bicyclist injury severity in Arizona between 2017-2021. Adopting a binary logistic regression modeling framework, vehicle type was found to be a significant predictor of both pedestrian and bicyclist injury severity, with an increased likelihood of a fatality or suspected serious injury occurring for pedestrians and bicyclists struck by an SUV or pickup truck compared to a passenger car. The odds of a pedestrian-involved crash resulting in a severe injury were 1.43 times higher for pickup trucks and 1.23 times higher for SUVs in comparison to passenger vehicles. For bicyclist crashes, the odds ratios increased to 1.50 and 1.25, respectively. Other contributing factors such as lighting condition, posted speed limit, crash location, driver action, driver age, and pedestrian and bicyclist age were also found to be significant determinants of increased injury severity. These study findings offer important insights into the seemingly detrimental impacts of increasing vehicle size on vulnerable road user safety that can help provide transportation agencies and policymakers with the empirical evidence needed to support and prioritize roadway safety strategies for protecting pedestrians and bicyclists.

Authors	Subasish Das, Texas State University Anandi Dutta, University of Texas, San Antonio David Mills
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-24-05637
Paper Title	**Assessing Causation of Bicycle Crashes through Bayesian Network Modeling**
Abstract	Cycling offers numerous benefits to individuals and society; however, cyclists remain vulnerable road users, necessitating advanced analytical methods to understand counterfactual scenarios that may arise. Despite the environmental and societal advantages associated with cycling, bicyclists face significant risks on urban roads. Understanding the factors contributing to bicycle-related crashes is crucial for effective allocation of treatment resources. A concerning increase in the number of fatal bicycle crashes (52% increase) in 2021 compared to 2017 emphasizes the urgency of implementing effective safety measures to protect vulnerable road users. This study examines crash data from over 4,098 bicyclists in Louisiana between 2017 and 2021, aiming to investigate the underlying factors influencing bicycle crashes. Using Bayesian Network analysis, the study provides valuable insights into the complex relationships and dependencies among various contributing factors, offering a foundation for targeted interventions and measures to enhance bicycle safety. Additionally, the study highlights a concerning increase in the number of fatal bicycle crashes in 2021 compared to 2017, emphasizing the urgency of implementing effective safety measures to protect vulnerable road users.

4 Safety Performance Functions

Francesco Galante, Filomena Mauriello, and Alfonso Montella
University of Naples Federico II

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 **twenty-two papers** that are related to SPFs.

Research related to SPFs can be classified according to the **roadway facility type**. Some papers analyzed the safety performance of signalized intersections (24-01303 and 24-00660) and curves (24-02292) or focused on more specific roadway facilities such as interchanges (24-03284) and ramps (24-00803, 24-05337). Some papers focused on developing SPFs for rural two-lane highways (24-00532, 24-01057), major arterials (24-00048), and freeways (24-04686, 24-05337). In addition, two papers developed macro-level SPFs to predict crashes for a geographic area rather than at a specific segment or intersection site (24-02850 and 24-04373)

SPFs regarding **different crash types and severities** have also been widely conducted. The crashes severities investigated were total (24-05337), fatal (24-04373, 24-04785), and severe injury (24-01057 and 24-06024). In addition, SPFs for nonmotorized crashes were developed in papers 24-00660, 24-01057, 24-04373, 24-04785, and 24-06024.

The paper 24-01303 aims to develop conflict-based SPFs to predict the number of rear-end conflicts at signalized intersections under mixed traffic flow conditions. 24-00059 proposes a novel methodological formulation to directly account for this MC error and incorporates it into the two most common count data models used for crash frequency prediction: Poisson and Negative Binomial (NB) regression.

Finally, multiple **methodologies** were proposed to develop SPFs such as Negative Binomial (24-00048, 24-01384, 24-04373), Negative Binomial with Random Parameters (RP-NBR) (24-00033), Negative Binomial-Lindley (NB-L) (24-05337 and 24-00033), Conway-Maxwell-Poisson (CMP) (24-00532 and 24-01057), heterogeneous Conway-Maxwell-Poisson (HTCMP) (24-00532, 24-01057), zero-inflated Conway-Maxwell-Poisson (ZI-CMP) (24-01057), zero-inflated heterogeneous Conway-Maxwell-Poisson (ZI-HTCMP) (24-01057), Poisson Lognormal (PLN) (24-05337), and Zero-Inflated Negative Binomial (ZINB) (24-06024). In addition, **machine learning techniques** were adopted in the safety performance analysis including Support Vector Machine (SVM) (24-02292), Random Forest (RF) (24-02292), and Fully Connected Neural Networks (FCNN) (24-02292).

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

Authors	Tarek Hasan, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	24-00033
Paper Title	**Short-Term Safety Performance Functions by Random Parameters Negative Binomial-Lindley Model for Part-Time Shoulder Use**
Abstract	Part-time Shoulder Use (PTSU) is a traffic management and operation strategy that allows the use of the left or right shoulder as a travel lane typically during the peak hours of the day. Though PTSU is an effective strategy for increasing roadway capacity in the congested traffic condition, there is very limited quantitative information about PTSU design elements and operational strategy in the existing literature which could impact the crash occurrence on freeways. This study contributes to the safety literature by analyzing various potential crash contributing factors related to PTSU operation and design elements through the development of short-term Safety Performance Functions (SPFs). A comparison of the estimated models demonstrated that with the mixed distribution and capturing unobserved heterogeneity through random parameterization, the Random Parameters Negative Binomial-Lindley (RPNB-L) model outperformed the traditional NB and fixed coefficient NB-L model. The results of the proposed RPNB-L model indicated that the PTSU implemented sections experienced a lower number of traffic crashes compared to the non-PTSU freeway sections. Among the attributes related to PTSU operation and design elements, the usage of left most shoulder lane as PTSU, presence of emergency rest areas for damaged vehicles, and adequate shoulder width would significantly reduce crash frequency for the PTSU implemented freeways. Moreover, investigation of the identified hotspots revealed that the transition areas (start/end location of PTSU) are the most critical sections. The findings from this research could assist transportation agencies to take appropriate countermeasures for preventing and reducing crash occurrence for PTUS implemented freeways.

Authors	John McCombs, University of Central Florida Haitham Al-Deek, University of Central Florida Adrian Sandt, University of Central Florida Nizam Uddin, University of Central Florida Grady Carrick, Enforcement Engineering, Inc.
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	24-00048
Paper Title	**Identifying Corridor-Level Safety Improvements for Urban and Suburban Arterials in Florida Within a Safe System Framework**
Abstract	Many agencies have adopted a Safe System approach to improving roadway safety. The Highway Safety Manual (HSM) provides methods for assessing safety, but these models are site-specific and require extensive data, making them difficult to use at large scales. This paper develops a corridor-level methodology for holistically looking at corridors made of consecutive intersections and roadway segments to identify safety improvements which align with the Safe System approach while requiring less data than HSM methods. Using a standardized definition, 549 corridors on urban and suburban arterials across Florida were identified which experienced over 10,000 fatal and serious injury (FSI) crashes from 2017 through 2021. A negative binomial regression model was developed to predict mean FSI (MFSI) crashes at the corridor level (using corridor length as exposure), with the predicted values adjusted using the Empirical Bayes method to provide more accurate results. The significant factors in the model were traffic volume, intersection densities and sizing, area type, bus stop presence, citation rate, and corridor lighting presence. Increasing citation rates (citations/year/mile) for unsafe driving behaviors by one unit was predicted to reduce MFSI crash frequency in corridors by 2%, and corridors without lighting were predicted to experience 2.85 times more MFSI crashes compared to corridors with lighting. Two sister corridors in South Florida with similar roadway characteristics but different crash frequencies were also analyzed. Improvements to lighting and access control in the identified high-risk corridor could help reduce FSI crashes. Overall, this corridor approach can help agencies proactively improve roadway safety.

Authors	Asif Mahmud, Kittelson & Associates, Inc. Vikash Gayah, Pennsylvania State University, University Park Rajesh Paleti, Pennsylvania State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	24-00059
Paper Title	**Estimation of crash type frequency accounting for misclassification in crash data**
Abstract	Crash misclassification (MC) – e.g., a crash of one type or severity being mistakenly miscategorized as another – is a relatively common problem in transportation safety. Crash frequency models for individual crash categories estimated using datasets with MC errors could result in biased parameter estimates and thus lead to ineffective countermeasure planning. This study proposes a novel methodological formulation to directly account for this MC error and incorporates it into the two most common count data models used for crash frequency prediction: Poisson and Negative Binomial (NB) regression. The proposed framework introduces probabilistic MC rates among different crash types and modifies the likelihood function of the count models accordingly. The capability of the proposed models to estimate true parameters, given the existence MC error, is examined via simulation analysis. Then, the proposed models are applied to empirical data to examine the presence of MC in crash data and further examine the robustness of the proposed models. Although the MC rates are found to be very low in the empirical data, the fit of proposed models are found to be better compared to the models that ignore MC error and thus likely provide more reliable parameter estimates.

Authors	Bharat Kumar Pathivada, Western Kentucky University Arunabha Banerjee, Western Kentucky University Kirolos Haleem (kirolos60@hotmail.com), Western Kentucky University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	24-00532
Paper Title	**Developing Motorcycle Crash-Specific Safety Performance Functions along Rural Two-Lane Undivided Road Segments in Kentucky Pre- and Post-COVID-19 Pandemic**
Abstract	This study develops safety performance functions (SPFs) for motorcycle crashes along rural two-lane undivided roadway segments in Kentucky, separately in each of the pre-COVID-19 pandemic (2015-2019) and post-COVID-19 pandemic (2020-2022) periods. Motorcycle crash records and various road-specific features (e.g., shoulder width, speed limit, and annual average daily traffic "AADT") were used. The systemic safety analysis using crash tree diagrams revealed that motorcycle crashes were frequently occurring on rural two-lane undivided roadways; hence, SPFs were fitted on this facility type. Conway-Maxwell-Poisson (CMP) and heterogeneous ConwayMaxwell-Poisson (HTCMP) models were applied and compared (since both models account for under-dispersed motorcycle crashes, i.e., with variance being less than the mean). For both pre- and post-pandemic period, the HTCMP model (with a varying dispersion parameter) outperformed its CMP counterpart using various goodness-of-fit measures (e.g., Akaike information criterion "AIC", Bayesian information criterion "BIC", and McFadden pseudo R2). The empirical Bayes (EB) method was then used to rank the top ten high-crash roadway segments pre- and postpandemic. From the developed SPFs, for both pre- and post-pandemic, presence of horizontal curves, mountainous terrain, and AADT were significantly associated with increased motorcycle crash frequencies. For the pre-pandemic period, presence of roadside guardrails, posted speed limit (50-55 mph), and wider right shoulders were associated with reduced motorcycle crash frequency, whereas post-pandemic, only the presence of roadside guardrails significantly reduced motorcycle crash frequency. Several motorcycle safety countermeasures were proposed, such as installing chevrons on curved road sections along with grooved rumble strips on the edge of the road

Authors	Myunghoon Ko, Texas A&M Transportation Institute Robert Wunderlich, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-00660
Paper Title	**Risk and Contributing Factors of Pedestrian Involved Crashes at Urban Four-leg Signalized Intersections**
Abstract	The primary objectives of this paper are 1) to examine the relationship between pedestrian crash frequency and predictor variables at four-leg signalized intersections and 2) to identify the risk and contributing factors that influence the probabilities of a pedestrian being injured or killed at pedestrian crashes and pedestrian's failure of signal/right-of-way (ROW) compliance to vehicle resulted in a crash. This paper analyzed pedestrian crashes from 2016 to 2019 at 512 four-leg signalized intersections. A negative binomial regression model was used to estimate the frequency of pedestrian crashes with predictor variables, and two binary logistic regression models were used to examine the probabilities of a pedestrian being injured or killed and pedestrian's failure of signal/ROW compliance at the pedestrian crashes. The results present that daily pedestrian crossing volume, average daily traffic (ADT), the number of bus stops, and the number of exclusive left-turn lanes are significant variables to predict pedestrian crash frequency at the intersection. Pedestrian's failure of signal/ROW compliance, lower ADTs, higher speed limits, and dark conditions were found to be associated with increasing the probability of pedestrian being severely injured or killed at the crash. The results also present that male pedestrians, lower daily pedestrian crossing volume, more bus stops, and dark conditions at the intersection increase the likelihood of pedestrian's failure of signal/ROW compliance resulting in a crash. Through understanding these risk and contributing factors of pedestrian-involved crashes will help identify countermeasures and interventions to improve pedestrian safety at urban signal controlled intersections.

Authors	Justice Appiah, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	24-00803
Paper Title	**Development of Calibration Functions for Freeway Ramp Terminal Safety Performance Functions in Virginia**
Abstract	The Highway Safety Manual (HSM) provides safety performance functions (SPFs) for freeway ramps and crossroad terminals. These SPFs were developed with data from other states and need to be calibrated to Virginia conditions to ensure that they accurately reflect the driver population and environment. The application of uncalibrated SPFs may produce misleading results, compromise safety outcomes, and lead to inappropriate design decisions. This study conducted systematic calibration of the HSM ramp terminal SPFs to account for conditions in Virginia. This involved determining appropriate multipliers or functions that aligned the expected average crash frequencies estimated using HSM methodologies with field-observed crash frequencies from selected sites. A review of cumulative residual plots for fitted values suggested that using a single calibration factor as a multiplier to adjust the HSM ramp terminal SPF predictions did not provide a good fit to Virginia data. Consequently, calibration functions were developed that provided a better fit of Virginia data to the HSM ramp terminal SPF predictions.

Authors	Arunabha Banerjee, Western Kentucky University Bharat Kumar Pathivada, Western Kentucky University Dylan Justice Kirolos Haleem (kirolos60@hotmail.com), Western Kentuck\y University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	24-01057
Paper Title	**Comprehensive Investigation of Severe Distraction-Related Crashes along Kentucky's Rural Two-Lane Roads**
Abstract	This study develops safety performance functions (SPFs) for severe ("KA" or "fatal & suspected serious injury") distraction-related crashes along Kentucky's rural two-lane undivided road segments. Recent four-year (2018-2021) of distraction-related crash records and police narratives were carefully reviewed. The systemic safety analysis revealed that severe distraction-related crashes frequently occurred along rural two-lane roadways; thus, SPFs were fitted for this facility. To account for under-dispersion when the crash variance is less than its mean, Conway-Maxwell-Poisson (CMP) model and CMP-based models, including the heterogeneous Conway-Maxwell-Poisson (HTCMP), zero-inflated Conway-Maxwell-Poisson (ZI-CMP), and zero-inflated heterogeneous Conway-Maxwell-Poisson (ZI-HTCMP), were fitted and compared. The ZI-HTCMP model outperformed the other comparative models in terms of goodness-of-fit measures (e.g., Akaike information criterion "AIC", Bayesian information criterion "BIC", and pseudo R2). From the developed SPFs, presence of horizontal curves, wider shoulder widths, posted speed limit (55 mph), and lower annual average daily traffic (AADT) were associated with increased severe distraction-related crash frequency, whereas mountainous terrain was associated with reduced severe distraction-related crashes. The empirical Bayes (EB) method was then used to rank the top ten high distraction-related crash locations (HCLs). The HCL in-depth investigation revealed that single-vehicle distraction-related crashes were the most frequent crash type. Furthermore, "using cell phones", "falling asleep", and "driving under the influence" were the common forms of distraction. Countermeasures were proposed to help reduce severe distraction-related crashes on rural two-lane segments, including installation of chevron signs before sharp curves, installation of edge rumble strips, and use of high visibility dynamic message signs on overhead digital billboards.

Authors	Shao-Fu Li Shou-Ren Hu (srhu@nycu.edu.tw), National Yang Ming Chiao Tung University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	24-01303
Paper Title	Thresholds and Contributing Factors for Rear-End Traffic Conflicts at Signalized Intersections under Mixed Traffic Flow Conditions
Abstract	In the past decade, many studies have attempted to collect traffic conflict data to evaluate the safety levels of road designs and traffic operations as a faster alternative to the time-consuming collection of crash data for road safety improvement. Nevertheless, establishing suitable measures and corresponding thresholds to define different patterns of traffic conflicts is a challenging task. In the present study, we developed a peak-over-threshold method involving graphical diagnostics to identify a preliminary threshold range for rear-end traffic conflicts. We then used an automated threshold selection method (ATSM) to confirm the specific threshold value within this range. This capability of the ATSM ensures that the threshold values associated with different traffic conflicts can be accurately determined. The factors that might contribute to different types of traffic conflicts remain to be investigated. To address the aforementioned problems, we used an unmanned aerial vehicle to collect vehicle trajectory data at 19 signalized intersections under mixed traffic flow conditions. We then used these data to identify appropriate rear-end traffic conflict thresholds for different pairs of vehicles. Notably, when the rear vehicle in a vehicle pair was a scooter, the conflict thresholds were significantly smaller than those when the rear vehicle was a car. Moreover, we conducted negative binomial regression analysis to estimate the frequency of rear-end traffic conflicts. According to our findings, compared with unprotected left-turn lanes, protected left-turn phases are more effective in reducing the number of rear-end traffic conflicts.

Authors	Sailesh Acharya, National Renewable Energy Laboratory (NREL) Atul Subedi, Utah State University Michelle Mekker, Utah State University Patrick Singleton, Utah State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	24-01384
Paper Title	**Developing Safety Performance Functions and Crash Modification Factors for Skid Resistance**
Abstract	Pavement friction is a critical factor in determining road safety, especially in adverse weather conditions. This study investigates the relationship between pavement friction, measured as Skid Number (SN), and crash frequency on Utah highways. Utilizing four years of data (2016–2019) from an interstate (I-15) and a non-interstate (US-89) highway, negative binomial models were employed to establish safety performance functions (SPFs) and crash modification factors (CMFs). The models controlled for traffic volume and segment length while examining various crash types, including dry and wet weather, property damage only, and injury-related crashes. Results indicate a significant negative association between SN and crash frequency for all crash types on both highway types. Higher SN values (more friction) were associated with fewer crashes, with a 10-point increase in SN leading to a 12–13% decrease in total crashes. The impact of friction on wet weather crashes and injury crashes on non-interstate highways was even more pronounced. These findings suggest that increasing pavement friction through measures like high friction surface treatments could lead to substantial traffic safety improvements. Overall, the results support the continued collection of skid data by transportation agencies, such as the Utah Department of Transportation (UDOT), to identify high-risk locations and prioritize friction improvement efforts to enhance roadway safety.

Authors	Jimoku Salum, SRF Consulting Cecilia Kadeha, World Bank Priyanka Alluri, Florida International University Srinivas Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	24-01476
Paper Title	**Quantitative Safety Measures for Managed Lanes on Freeway Facilities with Reversible Flow**
Abstract	Managed lanes have emerged as an effective solution for alleviating freeway congestion in the United States. This study focuses on reversible flow managed lanes and aims to develop quantitative measures, including safety performance functions (SPFs) and crash modification factors (CMFs), to enhance safety and guide targeted interventions. Data from Florida, Georgia, and Texas facilities were analyzed, including roadway characteristics, average annual daily traffic (AADT), and crash data from 2015 to 2019. The results revealed that higher AADT was associated with increased crash frequency, while having more managed lanes and wider separation widths between managed and general-purpose lanes, with a concrete barrier, led to fewer crashes. The developed SPFs provide insights into crash patterns and expected crash rates based on specific roadway conditions and variables. By applying CMFs to predicted crash rates derived from SPFs, agencies can estimate the potential crash reduction achievable through specific design modifications or countermeasures. This facilitates informed decision-making and prioritization of strategies to enhance roadway safety. It is important to note that the findings are based on specific datasets and focused on priced managed lanes during a particular time period. Therefore, their generalizability to other contexts may be limited. Nevertheless, these findings provide valuable information for agencies involved in managed lane operations and the selection of separation treatments, contributing to the enhancement of safety in reversible flow managed lanes.

Authors	Zhongyu Yang, Georgia Institute of Technology Pingzhou (Lucas) Yu, Georgia Institute of Technology Ronit Shah Ron Knezevich, Georgia Department of Transportation
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 3231
Session Title	Analytical Methods of Safety Performance
Paper Number	24-02292
Paper Title	**Crash Prediction on Horizontal Curves: Review and Model Performance Comparison**
Abstract	More than 25 percent of all roadway fatalities are associated with a horizontal curve, and the average crash rate for horizontal curves is about three times that of other types of highway segments. A focus on horizontal curves can prove to be a cost-effective approach to reducing safety issues. Accurate Crash Prediction Models (CPMs) on horizontal curves can help roadway safety practitioners assess and prioritize safety improvements. Although many CPMs have been developed, there are no extant studies that compare different CPMs on a singular, real-world, large-scale, and comprehensive dataset to evaluate their capability for horizontal curve crash prediction. This study critically evaluated commonly used CPMs, including multiple linear regression (MLR), Poisson Regression (PR), Negative Binomial Regression (NBR), Support Vector Machine (SVM), Random Forest (RF), and Fully Connected Neural Networks (FCNN) models, on 18,000 centerline miles of Georgia's state-maintained routes and statewide historical crash data set from 2013 to 2021. Results show PR and NBR models outperform the MLR by around 6%. Moreover, the FCNN and RF models further improved this performance by around an additional 6% over the PR and NBR models. Overall, machine learning (ML)-based models outperform generalized linear regression models. The results prove ML-based models can be recommended to transportation agencies to forecast horizontal curve crashes more accurately.

Authors	In Je Lee, University of Florida Shraddha Sagar Nithin Agarwal, University of Florida Sivaramakrishnan Srinivasan, University of Florida Ruth Steiner, University of Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2236
Session Title	School Transportation and Planning Research
Paper Number	24-02363
Paper Title	**A Data-Driven Approach to Develop Master Plan to Prioritize Schools for Safe Routes to School (SRTS) Program**
Abstract	Safe Routes to School (SRTS) programs initiated by the U.S. Department of Transportation aim to promote active modes of transportation (walking and biking) among students commuting to school through several means, including infrastructure improvements and educational programs. A review of SRTS programs at the state level reveals that there is lack of standard framework to quantify and prioritize the needs of school districts and/ or communities. The primary objective of the study is to develop a systematic and data-driven framework to identify site-specific infrastructure improvements that have the potential to positively impact student safety and mobility. There is limited literature on risk factors associated with bike and pedestrian crashes around schools. This study investigates roadway infrastructure, socioeconomic and demographic conditions and land use characteristics to identify risk factors impacting the safety of bicyclists and pedestrians around schools. The study encompassed the analysis of around 3,000 schools in the State of Florida and tests over 20 potential independent variables to develop safety performance functions (SPFs) assessing the safety of bicyclists and pedestrians near schools. The research reveals significant factors influencing the risk of school-related bike and pedestrian crashes, including school location, the number of schools in the service area, intersections with stop signs, retail land uses, median age of population in the service area, median household income, and the proportion of the white population. Practitioners can adopt the models to prioritize the schools for the SRTS infrastructure investments.

Authors	Kazi Redwan Shabab Tanmoy Bhowmik, Portland State University Naveen Eluru, University of Central Florida Mohamed Zaki, University of Western Ontario
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Lectern Session 4003
Session Title	Safety Performance and Analysis Research
Paper Number	24-02850
Paper Title	**A Systematic Unified Approach for Addressing Temporal Instability in Road Safety Analysis**
Abstract	Multivariate models are widely employed for crash frequency analysis in traffic safety literature. In the context of analyzing data for multiple instances (such as years), it becomes essential to evaluate the stability of parameters over time. The current research proposes a novel approach, labelled the mixed spline indicator pooled model, that offers significant enhancement of current approaches to capture temporal instability. The proposed entails carefully creating additional independent variables that allow us to measure parameter slope changes over time and can be easily integrated into existing methodological frameworks. The current research effort compares four multivariate model systems: year specific negative binomial model, year indicator pooled model, spline indicator pooled model, and mixed spline indicator pooled model. The model performance is compared using log-likelihood and Bayesian Information Criterion. The empirical analysis is conducted using the Traffic Analysis Zone (TAZ) level crash severity records from Central Florida for the years from 2011 to 2019. The comparison results indicate that the proposed mixed spline indicator pooled model outperforms the other models providing superior data fit with significantly fewer parameters. The proposed mixed spline model can allow a piece-wise linear functional form for the parameter and is suitable to forecast crashes for future years as illustrated in our predictive performance analysis.

Authors	Jimoku Salum, SRF Consulting Cecilia Kadeha, World Bank Saif Alarifi, King Saud University Khalid Alkahtani
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	24-03284
Paper Title	**Developing Safety Performance Functions for Diamond Interchanges on Rural Freeways in Saudi Arabia**
Abstract	This paper aims to develop full safety performance functions (SPFs) for diamond interchanges on rural freeways in Saudi Arabia. The data for this study was obtained from different sources for the period of 2017 to 2019 (3 years) before COVID-19 pandemic for the development of SPFs. Diamond interchanges represent about 55% of all rural interchanges in KSA and have the highest crash frequency during the study period. Data for 32 diamond interchanges were collected, and simple and full SPF models were developed in this study. Goodness-of-fit measure indicated that full SPF models provide better fit of the data compared to simple SPF models. Also, it was found that Poisson regression models were able to explain FI crashes better than NB models. Volume exposure was not found as a statistically significant explanatory variable for FI crashes. Center-to-Center Distance, number of through lanes on crossroad, presence of junctions in buffer, presence of new jersey median, and presence of painted median variables were significant in the Poisson model. Those variables had negative coefficient in the SPF, therefore, they tend to decrease crash occurrence. This study is very useful to enhance the methodology used in identifying hotspots at interchanges on rural freeway. It will also help to develop local crash modification factors using more accurate methods, which include SPF. Lastly, this study covers only the most common design of interchanges on rural freeways, and it is recommended to develop SPFs for the other popular designs, such as cloverleaf and partial cloverleaf interchanges.

Authors	Ge Shi, University of Connecticut Yu (Fred) Song, University of Wyoming Carol Atkinson-Palombo, University of Connecticut Norman Garrick, University of Connecticut
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	24-04373
Paper Title	**Pedestrian and Car Occupant Crash Casualties over a 9-Year Span of Vision Zero in New York City**
Abstract	Vision zero has been increasingly embraced by jurisdictions in the U.S. Existing research primarily focuses on the theoretical principles and the effectiveness of some specific engineering measures. However, there is still limited understanding of the holistic effects of vision zero treatments, in the context of street types and urban environment. In this study, we developed a street typology framework to categorize street segments using four street design and operational features: street width, traffic direction (one-way vs. twoway), number of travel lanes, and presence of on-street parking. We applied a sample-based Partitioning Around Medoids algorithm to classify 90,327 street segments in NYC. This process results in six distinctive types of street segments. To integrate the neighborhood level factors (e.g., land use variables and sociodemographics), we aggregated street segments of a given street type for each neighborhood. Negative binomial regression models were developed for pedestrian and car occupant crash injuries and fatalities for three periods separately- 2014-2016, 2017-2019, and 2020-2022. Our findings show that street groups with narrower, two-way sections, and higher tree canopy coverage are significantly associated with a lower risk of casualties for both pedestrians and motorized users. Conversely, street groups located in neighborhood with a larger percentage of African American suffered significantly greater risk of injuries and fatalities. Vision zero treatments had mixed effects on safety outcomes. Street groups treated with leading pedestrian interval showed a lower risk of casualties. Neighborhood slow zones and arterials slow zones were associated with lower risk of car occupants' injuries and fatalities..

Authors	Bhagwant Persaud, Toronto Metropolitan University Raghavan Srinivasan, University of North Carolina, Chapel Hill Vikash Gayah, Pennsylvania State University, University Park Kristin Kersavage, VHB Taha Saleem, UNC Highway Safety Research Center Shauna Hallmark Cameron Mohammadi
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	24-04686
Paper Title	**Estimating the Expected Change in Safety for a Potential Application of Three Its Treatments**
Abstract	The paper documents and illustrates a practice-ready procedure for estimating changes in crash frequency for specific application circumstances for three ITS treatments – Closed Circuit Television Cameras (CCTV), Dynamic Message Signs (DMS) and Road Weather Information Systems (RWIS). The procedure will allow an agency to directly evaluate the change in safety that may be associated with a contemplated treatment. In effect, the approach mimics the application of a Crash Modification Function (CMFunction) in that each potential application will, in principle, have its own Crash Modification Factor (CMF). The procedure uses an empirical Bayes framework with safety performance functions (SPFs) for treatment and non-treatment reference sites. The paper also presents those SPFs, which were developed from Pennsylvania freeway data. In principle, this cross-sectional approach can be applied, as it has been, for other safety treatments where safety effects vary with application circumstance and where that variability cannot be captured with conventional before-after studies.

Authors	Boniphace Kutela, Texas A&M Transportation Institute Frank Ngeni Cuthbert Ruseruka, South Carolina State University Tumlumbe Juliana Chengula, South Carolina State University Norris Novat Hellen Shita Abdallah Kinero, Florida International University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	24-04709
Paper Title	**The Influence of Roadway Characteristics and Built Environment on the Extent of Overspeeding. An Exploration Using Mobile Automated Traffic Camera Data**
Abstract	Over-speeding is a leading cause of traffic fatal crashes worldwide which need effective speed management strategies to enhance road safety. The National Highway Traffic Safety Administration reported more than 12,000 speed-related deaths were reported in 2021 in the United States alone. This study addresses the need for a deeper understanding of the prevalence and magnitude of over-speeding in different scenarios. Using data collected from traffic cameras in Edmonton, Canada, the study applies a negative binomial statistical model to analyze the extent of over-speeding. By incorporating temporal and built environment variables such as year, month, number of lanes, dwelling unit types, school-related, and open green space, the model provides insights into the significance of these variables and the likelihood of speeding tendencies. The findings of this study revealed that the increased posted speed limit and summertime are associated with the increased propensity for drivers to exceed the speed limit. On the other hand, the cameras showed the effectiveness of reducing the over-speeding tendency as a declining pattern of over-speeding is observed as the years increase. The built environment variables indicated mixed findings across varying extents of over-speeding. These results highlight the importance of considering speed limit design and enforcement strategies in efforts to mitigate over-speeding and enhance road safety. The insights gained can inform policymakers and road design practitioners in developing more targeted interventions and countermeasures to reduce speed limit violations and improve overall road safety conditions.

Authors	A. Latif Patwary, University of Tennessee Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	24-04785
Paper Title	**Exploring How Urban Form, Demographics, and Disadvantaged Communities are Linked with Pedestrian and Bicycle Safety**
Abstract	With pedestrian and bicycle safety as the main focus, this study investigates the role of urban form, disadvantaged communities (DACs), and demographics at the national level. All three are closely related, e.g., the urban form can lead to segregation and concentration of DACs with limited access to resources such as safe infrastructure, services, and economic opportunities. The study uses the recently released US Department of Transportation data on DACs. This information is available at the census tract level through the Justice40 initiative and aims to address transportation equity issues. Specifically, six comprehensive indicators identify DACs based on economy, environment, equity, health, resilience, and transportation. This study uses these DAC indicators, urban form (e.g., developed area and alternative modes), and demographics (race or gender) to explore their association with pedestrian and bicycle fatal crashes. The study creates a unique database combining ten years of pedestrian-bicycle-involved fatal crashes with data for the 71,729 census tracts. The data are analyzed using descriptives and rigorous zero-hurdle negative binomial models, which account for excessive zeros. The inference-based analysis results reveal that all the disadvantaged indicators are positively associated with pedestrian-bicycle-involved fatal crashes. Furthermore, fatal-crash rates are positively associated with high-intensity development in census tracts. Higher Black, American Indian, or Alaska Native populations are associated with more fatal crashes. The study creates new knowledge about safety in different contexts characterized by urban forms, DACs, and demographics. The information can assist policymakers in allocating resources to improve DACs on a priority basis, promoting transport social justice.

Authors	ka Iqbal, Clemson University Wayne Sarasua, Clemson University Afshin Famili, City of Richmond jennifer ogle, Clemson University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2096
Session Title	Safety Performance and Analysis
Paper Number	24-05198
Paper Title	**Evaluating the Capability of a Short Segment Peak Search Approach to Detect High Crash Locations**
Abstract	South Carolina crash geocoding has improved over the years and this enhanced spatial accuracy of crashes can potentially lead to a new paradigm for midblock crash safety analysis. This paper focuses on a short segment peak search analysis using segment lengths less than the Highway Safety Manual (HSM) recommended minimum of 0.1 miles for statewide screening of midblock crash locations. The main objective of this research was to compare the short segment peak search approach to other HSM network screening methods. State-specific SPFs, Driveway SPFs (using only AADT), and driveway SPFs with adjusted CMFs were used to evaluate the short segment screening method. Frequency-based identification of short segments stratified by six different roadway geometry types (R2U, R4D, U2U, U4D, U3T, and U5T) were compared with three SPF based screening methods to determine segments with the highest excess predicted average crash frequency. For short segment sites with highest crash frequencies (three crashes for U3T, U4D, and U2U; four crashes for U5T and two crashes for R4D and R2U), the comparison showed similar results (Top 90% agreement). Thus, should insufficient data be available to conclude SPFs, a frequency-based approach will likely identify the highest ranked crash sites. While this method works relatively well with highest ranked crash sites, the reliability of this method will wane with lower-ranked sites.

Authors	Srinivas Geedipally, Texas A&M Transportation Institute Subasish Das, Texas State University Lingtao Wu, Texas A&M Transportation Institute Michael Pratt, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	24-05337
Paper Title	**Safety Performance Functions for Frontage Roads**
Abstract	Frontage roads play a vital role in the nation's highway system because they serve as critical access routes between principal arterials, freeways, and surrounding businesses. Despite their importance, limited studies conducted an in-depth analysis of frontage road safety. The limited availability of suitable data for frontage roads has been a significant barrier to conducting comprehensive safety studies on these critical road segments. This study developed a robust methodology that allows for the correct attribution of crashes to the corresponding frontage road segments. This methodology is a novel contribution to the field of transportation safety research, as it addresses a critical data challenge that has hindered the advancement of frontage road safety analysis in the past. Moreover, there is limited research in regard to developing the safety performance functions (SPFs) and crash modification factors (CMFs) for frontage roads. In fact, the first edition of the Highway Safety Manual (HSM) does not include the SPFs for the frontage roads. In this study, the authors considered four years (2017–2020) of crash data for conducting a comprehensive analysis of four types of frontage roads (rural one-way, rural two-way, urban one-way, and urban two-way) and developed the SPFs and CMFs specifically tailored for frontage roadways in Texas. Several CMFs were calibrated in conjunction with the SPFs. This study developed CMFs for left and right shoulder widths, access point density, presence of entrance and exit ramps, posted speed limit and the horizontal curve density.

Authors	Abdulrahman Faden Mohamed Abdel-Aty, University of Central Florida Tarek Hasan Heesub Rim, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	Poster Session 2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	24-05917
Paper Title	**Developing Temporal Safety Performance Functions of Ramp Metering Operated**
Abstract	Ramp metering (RM) is widely used Active Traffic Management (ATM) system on freeways to enhance mobility. However, research on RM systems has predominantly focused on operational efficiency, with limited attention to their impact on traffic safety. In this paper, we develop short-term Safety Performance Functions (SPFs) for RM at two peak periods aggregation, using microscopic traffic detector data and detailed RM operation data from three states—Florida, California, and Wisconsin—to predict total crashes (KABCO) for both freeway merge and on-ramp segments. The proposed short-term crash prediction has the potential to enhance accuracy and flexibility, providing deeper insights into the fluctuation of safety evaluation over time. Two statistical methods, namely Poisson-lognormal (PLN) and negative binomial Lindley (NB-L), are employed besides the NB to develop the short-term SPFs. Independent variables such as traffic characteristics and specific geometric data (e.g., number of lanes, ramp configurations, presence of weaving segments, and interchange connector type), along with the ramp metering control strategy (fixed rate and local traffic responsive), are considered in the analysis. The exposure parameters and other geometric feature variables for ramp and merge segments were significant variables. These results would aid practitioners, policymakers, and operators in identifying critical crash frequency-related factors and assessing the effectiveness of ramp metering techniques. Ultimately, this research could pave the way for implementing appropriate safety interventions and further advance the traffic safety and management field.

Authors	Hongtai Yang, Southwest Jiaotong University Shanlan Sun Yicheng Song Guocong Zhai, Old Dominion University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	Poster Session 2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	24-06024
Paper Title	**Does the Left Turn Calming Program Work in New York City? A Difference-in-differences Approach**
Abstract	With the rapid development of urbanization, urban traffic safety has garnered increasing attention. As the most vulnerable group among all road users, pedestrians and cyclists often suffer severe injuries in traffic accidents. The left turn calming program, implemented by New York City in 2016, is a road intersection facility improvement initiative aimed at reducing turning speeds and enhancing safe turning behaviors through the improvement of traffic operating conditions. Its ultimate goal is to eliminate traffic accident fatalities and reduce the number of serious injuries. This study collects accident datasets and independent variables (socioeconomic, built environment, and traffic-related data) in the Manhattan area of New York City. Through a difference-in-differences (DID) approach based on zero-inflated negative binomial regression, we explore the effectiveness of the left turn calming and the characteristics of intersections suitable for its implementation. The paper reveals that the program can reduce accidents by over 28%, pedestrian-related fatalities and injuries by 29.7%, and cyclist-related fatalities and injuries by 23.2%. The significance of the independent variables affecting accidents varies across different models.

5 Crash Severity Prediction

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

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

Most paper dealing with crash severity prediction are presented in the following sessions:

- 2037 Advances in Truck and Bus Safety Research (Monday, January 8 8:00 AM- 9:45 AM) (seven papers);
- 2096 Safety Performance and Analysis (Monday, January 8 3:45 PM- 5:30 PM) (nine papers);
- 2159 Motorcycle Operation and Safety Research (Monday, January 8 1:30 PM- 3:15 PM) (seven papers);
- 2235 Transportation Safety Management Systems from Start to Finish (Monday, January 8 6:00 PM- 7:30 PM) (five papers);
- 3231 Analytical Methods of Safety Performance (Tuesday, January 9 6:00 PM- 7:30 PM) (eighteen papers);
- 4070 Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others (Wednesday, January 10 10:15 AM- 12:00 PM) (fourteen papers).

Thirty-eight papers investigated **vulnerable road users**, i.e., pedestrians, cyclists, and powered two-wheelers:

- Pedestrians (24-00784, 24-04785, 24-01582, 24-03757, 24-06499, 24-03069, 24-03794, 24-0230, 24-00826, 24-00966, 24-01053, 24-01315, 24-02289, 24-04714, 24-04777, 24-05020, 24-05415, 24-00660, 24-02574, 24-02989, 24-04322, 24-06095, 24-05490);
- Cyclists (24-00784, 24-04785, 24-01582, 24-03757, 24-06499, 24-03069, 24-02289, 24-02780, 24-05020, 24-00703, 24-05635); and
- Powered two-wheelers (24-00164, 24-00356, 24-00596, 24-02140, 24-0342, 24-04774, 24-05047, 24-05071, 24-02731, 24-00703).

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:

- Bayesian Regression (24-00164, 24-01876);
- Bayesian Spatially Varying Coefficients Logit (24-00966);
- Conditional Autoregressive Logit (24-00966);
- Correlated Random Parameter Logit with Heterogeneity in Means (24-00179);
- Geographically Weighted Logistic Regression (24-00966, 24-02956);
- Hierarchical binary Logit (24-04774);
- Logistic Regression (24-00293, 24-00660; 24-00817; 24-00955; 24-00966, 24-01053, 24-02061; 24-02140, 24-02956, 24-02989; 24-03876, 24-04925, 24-05020, 24-05635, 24-06018);
- Negative Binomial (24-05635);
- Partial Proportionality Odds (24-00326);
- Random intercept Multinomial Logit (24-03250);
- Random Parameter Logit (24-00817, 24-01053, 24-03421, 24-03794, 24-04777);
- Random Parameter Logit with Heterogeneity in Means (24-01315, 24-05963);
- Random Parameter Logit with Heterogeneity in Means and Variances (24-04322, 24-05405, 24-06499);
- Random Parameters Logit with Heterogeneous Means and Heteroscedastic Variances (24-01379).

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

- Correlated Random Parameters Ordered with Heterogeneity in Means (24-00437);
- Geographically Weighted Ordered Logistic Regression (24-02905, 24-05071);
- Latent segmentation-based correlated Random Parameters generalized Ordered Logit model with piecewise linear function (24-03374);
- Ordered Logit (24-02301, 24-02574, 24-02731, 24-03069, 24-03353, 24-05398);
- Ordered Probit (24-00826);
- Random Parameter recursive bivariate Ordered Probit (24-04171);
- Random Parameters Ordered Logit (24-03421);
- Random Parameters Ordered with interaction effects (24-02648);
- Random Parameters Ordered Probit (24-01582, 24-03757).

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

- AdaBoost (24-02420);
- Artificial Neural Networks (24-00293);
- Association Rule (24-00179, 24-03319, 24-03969, 24-05047, 24-05415, 24-05449, 24-06095);
- Bayesian Networks (24-02780, 24-05240);
- Catboost (24-02420, 24-04614, 24-05730);
- Causal Bayesian Network (24-04857);
- Conditional Tabular Generative Adversarial Networks (24-02238);
- Deep Neural Network (24-00955);
- Geographically Weighted Neural Network (24-02956);
- Gradient boosting (24-04614);
- K-Nearest Neighbors (24-00293);
- Latent Class Clustering (24-00326, 24-03319, 24-03353, 24-04734; 24-04857);

- Light GBM (24-02420, 24-05730);
- Naïve Bayes (24-00293);
- Neural Network (24-02956);
- Principal Component Analysis (24-00955);
- Random Forest (24-00293; 24-00955, 24-02420; 24-02948, 24-05730, 24-06189);
- Stacking Ensemble Model (24-00826, 24-02574);
- Support Vector Machine (24-00955, 24-01876, 24-02420);
- XGBoost (24-02061, 24-02164; 24-02420, 24-02571, 24-04807, 24-05175, 24-05730, 24-06189, 24-06465).

One paper (24-00596) conducts an in-depth investigation into motorcycle crashes in Thailand, identifying various factors that influence the severity of such crashes. Another paper (24-00703) employs various statistical and machine learning techniques to analyze e-scooter and bicycle crashes in the City of Austin from 2018 to 2021.

One paper (24-00784) uses statistical testing and regression analyses to explore crash characteristics and severity outcomes in non-motorist crashes involving electric vehicles compared to traditional internal combustion engine vehicles. Another paper (24-00826) investigates the factors influencing pedestrian crash severities using different statistical, machine learning, and deep learning methods. Specifically, the paper applies the ordered probit, stacking ensemble (with multinomial logistic model, XGBoost, and ET models), and TabNet models to analyze pedestrian crash severity based on a dataset from Utah spanning from 2010 to 2022.

One paper (24-01681) conducts a retrospective analysis of crash data from the Queensland Road network during the period 2012-2016 aimed to understand the factors contributing to fatal and serious injury crashes involving heavy vehicles. Models includes the Negative Binomial and its random parameter variants to account for unobserved heterogeneity.

One paper (24-02911) develops an integrated framework that considers the influence of independent variables on crash type and severity components at both disaggregate and aggregate levels by using 2019 crash data from Orlando, and Florida. Another paper (24-03450) addresses the serious concern of severe crashes, particularly those resulting in three or more deaths, with a focus on truck drivers committing traffic violations. The unique approach involves using police narrative reports for a comprehensive analysis, leveraging text mining and network analysis to gain insights into the patterns and characteristics of such crashes.

One paper (24-03872) assesses roadway departure crashes, frequently associated with severe outcomes, by assisting in the mapping of risk elements for such crashes. The paper also provides recommendations to improve the transferability of findings. Another paper (24-04377) utilizes natural language processing to analyze unstructured crash narratives of autonomous vehicle incidents, extracting 15 structured topics related to behavior, parties involved, location, and general aspects. It identifies areas for improvement in autonomous vehicle interactions with road users and employs an XGBoost model to validate relationships between topics and crash severity.

One paper (24-04714) predicts pedestrian crash severity by leveraging the Inception-v3 deep learning model and analyzing five years of comprehensive data from Louisiana (2016-2021). Using the Boruta algorithm, the research identifies key factors influencing crash severity. Finally, the approach includes

data balancing techniques, such as Random Under Sampling and SMOTE, and employs DeepInsight to transform numeric data into images. Another paper (24-04774) uses the cluster correspondence analysis and a hierarchical binary logit model to explore the factors associated with the motorcyclist crash injuries and fatalities in Utah between 2016 and 2020.

One paper (24-04785) employs advanced statistical models, including "zero-hurdle negative binomial models to understand how factors such as urban form, disadvantaged communities, and demographics at the national level are related to fatal crashes involving pedestrians and cyclists. Another paper (24-04843) extends the duration-based modeling framework to predict road crashes and their severity, addressing computational complexities associated with incorporating crash severity.

One paper (24-05490) employs statistical analysis to examine data provided by the Oregon Department of Transportation to assess the impact of vehicle characteristics, road features, and user characteristics on fatal and serious injury crashes involving pedestrians. Another paper (24-05968) utilizes probabilistic severity models, incorporating Maximum Abbreviated Injury Scale (MAIS) Scores, to explore crash frequency and severity by specific crash types at the approach level. The goal is to identify more effective countermeasures tailored to individual intersection sites.

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

Authors	Milan Zlatkovic, University of Wyoming Isaac Baah Sarah Zlatkovic, Claremont Graduate University Zorica Cvijovic, Trihydro Corporation
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-00164
Paper Title	**Assessment of Motorcycle Crash Severity in Wyoming through Bayesian Regression**
Abstract	Approximately 15% of all traffic fatalities in the United States involve motorcycle riders and passengers. According to the National Highway Traffic Safety Administration (NHTSA), the crash rate for motorcyclists is 15 times higher than for passenger car occupants. To evaluate the characteristics of motorcycle safety in Wyoming, this study analyzed 12 years of motorcyclerelated crash data from the Wyoming Department of Transportation crash database. Utilizing Bayesian regression modeling, the study found that alcohol and animal involvement, reduced lighting conditions, inclement weather, poor road conditions, and driver actions increase the odds of fatal and severe injury crashes. Additionally, not wearing a helmet, particularly in rural areas, was seen to increase the odds of fatal crashes. The Bayesian models on the vehicle level also showed that the vehicle's level of damage is related to the crash severity level. On the person level, young and old drivers were found to have a higher risk of fatal and severe injury outcomes, while alcohol and drug use, rider distraction, and out-of-state riders were seen to have a lower odd of fatal and severe injuries. The study recommended several countermeasures for improved safety, such as installing motorcycle-friendly guardrails, minimizing the use of rubberized bituminous asphalt as surface treatments, maintaining high-traffic roadways more frequently during the riding season, and providing adequate education and training for motorcyclists.

Authors	Bharat Kumar Pathivada, Western Kentucky University Kirolos Haleem, Western Kentucky University Arunabha Banerjee, Western Kentucky University
Sponsoring Committee	ACS60
Session Number	3071
Session Title	**Driver Behavior Analysis for Driving Condition**
Paper Number	24-00179
Paper Title	**Impact of Microscopic Real-Time Weather Information on Commercial Motor Vehicle Crash Severity along Interstate-65 in Kentucky**
Abstract	This study comprehensively investigates the factors affecting crash injury severity associated with commercial motor vehicles (CMVs), i.e., large trucks and buses, on Interstate-65 (I-65) in the state of Kentucky. Unconventionally explored microscopic real-time weather variables (i.e., air temperature, relative humidity, solar radiation, wind speed, and precipitation) were extracted from 80 Mesonet stations in Kentucky and used in the analysis. Other variables explored were hourly traffic volume and speed, driver, roadway, vehicle, and environmental-related predictors. Recent five-year and four-month (January 1, 2016, through April 30, 2021) crashes along I-65 were used. The correlated mixed logit with heterogeneity in means (CMXLHM) model was applied to identify significant factors affecting CMV-related crash severity while accounting for unobserved heterogeneity and correlations among the random parameters. In addition, the association rules mining (ARM) technique was used to uncover associations between real-time weather and CMV-related severe injuries (KA). The ARM analysis showed that severe CMV-related crashes were associated with real-time weather conditions: solar radiation ≤ 5 Watts/m2, wind speed ≤ 5 mph, and zero precipitation (i.e., no rainfall). The CMXLHM model results showed that solar radiation ≤ 5 Watts/m2, air temperature ≤ 50 0F, and wind speed ≤ 5 mph increased the probability of severe CMV crash injury outcome by 44.30%, 24.38%, and 18.55%, respectively. Furthermore, middle-age drivers (31-59 years old), speeding, and weekend-related crashes were associated with increased CMV crash injury outcomes. Safety recommendations were proposed to enhance CMV safety. One example is feeding specific real-time weather states to dynamic message signs (DMS) for safety alerts.

Authors	Raja Daoud Matthew Vechione, University of Texas, Tyler Okan Gurbuz, Texas A&M Transportation Institute Prabha Sundaravadivel
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-00293
Paper Title	**Development of an Illumination Data Collection Tool and Nighttime Crash Severity Prediction Models Using Machine Learning**
Abstract	Past research has shown that driving at night is riskier in terms of crash involvement than during the day. Fortunately, it is clearly established that illumination on roadways can reduce the number of nighttime crashes. However, state and municipal departments of transportation (DOTs) lack the available illumination data. Therefore, the objective of this research is threefold: (i) to develop machine learning models that use readily available roadway characteristic data to predict the crash severity of nighttime crashes; (ii) determine the effect illumination has on crash severity; and (iii) develop a tool to assist DOT decision-makers in collecting illumination data. To accomplish this objective, we have extracted data from the Texas Department of Transportation (TxDOT) Crash Record Information System (CRIS) database, which was then further split into a training and a test data set. Then, five machine learning techniques, namely binary logistic regression, k-nearest neighbors, naïve Bayes, random forest, and an artificial neural network, were all applied to the unseen test data. The random forest model produced the most promising results by predicting severe crashes with 97.6% accuracy. In addition, we conducted a pilot study to test the collection of illumiation data using a light meter. In the future, we aim to complete the development of a smartphone application, which can be used in conjunction with the random forest model presented in this paper, to collect crowdsourced illumination data and predict nighttime crash hotspots. This may assist DOT decision-makers to prioritize funding for illumination at the hot spots.

Authors	Jingcai Yu, Southeast University Tao Feng, Hiroshima University Shunchao Wang, Southeast University Jingfeng Ma, Southeast University Wenquan Li, Southeast University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-00326
Paper Title	**Identifying the Heterogeneous Effects of Road Characteristics on Taxi-involved Crash Severity**
Abstract	Taxi-involved trips play a critical role in improving road safety in many countries. This study aims at investigating the heterogeneous effects of road characteristics on different severities of taxi-involved crashes. A latent class clustering is first employed to identify and characterize distinct classes. Subsequently, a partial proportional odds model is applied to analyze the heterogeneous effects of road characteristics on crash severities within each class. The findings reveal that road characteristics and parameters have varying impacts on different classes and crash severities. For example, Junction detail has a lower risk of causing severe injuries in Class 4, while it is insignificant on crash severities in Class 1. In terms of the same class, motorized vehicle lanes are less likely to cause severe injuries in Class 2, while non-motorized vehicle lanes are insignificant. The top three road characteristics influencing crash severities are speed limits, junction controls, and restricted lanes. Speed limits have the most significant effect on causing severe injuries, with a marginal effect of +14.76% for serious injury. Junction controls, especially traffic signals, contribute to a decrease in severe injuries, with a marginal effect of -11.68% for serious injury. Restricted lanes are observed to significantly mitigate severe injuries, with a marginal effect of -11.55% for serious injury. The study provides valuable insights for researchers and offers targeted policy recommendations to enhance taxi-involved travel safety.

Authors	renteng yuan, Southeast University shengxuan ding, University of Central Florida zhiheng fang Xin Gu, Beijing University of Technology Qiaojun Xiang, Southeast University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-00437
Paper Title	**Investigating the spatial heterogeneity of factors influencing speeding-related crash severities using correlated random parameter order models with heterogeneity-in-means**
Abstract	Speeding has been acknowledged as a critical determinant in increasing the risk of crashes and their resulting injury severities. This paper employs Global Moran's I coefficient and local Getis–Ord G* indexes to systematically account for the spatial distribution feature of speeding-related crashes, study the global spatial pattern of speeding-related crashes, and identify severe crash cluster districts. The findings demonstrate that severe speeding-related crashes within the state of Pennsylvania have a spatial clustering trend, where four crash datasets are extracted from four hotspot districts. Two log-likelihood ratio (LR) tests were conducted to determine whether speeding-related crashes classified by hotspot districts should be modeled separately. The results suggest that separate modeling is necessary. To capture the unobserved heterogeneity, four correlated random parameter order models with heterogeneity in means are employed to explore the factors contributing to crash severity involving at least one vehicle speeding. Overall, the findings exhibit that some indicators are observed to be spatial instability, including hit pedestrian crashes, head-on crashes, speed limits, work zones, light conditions (dark), rural areas, older drivers, running stop signs, and running red lights. Moreover, drunk driving, exceeding the speed limit, and being unbelted present relative spatial stability in four district models. This paper provides insights into preventing speeding-related crashes and potentially facilitating the development of corresponding crash injury mitigation policies.

Authors	Kunnawee Kanitpong, Asian Institute of Technology Auearree Jensupakarn, Asian Institute of Technology Pathumporn Dabsomsri Kannika Issalakul
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-00596
Paper Title	**Factors Affecting Motorcycle Crash Severity in Thailand: Evidence from In-Depth Crash Investigation**
Abstract	Motorcycles are vehicles with the highest risk of involvement in crashes. Based on the integrated data of road crash fatalities reported by the police, hospitals, and insurance companies, motorcycle crashes account for more than 80 percent of all crashes in Thailand, and the number of fatalities from motorcycle crashes was as high as 84 percent of the total fatalities from road crashes in the country. This study conducted an in-depth motorcycle crash investigation to identify the contributing factors affecting the severity of motorcycle crashes in Thailand. The types of opponent vehicles, crash areas, the time of the crash, riders' age, possession of a motorcycle license, riders' attention failure, types of human failure, collision avoidance, alcohol use, helmet use, headlight, and traveled speed were discovered to be significant factors affecting motorcycle crash severity. Based on the findings of this study, it has been suggested that to reduce the number of fatalities from motorcycle crashes, the related government agencies should seriously consider how to improve the safe riding skills of motorcycle users. The need for basic safety skills should be practiced by all riders, such as defensive driving skills, knowledge of alcohol risks, proper helmet use, and proper collision avoidance maneuvers. Proper rider training courses are necessary to provide basic knowledge for safe motorcycle operation in traffic, as well as safe traffic strategy and collision avoidance skills.

Authors	Myunghoon Ko, Texas A&M Transportation Institute Robert Wunderlich, Texas A&M Transportation Institute Show Abstract
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-00660
Paper Title	**Risk and Contributing Factors of Pedestrian Involved Crashes at Urban Four-leg Signalized Intersections**
Abstract	The primary objectives of this paper are 1) to examine the relationship between pedestrian crash frequency and predictor variables at four-leg signalized intersections and 2) to identify the risk and contributing factors that influence the probabilities of a pedestrian being injured or killed at pedestrian crashes and pedestrian's failure of signal/right-of-way (ROW) compliance to vehicle resulted in a crash. This paper analyzed pedestrian crashes from 2016 to 2019 at 512 four-leg signalized intersections. A negative binomial regression model was used to estimate the frequency of pedestrian crashes with predictor variables, and two binary logistic regression models were used to examine the probabilities of a pedestrian being injured or killed and pedestrian's failure of signal/ROW compliance at the pedestrian crashes. The results present that daily pedestrian crossing volume, average daily traffic (ADT), the number of bus stops, and the number of exclusive left-turn lanes are significant variables to predict pedestrian crash frequency at the intersection. Pedestrian's failure of signal/ROW compliance, lower ADTs, higher speed limits, and dark conditions were found to be associated with increasing the probability of pedestrian being severely injured or killed at the crash. The results also present that male pedestrians, lower daily pedestrian crossing volume, more bus stops, and dark conditions at the intersection increase the likelihood of pedestrian's failure of signal/ROW compliance resulting in a crash. Through understanding these risk and contributing factors of pedestrian-involved crashes will help identify countermeasures and interventions to improve pedestrian safety at urban signalcontrolled intersections.

Authors	Pranik Koirala, CONSOR Engineers Ipek Sener, Texas A&M Transportation Institute Yunlong Zhang, Texas A&M University
Sponsoring Committee	ACH20
Session Number	4027
Session Title	**Omnibus Session on Bicycle Modeling and Shared Micromobility Research**
Paper Number	24-00703
Paper Title	**Injury Severity Analysis of Imbalanced E-scooter and Bicycle Crash Data Using Statistical and Machine Learning Models**
Abstract	E-scooters are often required to share urban space with bicycles, raising important questions about safety and potential conflicts between the two modes. This study focused on a robust examination of e-scooter and bicycle crashes from 2018 to 2021 in the City of Austin to have a better understanding of the contributing factors and their different impacts on crash injury severities of micromobility riders. A rich, unique set of data were compiled through an array of techniques, encompassing text mining of crash records alongside the utilization of other publicly accessible data sources (e.g., the city's open database and smart location database). Topic modeling was employed to extract new features from crash reports, while various resampling techniques were assessed, highlighting the efficacy of a hybrid resampling method in addressing imbalanced classification problems. The resampled dataset was used to train different models for injury severity classification, and Shapley additive explanations model was used to evaluate the importance of features in a machine learning model. This study highlighted the importance of considering the unique characteristics and behaviors of different micromobility modes and users when designing infrastructure and developing policies to enhance road safety. The methods and results obtained have broader applicability beyond this context.

Authors	Jiahe Ling, University of Wisconsin,Madison Xiaodong Qian, Wayne State University Konstantina Gkritza, Purdue University
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-00784
Paper Title	**Electric Vehicles vs. Internal Combustion Engine Vehicles: A Comparative Study of Non-Motorist Crash Injury Severity**
Abstract	Powered by electric engines, electric vehicles (EVs) exhibit unique dynamic characteristics that may lead to different crash characteristics and outcomes compared with traditional internal combustion engine vehicles (ICEVs). This paper focuses on non-motorist crashes and estimates crash characteristics and severity outcomes using statistical testing and regression analyses based on Chicago crash data from 2015 to 2022. Innovatively, this study supplements traditional police crash reports with Google Street View (GSV) images and employs computer vision neural network models to uncover previously unreported environmental variables at crash scenes. The results reveal both similarities and disparities in nonmotorist crash characteristics between EV-involved and ICEV-involved incidents. The Likelihood Ratio Test suggests parameter transferability in injury severity models for both vehicle types. However, notable distinctions in factor distributions, such as non-motorist type, hit-and-run incidents, damage level, crash hour, crash weekday, weather conditions, and road surface conditions, along with the influence of season and road surface condition on injury severity, exist between EV and ICEV crashes. These distinctions may be attributed to driver demographics, vehicle design, and usage characteristics. These insights can guide the development of safety regulations for EVs and aid in devising specific safety measures and policies for non-motorists, including pedestrians and cyclists.

Authors	Carlos Roque, Laboratorio Nacional de Engenharia Civil João Cardoso, Laboratorio Nacional de Engenharia Civil Heike Martensen Quentin Lequeux
Sponsoring Committee	AKD20
Session Number	2191
Session Title	**Roadside Safety Features and Design**
Paper Number	24-00817
Paper Title	**The Influence of High Energy Absorbing Passive Safe Poles in Run-Off-Road Crash Severity**
Abstract	This study aims to investigate the mitigating effect of passive safe poles in run-off-road crash severity in Belgium. Run-off-road (ROR) crash data were collected, from 2015 to 2020, on sections of roads in Flanders, and multinomial and mixed logit models were estimated using the driver injury and the most severely injured occupant as outcome variables. Our results are in line with previous findings reported in the literature on ROR crash severity in a number of distinct settings. Most importantly, findings from this study provide evidence that High Energy absorbing passive safe poles (CEN 12767 HE compliant) contribute towards minor injuries and support the current Flemish policy concerning the instalation of lighting columns and the "forgiving roadside" concept, to mitigate ROR crash severity on Belgium roads. The study also indicates the importance of protecting errant vehicles from traditional poles, as these are linked to severe injuries. Data is a central limitation in attempts to study the effects of roadside objects on crash outcomes, especially when crashes result in minor or no injury. This limitation means that results must be interpreted cautiously, and further data on property damage only (PDO) crashes involving passive safe poles should be collected to develop more flexible and robust model specifications. Finally, it should also be stressed that further developments in road inventory systems should provide additional and enhanced data on roadside characteristics and crashes. These data will create the basis for further research leading to more accurate recommendations on how to increase roadside safety most effectively.

Authors	Amir Rafe, Utah State University Mohammad Ali Arman, Katholieke Universiteit Leuven (KU Leuven) Patrick Singleton, Utah State University
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-00826
Paper Title	**An In-depth Investigation into Factors Influencing Pedestrian Crash Severity: Comparative Analysis of Ordered Probit, Stacking Ensemble Model, and TabNet**
Abstract	In this study, we investigated the factors influencing pedestrian crash severities using different statistical, machine learning (ML), and deep learning (DL) methods. Specifically, we applied the ordered probit, stacking ensemble (with multinomial logistic model, XGBoost, and ET models), and TabNet models to analyze pedestrian crash severity based on a dataset from Utah spanning from 2010 to 2022. Notably, we introduced the TabNet model for the first time in pedestrian crash severity analysis and employed SHapley Additive exPlanations (SHAP) to interpret this DL model's output. The results of our study demonstrated that TabNet achieved higher prediction accuracy on our dataset compared to other models. However, we encountered challenges in terms of running time when tuning hyperparameters and implementing methods to prevent overfitting in TabNet. The importance of explanatory variables varied among the models for predicting pedestrian crash severities. However, some variables—such as pedestrian age, left turn and right turn involvement, lighting conditions, and alcohol consumption—consistently emerged as significant factors across all models. A key aspect of using TabNet and SHAP for result interpretation was the ability to ascertain factors' importance for each crash severity class and unique crash observation or their combinations. Our findings can empower transportation safety engineers and decision-makers to identify crucial factors affecting pedestrian crash severity in both urban and rural settings and devise targeted countermeasures to address pedestrian-related safety concerns with high accuracy.

Authors	Jingyang Li Fengxiang Guo Bijiang Tian Feng Zhu, Nanyang Technological University Wenchen Yang, National Engineering Laboratory for Surface Transportation Weather Impacts Prevention
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-00955
Paper Title	**Traffic accident severity prediction of rural two-lane highways using machine learning: A case study in China**
Abstract	The utilization of machine learning models to analyze the traffic accident severity (TAS) in rural conditions is significant for traffic accident prevention. This research is based on rural road accidents, and three categories of TAS influencing factors: accidents, traffic flow, and road conditions are selected to establish the TAS model of lightGBM, incorporating two feature engineering (random forest and principal component analysis) and three algorithm models (support vector machine, binary logistic regression, and deep neural network) to analyze the performance in classifying TAS, considering different feature engineering and training set proportions. Additionally, the SHAP values were employed to analyze the main factors contributing to the TAS. The results show that The model's performance for different categories of accident severity varies significantly. Relying solely on the model for overall accident prediction accuracy is insufficient to evaluate model performance accurately. When the training set is 80%, the four models achieve the highest predictive accuracy for severe accidents. Among them, the PCA+lightGBM combination model exhibits the highest predictive accuracy for overall accidents, as well as the highest recall rate and F1 score for severe accidents, enabling better identification of severe accidents that pose greater risks to traffic safety; The impact of selecting important features on the model is lower compared to reducing the heterogeneity of the overall data; SHAP reveals that the modes of transportation involved in the accident, perpetrator, accident type, and seasons significantly contribute to the severity of accidents. Specifically, driving motorcycles and non-motorized vehicles substantially elevate the severity of accidents.

Authors	Qianfang Wang, South China University of Technology Pengpeng Xu, University of Hong Kong Keke Zhang, Hunan Provincial Transportation Planning, Survey & Design Institute CO., LTD Qiang Zeng, South China University of Technology
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-00966
Paper Title	**Exploring Risk Factors Associated with Pedestrian Crash Severity: Accounting for Spatial Heterogeneity and Out-of-Sample Prediction**
Abstract	Bayesian logit models with the conditional autoregressive prior are typically used to determine the relationship between crash severity and risk factors within spatial units. However, these models fail largely to account for the spatially heterogeneous effects and thus provide global and fixed outputs. Given the potential of capturing spatially varying relationships between response variables and risk factors, local modeling approaches such as the geographically weighted logit regression (GWLR) models and Bayesian spatially varying coefficients (BSVC) models are promising tools for investigating spatial heterogeneity. In this study, we compare four models: a basic binary logit model, a conditional autoregressive logit model, a Bayesian spatially varying coefficients logit model, and a geographically weighted logit regression model. The four models were calibrated and validated through a case study of pedestrian crashes on road segments in Hong Kong during 2010–2019. An out-of-sample prediction test was used to evaluate their performance in terms of generalization ability. Our results showed that BSVC model outperforms in terms of model fitting and prediction performance. The GWLR model was sensitive to outliers, leading to dramatic degradation in out-of-sample predictive accuracy. According to the parameter estimation, pedestrian age, head injury, pedestrian action, driver operation, vehicle type and first collision point have significant effects on pedestrian injury severity.

Authors	Gang Xue, Guangdong Polytechnic Normal University Huiying Wen, South China University of Technology
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-01053
Paper Title	**Contributing Factors of Pedestrian Injury Severities in Pedestrian-vehicle Crashes with Drivers of Different Route Familiarity Levels**
Abstract	Pedestrian injury in pedestrian-vehicle crash is significantly related to the driver, pedestrian, vehicle, crash and environment characteristics. Driver's route familiarity has been found greatly associated with driving behaviors, crash occurrence and injury severity of the driver. Two-year detailed pedestrian-vehicle crash data in Yunnan Province were studied to investigate the factors that affect pedestrian injury severities in pedestrian-vehicle crashes with familiar driver and unfamiliar drivers by employing multinomial logit models and mixed logit models. It is found that there is a large difference of significant factors contributing to the injury severities of pedestrians in crashes with familiar drivers and unfamiliar drivers. There are 8 variables which are only significant in the familiar driver model while not in the unfamiliar driver model. And there are 6 variables which were found to be significant in the unfamiliar driver model only. Estimation findings indicate that the factors of early morning (00:00-06:59) and sunny weather condition will be better modeled as random-parameters in the model for pedestrian-vehicle crashes with familiar drivers and the same with the factors of rainy weather condition and afternoon peak (17:00-19:29) in the model for pedestrian-vehicle crashes with unfamiliar drivers. Some more effective and targeted countermeasures are put forward for familiar drivers, unfamiliar drivers and transportation managers to reduce pedestrians' injury severities in pedestrian-vehicle crashes.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette Subasish Das, Texas State University Monire Jafari M. Ashifur Rahman, Louisiana Transportation Research Center (LTRC)
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-01315
Paper Title	**Investigating Pedestrian-Vehicle Crashes on Interstate Highways: Applying Random Parameter Logit Model**
Abstract	In the U.S., the interstate highway system is categorized as a controlled-access or limited-access route, and it is unlawful for pedestrians to enter or cross this type of highway. However, pedestrian-vehicle crashes on the interstate highway system pose a distinctive safety concern. Most of these crashes involve 'unintended pedestrians', drivers who come out of their disabled vehicles, or due to the involvement in previous crashes on the interstate. Because these are not 'typical pedestrians', a separate investigation is required to better understand the pedestrian crash problem on interstate highways and identify the high-risk scenarios. This study explored 531 KABC (K = Fatal, A = Severe, B = Moderate, C = Complaint) pedestrian injury crashes on Louisiana interstate highways during the 2014-2018 period. Pedestrian injury severity was categorized into two levels: FS (fatal/severe) and IN (moderate/complaint). The random parameter binary logit with heterogeneity in means (RPBL-HM) model was utilized to address the unobserved heterogeneity (i.e., variations in the effect of crash contributing factors across the sample population) in the crash data. Some of the factors were found to increase the likelihood of pedestrian's FS injury in crashes on interstate highways, including pedestrian impairment, pedestrian action, weekend, driver aged 35-44 years, and spring season. The interaction of 'pedestrian impairment' and 'weekend' was found significant, suggesting that alcohol-involved pedestrians were more likely to be involved in FS crashes during weekends on the interstate. The obtained results can help the 'unintended pedestrians' about the crash scenarios on the interstate and reduce these unexpected incidents.

Authors	Chengying Hua, University of North Carolina, Charlotte Wei Fan, University of North Carolina, Charlotte
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-01379
Paper Title	**Injury Severity Analysis of Time-of-day Fluctuations and Temporal Volatility in Reverse Sideswipe Collisions: a Random Parameter Model with Heterogeneous Means and Heteroscedastic Variances**
Abstract	Problem The sideswipe collisions in the opposite direction often result in more severe injuries than the typical same-direction crashes, especially when light trucks get involved. This study investigates the time-of-day fluctuations and temporal volatility of potential factors that affect the injury severity of reverse sideswipe collisions. Methods A series of random parameters logit models with heterogeneous means and heteroscedastic variances are developed and utilized to explore unobserved heterogeneity inherent in variables and preclude biased parameter estimation. The segmentation of estimated results is also examined through temporal instability tests. Results Based on the crash data in North Carolina, U.S.A, a number of contributing factors are identified that have profound associations with obvious and moderate injuries. Meanwhile, significant temporal volatility is observed in the marginal effects of several factors such as driver restraint, alcohol or drugs impact, Sport Utility Vehicle (SUV) at fault, and adverse road surface across three different periods. Fluctuations in the time of day indicate that restraint with belts is more effective in mitigating the obvious injury in the nighttime, and high-class roadway sustains a higher probability of resulting in more serious injury compared to the daytime. Practical Applications The findings of this study could help further guide the implementation of safety countermeasures related to atypical sideswipe collisions.

Authors	Ahmed Farid, California Department of Transportation Emily Lin, California Polytechnic State University, San Luis Obispo Anurag Pande, California Polytechnic State University, San Luis Obispo
Sponsoring Committee	ACS10
Session Number	2236
Session Title	**School Transportation and Planning Research**
Paper Number	24-01582
Paper Title	**Analysis of Severity Outcomes for School Zone Crashes with an Equity Lens: A Random Parameters Modeling Approach**
Abstract	Due to the potentially higher loss of human years in collisions involving young children, school zone safety is a significant public health concern. Past studies have identified several factors associated with school zone crashes, including inadequate traffic controls, speed management, and lack of enforcement. However, school zone safety remains relatively unexplored as an equity issue. Towards that end, Vulnerable road user (VRU) crashes, i.e., pedestrian/bicycle crash data from elementary schools in Los Angeles County, are collected alongside information about the proportion of students enrolled in the free and reduced-cost meals program. The latter serves as a proxy for the socioeconomic status of the school's neighborhood. The data are analyzed for severity outcomes of the collisions via the random parameters or mixed, ordinal probit regression structure to gauge the impact of the crash contributing factors on the injury severity risks. According to the results, the socioeconomic status of the school's neighborhood induces mixed effects on the injury severity risk. The results of this study suggest that more detailed investigations on the interaction of factors with equity are required to propose appropriate road safety countermeasures since the impact of the socioeconomic status of schools on crash severity risk varies across the data.

Authors	Paula Macias, Queensland University of Technology Florian Heraud Krishna Behara, Queensland University of Technology Alexander Paz, Queensland University of Technology
Sponsoring Committee	ACS60
Session Number	2037
Session Title	**Advances in Truck and Bus Safety Research**
Paper Number	24-01681
Paper Title	**Analysis of Diverse Crash Types Involving Different Heavy Vehicles: A Case Study from Queensland, Australia**
Abstract	Crashes involving Heavy Vehicles (HV) are more likely to cause serious injury or death compared to other vehicles. Even though HV operation is essential for the economy, it is crucial to prioritize improving HV safety. Studies involving HVs are very limited; to the best of our knowledge, there is no study analysing different Fatal and Serious Injury (FSI) crash types (head-on, rear-end, single-vehicle, intersection, and sideswipe) involving both Multi-Combination Vehicles (MCVs) and Articulated Trucks (ARTs) in Australia. A retrospective analysis of Queensland Road Network crash data from 2012 to 2016 was conducted, encompassing HV crashes that resulted in at least one fatality or serious injury. In addition to traffic volumes, roadway types and geometric aspects were considered as potential explanatory variables. Models considered included Negative Binomial (NB) and its random parameter variants to account for unobserved heterogeneity. Our analyses revealed that likely contributing factors varied across crash types. Variables that consistently exhibited positive associations with FSI crashes were HV traffic volume (head-on, rear-end, single-vehicle, intersection, sideswipe), rural single-carriageway (head-on, single-vehicle), rural single-carriageway with high-speed limit (head-on) and motorway (single-vehicle). Interestingly, head-on crashes involving MCVs decreased with an increase in formation width while crashes involving ARTs decreased as the number of lanes on the road increased. This suggests a potential positive impact of wider roads on mitigating such crashes. By understanding these factors, transportation authorities can develop targeted countermeasures that enhance safety for all road users, ultimately reducing the frequency and severity of crashes involving heavy vehicles.

Authors	Nuri Park, Hanyang University, Ansan Hyeonseo Kim, Hanyang University, Ansan Hojae Kim, Hanyang University, Ansan Juneyoung Park, Hanyang University Chunho Yeom, University of Seoul
Sponsoring Committee	ACS10
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	24-01876
Paper Title	**Port-Locate Area Safety Analysis with Spatial Heterogeneous Based on Regional Characteristics**
Abstract	In port cities, traffic safety management should take into account various types of cargo that will shift in the trucks and containers. This is true not only in the case of 'at port', but also 'near-port' areas within a 4-8-km radius. This is important for traffic safety because the crash severity can be high as there are many trucks that can cause large-scale crashes in 'at port' and 'near port' areas. Therefore, to prepare management strategies for port safety, it is necessary to identify risk factors that affect the crash severity in each port area. This study developed a two-stage crash severity model of 'at-port' and 'near-port' regions using a support vector machine and a Bayesian multinomial model. Additionally, a severity model suitable for Korean ports was proposed that considered multilevel spatial heterogeneity in the Bayesian multilevel multinomial model. Findings derived from this study can be used for policy development to increase traffic safety in port cities.

Authors	Ahmed Hossain, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette Ahmed Hasan, Rowan University Mohammad Jalayer, Rowan University Julius Codjoe, Louisiana Department of Transportation and Development
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-02061
Paper Title	**A Comprehensive Investigation of Pedestrian Hit-and-Run Crashes: Applying XGBoost and Binary Logistic Regression Model**
Abstract	The present trend in the USA suggests that one in five pedestrian fatalities in motor vehicle crashes involves a hit-and-run, a serious traffic safety issue. The over-representation of pedestrian hit-and-run collisions necessitates a systemic data-driven investigation to uncover the contributing factors that cause fatality or serious injuries. This study examined two crucial features of pedestrian hit-and-run crashes: RQ1) What factors contribute to pedestrian hit-and-runs? RQ2) What causes hit-and-run pedestrian fatalities? This study addresses the RQ's utilizing the XGBoost algorithm (RQ1) and binary logistic regression models (RQ2) to analyze the police-reported pedestrian crashes (2015-2019) in Louisiana state. The XGBoost model was used to classify pedestrian hit-and-run crashes (hit-and-run = yes/no). The XGBoost model identified some of the critical factors contributing to pedestrian hit-and-run crashes including – primary contributing factors (pedestrian action, pedestrian violation, prior movement, pedestrian condition), dark-with-streetlight, posted speed limit of 55+ mph, weekend, and older pedestrians (>64 years). The binary logistic regression model was further used to identify critical high-risk hit-and-run scenarios resulting in fatal or severe injury of pedestrians. Some of the identified factors were: posted speed limit of 55 mph or higher (OR = 14.31), pedestrian impairment (OR = 4.6), older pedestrians (OR = 2.62), younger pedestrians (OR = 1.78), and dark-no-streetlight condition (OR = 2.91). The study found crucial linkages between hit-and-run crashes and fatal-severe injuries (e.g., dark-with-streetlight, older pedestrians, high-speed situations). Identifying these critical links can help policymakers, law enforcement agencies, and transportation authorities develop targeted interventions and strategies to address the risk factors.

Authors	Anshu Bamney, University of Connecticut Niloufar Shirani, University of Connecticut Yu Song, University of Wyoming Eric Jackson, Connecticut Transportation Institute
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-02140
Paper Title	**Analyzing the Factors Affecting Injury Severity of Motorcyclists in Connecticut: A Multinomial Logit Approach for Single-Vehicle and Multi-Vehicle Crashes**
Abstract	Motorcycle safety is a public health issue around the world. The magnitude of this problem can be estimated by the national statistics of the United States which shows motorcycles represent only 3.5 percent of the registered vehicles but account for 14 percent of traffic fatalities. The present study aims to explore the factors contributing to single-vehicle and multi-vehicle motorcycle crashes in Connecticut using the data from Connecticut Crash Data Repository and NHTSA's VIN decoder. A series of multinomial logit models were used for these analyses and various environmental (roadway surface, lighting), driver (age, speeding behavior, helmet), vehicle (motorcycle make year), temporal (month, year), and crash-related (manner of collision, crash type, crash location, etc.) characteristics were considered. In general, the results of this study show several factors increase severe injuries such as not wearing a helmet, speeding, rider impairments (intoxicated by alcohol, drugs, medication, etc.), older and sports motorcycles, higher speed limits, summer or warmer months (May-August), pandemic years (2020-21), collision with fixed objects, negotiating a curve, manner of collision, and others. The findings of this study can be used to update motorcycle endorsement programs and formulate policies to reduce severe injuries such as stricter helmet laws. It can also be used to develop educational safety campaigns aimed at reducing risky behaviors such as impaired driving and speeding. To reduce injury severity other strategies such as the use of high-quality reflectors on fixed objects (e.g., trees and poles), rumble strips, and shoulder widening are also recommended.

Authors	Yichang Shao, Southeast University Yuhan Zhang, Southeast University Liyang Hu, Southeast University Xiaomeng Shi, Southeast University Zhirui Ye, Southeast University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02164
Paper Title	**Macro-Micro Fusion in Traffic Safety: Severity Prediction and Exploration of Behavior-Cause Relationships in Accidents**
Abstract	Traffic accidents remain a pressing global concern, demanding comprehensive analysis to devise effective prevention strategies and reduce casualties. In this study, we combine machine learning techniques and natural language processing (NLP) to provide a holistic understanding of traffic accidents at both macro and micro levels. On the macro-scale, we employ the XGBoost algorithm to predict the accident severity, identifying crucial factors through SHapley Additive exPlanations (SHAP) values that influence outcomes. Concurrently, on the micro-scale, we extract and categorize specific driver behaviors and actions connected to distinct accident causes by mining textual descriptions. The FP-growth algorithm and association method are utilized to form association rules, delineating the correlations between driver conduct and accident causation. These insights culminate in a behavior-cause relationship table, laying the groundwork for targeted interventions and the potential creation of a traffic safety knowledge graph. By synthesizing macrolevel severity predictions with micro-level behavioral analysis, this research paves the way for substantial advancements in traffic safety management and policy development.

Authors	Chen Junlan, Southeast University Xiao (Luke) Wen, Hong Kong University Nan Zheng, Monash University Xiucheng Guo, Southeast University Hongliang Ding Ziyuan Pu, Monash University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02238
Paper Title	**Rebalancing Traffic Crash Data Based on Generative Adversarial Networks for Crash Severity Modeling**
Abstract	Imbalanced crash data is a common problem in highway crash severity modeling, particularly with the rarity of fatal crashes. This issue can lead to poor performance for data-driven methods, especially those that require large amounts of data. Commonly used data resampling methods are often inadequate as they only handle continuous variables and cannot account for the correlation between risk factors. Additionally, deep learning-based resampling methods struggle with addressing the model collapse issue associated with sparse discrete data. Besides, previous research has not comprehensively explored and compared different resampling methods to address the data imbalance issue. In this study, we propose a novel approach that utilizes a deep generative model based on Conditional Tabular Generative Adversarial Networks (CTGAN) to generate synthetic crash data. The proposed method effectively handles both discrete and continuous risk variables in the data distribution, using a combination of one-hot vectors and a variational Gaussian mixture model (VGM). To compare the performance of our method with other resampling techniques, we conducted a comprehensive study. A 4-year crash dataset with imbalanced issues collected in Washington State, US was used for model validation. Our results demonstrate that CTGAN-RU is comparable to other resampling methods, and the generated data is consistent in terms of prediction accuracy, distribution derivations, statistical fit, and risk factor inference. This study provides valuable insights for traffic safety researchers and engineers who seek to improve crash severity modeling when dealing with imbalanced crash data.

Authors	Cong Chen, University of South Florida Kristine Williams, KMW Associates, LLC Pei-Sung Lin, University of South Florida Shubhankar Chintamani Shindgikar, University of South Florida, Tampa Elzbieta Bialkowska-Jelinska, University of South Florida Tia Boyd, USF Center for Urban Transportation Research Show Abstract
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-02289
Paper Title	**Pedestrian and Bicycle Safety Assessment at Commercial Driveways along Major Corridors**
Abstract	Pedestrian and bicycle safety is an important emphasis area in the Florida Strategic Highway Safety Plan. Commercial driveway access points involve complex traffic activities for both vehicles and non-motorists and therefore create significant risks for pedestrian and bicycle safety. This study assessed the impacts of commercial driveways along major corridors on pedestrian and bicycle safety through crash frequency and crash severity analyses and evaluated the impacts of driveway and connecting roadway design and traffic characteristics on pedestrian and bicycle safety. Five years (2015-2020) of driveway-related crashes in Florida with pedestrian or bicycle involvement were collected, and the characteristics of commercial driveways along selected major corridors with high pedestrian/bicycle crash frequency were reviewed and included in the analysis. The results revealed a number of significant factors affecting pedestrian and bicycle crash occurrence at commercial driveways, including the number of lanes on connecting streets, driveway design features, median opening type, traffic control device type, and painted bike lanes. Several factors were also identified as significant in affecting crash severity, including shoulder type, alcohol or drug involvement, driveway number of lanes, bike lane type, driveway throat length, and connecting street Annual Average Daily Traffic (AADT) in the crash year. These findings provide important insights on addressing pedestrian and bicycle safety issues at commercial driveways, which could be used as reference for future access management guideline improvement.

Authors	Sheikh Usman, The University of Tennessee Knoxville Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACS20
Session Number	4003
Session Title	**Safety Performance and Analysis Research**
Paper Number	24-02301
Paper Title	**Applying Artificial Intelligence Techniques to Examine Nighttime Pedestrian Crash Injury Severity at Intersections**
Abstract	Intersections require a trade-off between road user safety and mobility. Due to minimum protection, pedestrians are highly vulnerable to traffic crashes at such locations. Recently, fatal pedestrian crashes at intersections have risen in the US, and about 75% of pedestrian fatalities occurred at nighttime. To enhance the safety of pedestrians at intersections, this study identifies the correlates of nighttime pedestrian crash injury severity at intersections. The study examines police-reported pedestrian crashes in North Carolina from 2016-2019, recoded comprehensively using the Pedestrian and Bicyclist Crash Analysis Tool. The tool provides a multitude of crash descriptors and crash types, resulting in a unique multi-faceted pedestrian crash database. The analysis involves estimating rigorous statistical models and innovative application of Artificial Intelligence tools. An Ordered Logit Model is estimated to quantify the correlates of nighttime pedestrian crash severity at intersections. The modeling results reveal interesting and novel insights into the association of several behavioral, infrastructural, and regulatory factors, including pedestrian dash or dart-out behavior, drivers not yielding to pedestrians, inadequate lighting, and high speed limit at intersections with pedestrian injury severity, given a crash. The study applied a powerful prediction-based AI algorithm, Random Forest, to obtain accurate forecasts of pedestrian crash injury severity for devising effective urban planning strategies and infrastructure improvements to mitigate pedestrian crash injury severity at intersections. The study can assist in realizing USDOT's vision to develop an AI-based intersection safety system to anticipate, identify, and mitigate unsafe pedestrian-vehicle interactions at intersections by harnessing real-time information collected through emerging sensors.

Authors	Ahmed Hasan, Rowan University Mohammad Jalayer, Rowan University Subasish Das, Texas State University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02420
Paper Title	**Investigation of Run-off the Road Crashes Involving Distracted Drivers in New Jersey: A Utilization of Machine Learning Models and SHAP Analysis**
Abstract	Distracted driving and run-off road crashes are two major concerns for road safety. Every year thousands of people lose their lives in motor vehicle crashes in the USA for these two cases. Although studies focusing on both these crashes are ample, there has yet to be much research on run-off-the-road crashes involving distracted driving. This study aimed to analyze the factors associated with run-off road crashes involving distracted drivers using New Jersey crash data from 2015-2019. Various machine learning models, including Support Vector Machine, Random Forest, AdaBoost, Catboost, Light GBM, and XGBoost, were utilized to predict the injury severity. Accuracy, precision, and recall scores were utilized to evaluate model performance. An interpretable machine learning technique, Shapley values, was employed to identify the most influential factors contributing to these crashes. The results showed that XGBoost and CatBoost outperformed the other models in predicting crash severity. The SHAP values demonstrated that alcohol involved during daylight was more likely to result in severe injury crashes. These findings are expected to assist policymakers and practitioners in developing targeted countermeasures to reduce run-off road crashes involving distracted drivers and improve road safety in New Jersey.

Authors	Omar Al-Sheikh, Rowan University Mohammad Jalayer, Rowan University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02571
Paper Title	**Investigating the Severity of Curve-Related Roadway Departure Crashes: The Role of Driver Distraction, Automation Levels, and Environmental Conditions**
Abstract	This study addresses the severity of curve-related Roadway Departure (RwD) crashes, with a focus on driver distraction, automation levels, and environmental conditions. With the advent of automated vehicles and advanced driver assistance systems (ADAS), it becomes crucial to understand how these vehicles perform under diverse driving conditions and scenarios. A novel aspect of our approach is the estimation of Levels of Automation (LoA) for each vehicle in the dataset, which allows for a nuanced understanding of the role of automation in crash severity. The data, primarily single-vehicle incidents, is analyzed using the XGBoost machine learning model and Explainable Artificial Intelligence (XAI) techniques. The model achieved an accuracy of 0.88 when the "WEIGHT" feature was included and 0.60 when it was excluded. The findings underscore the significant role of human behaviors, vehicle characteristics, and environmental conditions in determining the outcomes of RwD crashes. The study aligns with the safe systems approach to road safety, emphasizing the need to understand and address the complex interplay of factors that contribute to crashes. The study provides insights for safer roadway design and automated vehicle guidelines, acknowledging limitations such as the focus on specific crash types and data quality. Future work could explore other crash types and the role of vehicle automation levels in crash severity.

Authors	Sheikh Usman, The University of Tennessee Knoxville Asad Khattak, The University of Tennessee Knoxville A. Latif Patwary, University of Tennessee
Sponsoring Committee	ACH10
Session Number	3159
Session Title	**Pedestrian Safety and Behavior**
Paper Number	24-02574
Paper Title	**Nighttime Pedestrian Safety in Disadvantaged Communities: Application of Artificial Intelligence Techniques**
Abstract	Pedestrian safety is a growing concern in the US transportation sector, with around 7500 pedestrian crash fatalities reported in 2021. Already highly susceptible to traffic crashes, pedestrians are at an even higher risk of crashes at night. This study integrates six unique transportation disadvantage indicators—Economy, Health, Equity, Resilience, Environmental, and Transportation Access—developed by the United States Department of Transportation at the census tract level with nighttime pedestrian crash data from 2016-2019 in North Carolina. The pedestrian crash data are extracted from police reports using the Pedestrian and Bicyclist Crash Analysis Tool, which provides high-quality detailed crash-type descriptors, resulting in a unique and comprehensive pedestrian crash database. The study applies rigorous methods for analysis, including the inference-based ordered logit model, to quantify key correlates of nighttime pedestrian crashes in disadvantaged communities (DACs). The model results reveal unique and novel associations of the Economy and Transportation Disadvantage indicators, roads without lights, pedestrian crossing violations, and alcohol impairment with nighttime pedestrian crash injury severity. To improve forecasting of pedestrian crashes and the resulting injury severity in DACs for planning purposes, an Artificial Intelligence (AI) based heterogeneous ensemble method, "Stacking" is applied with an Ordered Logit model and machine-learning techniques, Gradient Boosting, Decision Tree, and Random Forest as the base learners. The stacked model yields better predictive accuracy than the individual base learners. The study findings and the application of AI techniques can assist safety practitioners in improving planning and implementing targeted interventions in DACs to improve roadway infrastructure and overall safety.

Authors	Md Al Adib Sarker, RSG Hamid Rezaei, Florida International University Xia Jin, Florida International University
Sponsoring Committee	ACS60
Session Number	2037
Session Title	**Advances in Truck and Bus Safety Research**
Paper Number	24-02648
Paper Title	**Investigating the Temporal Stability of Factors Affecting Run-Off-Road Crashes Involving Large Trucks**
Abstract	This paper presents a comprehensive study aimed at investigating the factors influencing injury severity in run-off-road (ROR) crashes involving large trucks, with a special focus on understanding the temporal stability of these impacts. The research utilized crash data collected from January 2007 to December 2016 in Florida, and the data were categorized into five time periods, each spanning two consecutive years. Random parameter ordered logit models with interaction effects were employed, which allowed for variations in parameters across individual crashes and effectively addressed unobserved heterogeneity. To evaluate the temporal stability of the injury severity models, likelihood ratio tests were conducted. The results indicated considerable temporal instability across the study periods. Nonetheless, a few variables demonstrated significant and stable impacts over time, including single-vehicle crashes, state roadways, vehicle speeds, and the non-use of restraint systems. The study also unveiled the presence of several parameters with random effects on injury serenity outcomes. These findings contribute to a deeper understanding of the factors affecting injury severity in ROR crashes involving large trucks and underscore the importance of accounting for temporal variability in developing effective safety measures and policies. Understanding the variability and impact of these parameters can facilitate the development of targeted and effective safety interventions to reduce the severity and frequency of such devastating accidents.

Authors	Gustavo Riente de Andrade, Infraplan Consulting LLC Karla Rodrigues Silva Sivaramakrishnan Srinivasan, University of Florida Lily Elfeteriadou, University of Florida
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02731
Paper Title	**Investigation of the impact of traffic operations variables on crash severity on expressways**
Abstract	This paper aims to provide additional insights into the ongoing research containing the relationship between operational and capacity increase measures and their impact on safety. The paper models crash severity probabilities as a function of prevailing traffic conditions and other explanatory variables. The Ordered Multinomial Logit Model was used to fit separate models for single-vehicle (SV) and multiplevehicle (MV) crashes. A unique database was built by merging nine years of directional information, including over 12,000 crash records, road works reports, and 35 million observations of traffic flows and speeds on 1,039 km of freeways systems and divided multilane highways. A sensitivity analysis was conducted for several statistically significant variables. Lower visibility conditions reflected by nighttime and rain impacted the severity models. The presence of more vulnerable road users (VRU) in freeways represented by motorcycles and variations in the traffic composition, such as size differences between vehicles, were associated with increased severities. The impact of guardrails on the severity distribution was investigated for VRU and other SV crashes and proved effective in reducing the severity of SV crashes, with three times fewer fatal crashes and fewer overall injuries. Finally, the analysis of the influence of traffic variables suggested that linking MV crash severity and traffic density reflected better the relationship between crash severity and operational conditions than other traditional variables such as AADT. A preliminary relationship between densities and severity probabilities was identified, which can help supplement crash severity distribution tables.

Authors	Ramina Javid, Morgan State University Eazaz Sadeghvaziri, Mercer University
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-02780
Paper Title	**Predicting Bicycle-Involved Crashes in SCAG Region: A Machine Learning Analysis Using HSIS Data from California State**
Abstract	Bicycling is one of the popular modes of transportation in the U.S. However, crashes involving bicycles continue to be a significant safety issue. This study used Health and Safety Information System (HSIS) data to examine the factors influencing the severity of bicycle-involved crashes in the Southern California Association of Governments (SCAG) region between 2013 and 2017. The study developed a Bayesian network model with strong consistency validation and low error rate, indicating the effectiveness of the model in analyzing crash data and providing valuable insight into improving rider safety. The study also created two scenarios to understand the impact of different variables on the probability of having a fatal crash. The first scenario showed that having proper lighting and reflective clothing could increase visibility and reduce the probability of a fatal crash. The second scenario showed the need for designing roads and infrastructure that can handle wet conditions and provide adequate drainage to reduce the probability of a fatal crash. The study's results demonstrate the importance of designing effective infrastructure and highlighting the significance of proper lighting and visibility on bicycles to reduce the probability of a fatal crash. The findings can help policymakers and transportation engineers prioritize measures to improve rider safety. Furthermore, the study highlights the effectiveness of Bayesian network models in identifying the most significant factors contributing to bicycle-involved crashes. Overall, the study provides valuable insight into improving the safety of riders and demonstrates the effectiveness of Bayesian network models in analyzing and predicting bicycle-involved crashes.

Authors	Ningzhe Xu, University of Alabama Jun Liu, University of Alabama Zihe Zhang, University of Alabama Steven Jones, University of Alabama
Sponsoring Committee	AMR00, ACP10, ACS10, ACS30, AMROO
Session Number	2051
Session Title	**Emergency Responder Safety, Travel Demand, and Routing**
Paper Number	24-02905
Paper Title	**Injury Severity of Police Officers Involved in Traffic Crashes: A Spatial Analysis of Alabama**
Abstract	Police officers would in fact confront more frequent and severe hazards when responding to traffic incidents or providing roadside assistance. Traffic incidents are the leading cause of injuries and deaths for police officers in the US. There has been limited research to investigate the characteristics of traffic incidents or crashes that involve police officers. This study aims to cover the under-explored traffic safety topic with a focus on traffic crashes that involve police officers. Considering the inherent spatial correlation between traffic crashes and the geographical environment, this study conducts a spatial analysis to identify the contributing factors of police officers' injuries in traffic crashes. Specifically, this study employs the Geographically Weighted Ordered Logistic Regression (GWOLR) approach to quantify the correlates of police injury severity in crashes. This study explored five years of traffic crashes (N = 4,231) that involved police officers in the State of Alabama. Results showed that some variables, such as crash location, pre-crash behaviors, and seatbelt usage, passed the non-stationarity tests, indicating significant spatial variations in their relationships with the police injury severity in traffic crashes. The local correlates of police injury severity are valuable information for law enforcement agencies to localize strategies for improving officer safety on the road. For example, Move Over laws may need to be enhanced in southeast Alabama area, where failing to yield (to police officers') seems to lead to increased traffic injury severities of police officers compared to other areas in Alabama.

Authors	Shahrior Pervaz, University of Central Florida Tanmoy Bhowmik, Portland State University Naveen Eluru, University of Central Florida
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02911
Paper Title	**An Integrated Multi-Resolution Framework for Jointly Estimating Crash Type and Crash Severity**
Abstract	The current research effort contributes to safety literature by developing an integrated framework that allows for the influence of independent variables from crash type and severity components at the disaggregate level within the aggregate level propensity to estimate crash frequency by crash type and severity. The proposed framework can also incorporate unobserved heterogeneity in the model system. The empirical analysis is based on 2019 crash data drawn from the city of Orlando, Florida. The disaggregate level analysis uses 15,518 crash records of three crash types: rear end, angular and sideswipe. Each crash record contains crash specific factors, driver and vehicle factors, roadway, temporal, road environmental and weather information. For aggregate level model analysis, the study aggregates the crash records by crash type over 300 traffic analysis zones. The empirical analysis is further augmented by employing several goodness of fit and predictive measures. A validation exercise is also conducted using a holdout sample to highlight the superiority of the proposed integrated model relative to the non-integrated model system. The findings of the study indicate that the proposed framework is advantageous for capturing the variable effects simultaneously across the aggregate and disaggregate levels.

Authors	Tonghui Li, Auburn University Huaguo Zhou, Auburn University Fangjian Yang, Auburn University Zijie Zhao, Auburn University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-02948
Paper Title	**Exploring Contributing Factors to Wrong-Way Driving Crash Severity: Insights from California Highway Patrol Data**
Abstract	Wrong-Way driving (WWD) crashes continue to be a pressing traffic safety concern in the United States, prompting numerous studies focused on predicting crash severity using various models and variables. While many of these studies utilize state transportation department data or national databases such as the Fatality Analysis Reporting System (FARS), there are still opportunities for improvement. Leveraging the California Highway Patrol's (CHP) comprehensive five-year dataset on Wrong-Way crashes, this study explores unique variables, such as the WWD distance before the crash and drivers' blood alcohol concentration (BAC) levels, absent in previous datasets. By employing random forest models, this research aims to identify key determinants for WWD crash severity and unveil associated factors. The random forest model demonstrates superior performance with an overall accuracy of 68 %. The findings indicate that WWD crashes are more severe during weekends, over 8.6 miles WWD distances, with BAC levels over 0.21, during late-night hours (11 PM - 5 AM), involving drivers over 80 years old, and airbags deployment. These findings provide valuable insights for policymakers and transportation safety professionals to develop targeted interventions and strategies to reduce the severity of WWD crashes on roadways. By addressing these contributing factors, it is possible to enhance traffic safety and mitigate the impact of WWD incidents.

Authors	Zihe Zhang, University of Alabama Chenxuan Yang, University of Alabama Jun Liu, University of Alabama Cong Chen, University of South Florida Steven Jones, University of Alabama
Sponsoring Committee	ACS10
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	24-02956
Paper Title	**Revisiting the Roles of Speeds in Traffic Crashes: A Geographically Weighted Neural Network Approach**
Abstract	Improper speed behavior is a major contributing factor in traffic fatalities and injuries, especially on rural roads. Extensive research has been conducted to investigate factors related to speeding behavior and its impact on injury severity. However, previous studies have neglected the distinction between two types of improper speed behaviors: exceeding the posted speed limit (EPSL) and driving too fast for conditions (DTFFC). Crashes involving these two types of behaviors may exhibit different contributing factors and crash injury outcomes. This study utilizes a statewide crash database to develop separate models and compare the correlates of injury severity in crashes involving EPSL and DTFFC, respectively. Considering the complex relationships inherent in crashes, such as spatial unobserved heterogeneity, variable interaction, and non-linear patterns, besides the traditional logit regression (LR), this study adopts Geographically Weighted Logistic Regression (GWLR), Neural Network model (NN), and Geographically Weighted Neural Network (GWNN) to model injury severity. The relationship between explanatory variables and injury severity is quantified using marginal effects (ME) to explain the machine learning models. The findings indicate that: 1) GWLR and NN models exhibit better goodness-of-fit compared to LR; 2) the ME of injury severities differs between the two types of crashes in all models; 3) both GWLR and GWNN show substantial variation in ME across different spatial regions. This study contributes by incorporating NN into the spatial modeling framework and is expected to help identify high-risk regions for specific speeding behavior-related crashes, allowing for localized countermeasures to be implemented.

Authors	Robert Schneider, University of Wisconsin, Milwaukee Rebecca Sanders, Safe Streets Research & Consulting Bryan Walter Natalie Marshall William Henning, Southeastern Wisconsin Regional Planning Commission (SEWRPC)
Sponsoring Committee	ACH10
Session Number	3159
Session Title	**Pedestrian Safety and Behavior**
Paper Number	24-02989
Paper Title	**Factors Associated with Pedestrian Fatalities in Darkness, 2010 to 2020**
Abstract	US pedestrian fatalities increased by 51% between 2010 and 2020 (4,302 to 6,516 fatalities per year), and nighttime accounted for 87% of the additional pedestrian crashes. Now more than three-quarters of pedestrian fatalities occur at night. This paper builds on recent research to quantify the relative risk of pedestrian fatalities at night and explore the factors associated with pedestrian fatalities occurring at night rather than other times of day. We used binomial logistic regression models to identify factors that were associated with particularly high likelihoods of fatalities at night. The odds of a pedestrian fatality occurring at night were more than twice as high for crashes with these characteristics: during October through December, during rainy weather, in the roadway at non-intersection locations, on roadways with posted speed limits higher than 35 mph (56 km/h), when drivers were going straight (rather than turning), when drivers or pedestrians were drinking, and when pedestrians aged 16 to 64 were involved. Other significant characteristics included: uncontrolled location along an arterial roadway, hit and run, pedestrian drug use, and the pedestrian being Black, Native American, or Pacific Islander. Some of these factors are likely due to higher exposure at night, while others, such as higher posted speed limits and rainy weather, may be associated with drivers having greater difficulty detecting and stopping for pedestrians when it is dark. Our findings support lighting, roadway design, and other policy and program strategies to improve pedestrian safety at night, such as pilot testing lower nighttime speed limits.

Authors	Robert Marcoux Shahrior Pervaz, University of Central Florida Naveen Eluru, University of Central Florida
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03069
Paper Title	**Assessing Non-Motorist Safety in Motor Vehicle Crashes – A Copula-Based Approach to Jointly Estimate Crash Location and Injury Severity**
Abstract	Recognizing the distinct non-motorist injury severity profiles by crash location (segment or intersection), we propose a joint modeling framework to study crash location type and non-motorist injury severity as two dimensions of the severity process. We employ a copula-based joint framework that ties the crash location type (represented as a binary logit model) and injury severity (represented as a generalized ordered logit model) through a closed form flexible dependency structure to study the injury severity process. The data for our analysis is drawn from the Central Florida region for the years of 2015 to 2021. The model system explicitly accounts for temporal heterogeneity across the two dimensions. A comprehensive set of independent variables including non-motorist user characteristics, driver and vehicle characteristics, roadway attributes, weather, environmental, temporal, and socio-demographic factors are considered for the analysis. We also conducted an elasticity analysis to show the actual magnitude of the independent variables on non-motorist injury severity at the two locations. The results highlight the importance of examining the effect of various independent variables on non-motorist injury severity outcome by different crash locations.

Authors	Hanlong Fu Tiantian CHEN Jinhua Zhao, Massachusetts Institute of Technology Xiaowen Fu
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03250
Paper Title	**Unraveling the Enigma: New Insights into Factors Impacting the Severity of Autonomous Vehicle Crashes from Two Sources of AV Incident Records**
Abstract	As autonomous vehicles (AVs) become more prevalent on public roads, concerns have arisen over their actual safety performance. Their expected potential to reduce crash and injury rates would be overshadowed by current technological limitations. This study aims to identify the key factors affecting crash severity by analyzing real-world AV incident data from the U.S. between 2015 to 2022. The analysis employs random intercept multinomial logit models to estimate crash severity levels (i.e., non-jury, slight injury, and severe injury). The findings reveal that crashes involving engaged Level 2 AVs (with ADAS) tend to result in higher crash severity, compared with conventional driving mode. On the contrary, the injury risk was reduced by Level 3+ AVs with engaged ADS system. In addition, rear-end collisions and the presence of commercial vehicles are associated with slight injuries involving AVs. On the other hand, adverse weather, driving on highways, as well as the presence of vulnerable road users (VRUs) contribute to serious injuries. Overall, this research is expected to provide policymakers and AV manufacturers with valuable insights to enhance AV safety, emphasizing that addressing the identified factors will lead to improved AV design and control algorithms.

Authors	Qinghai Lin Chunting Nie Shunchao Wang, Southeast University
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03319
Paper Title	**Identifying the Contributory Chains and Patterns of Road Facilities on Bus-Involved Crashes by Using Latent Class Clustering and Association Rules Mining Approaches**
Abstract	Public concern has always surrounded bus-involved crashes due to buses' high passenger-carrying capacity and the substantial casualty rate. Existing studies, which typically treat all crashes as a single cluster, have primarily focused on the independent influence of risk factors, neglecting the interactive effects of multiple factors. They have also overlooked that the causative differences might vary across different crash types and severities. This study uses data from 14,560 bus-involved crashes in London between 2010 and 2019 to identify the contributory chains and patterns of road facilities. The Latent Class Clusteringmethod is utilized to identify typical classes and features of motorcycle-involved crashes, considering driver, vehicle, and environmental characteristics. The Association Rules Mining approach is applied to uncover the contributory chains and association patterns of road characteristics across different crash clusters and severities. The results suggest that differences in typical features and causal patterns do exist across different crash clusters and severities. On the one hand, a single causal chain may lead to different levels of severity in various crash types. For example, dual carriageway and daylight are important contributing factors of slight and severe crashes. On the other hand, the causal chains associated with the same crash severity may vary among different crash types. For example, give way or uncontrol, zebra, daylight are important influencing factors of slight crashes in cluster 3, but they are not crucial for other clusters. These findings assist in formulating practical measures and policy recommendations to enhance bus safety through the improvement of road facilities.

Authors	John Kodi Angela Kitali, University of Washington, Tacoma Henrick Haule, University of Arizona Emmanuel Kidando, Cleveland State University Boniphace Kutela, Texas A&M Transportation Institute Subasish Das, Texas State University
Sponsoring Committee	ACS60
Session Number	2037
Session Title	**Advances in Truck and Bus Safety Research**
Paper Number	24-03353
Paper Title	**Enhancing Safety in Freight Logistics: Insights from Heterogeneity of Truck Fatal Crashes Based on Nationwide Crash Data**
Abstract	Truck safety has drawn considerable attention from transportation agencies and the public due to their vital importance in freight logistics and the economic well-being of a nation. However, large-scale studies on the heterogeneity of truck crashes and associated factors are relatively scarce, although there is a need to understand such factors. Thus, this study investigated the risk factors associated with fatal crashes of truck-related fatal crashes in the United States. The study used five years of nationwide truck-involved fatal crashes from 2016 through 2020 collected from the Fatality Analysis Reporting System (FARS) database. A two-step approach, i.e., latent cluster analysis (LCA) and an ordered logistic regression model, was used in analyzing the truck-related fatal crashes. Based on the LCA, four clusters were identified based on the crash types i.e.: head-on rear-end, angle, and fixed object crashes. The ordered logistic model revealed that vehicles going straight, late evening period, late night period, weekend, hill alignment, arterials, rollover, driving under the influence, and speeding were associated with higher equivalent fatalities. In contrast, dark-lighted conditions, intersections, and urban areas were significantly associated with a low likelihood of fatal crashes. The findings of this study provide insights regarding the different effects of the various risk factors on fatal truck crashes, which could help transportation agencies and other stakeholders to deploy countermeasures to prevent truck-related crashes strategically.

Authors	Natakorn Phuksuksakul, Queensland University of Technology Shamsunnahar Yasmin, Queensland University of Technology Md. Mazharul Haque, Queensland University of Technology
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03374
Paper Title	**A Latent Segmentation Based Correlated Random Parameter Generalized Ordered Logit Model to Address Systematic and Unobserved Heterogeneity in Active Traveler Injury Severity Model**
Abstract	The posted speed limit, as a proxy of actual speed, is one of the most fundamental predictors of active travelers' (pedestrian and bicyclist) injury when involved in a crash with motor vehicles. Although earlier studies predominantly considered posted speed limit as an exogenous variable and provided highly insightful finding, majorities of them assume the effects of active traveler behavior to remain the same across different posted speed limit locations, which in turn neglect the heterogeneity in active traveler behaviors across different posted speed limit locations. This study proposes to develop a latent segmentation-based active traveler injury severity model to relax the homogeneity assumption of the posted speed limit by active traveler behavior. Specifically, we propose to estimate a latent segmentation-based correlated random parameters generalized ordered logit model with piecewise linear function to examine active travel injury severity mechanisms. The proposed model is demonstrated by using active traveler crash data from Queensland, Australia, for the years 2015 through 2020. Results clearly highlight the importance of segmentation which can be characterized as "Road rule compliant" and "Road rule non-compliant" active traveler groups. The key factor resulting in severe active traveler are roadways with posted speed limit of 70-90, and 100-110km/hr. Further, the results reveal the variation of the effect of distracted motorists across different posted speed limit roadways while also indicate the correlation between segmentation and injury severity components.

Authors	Yunfei Zhang, Peking University Peng Wang Wenjian Jia Tong Zhu, Chang'an University
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-03421
Paper Title	**Examining the Role of Run-Over on Injury Severity in Two Wheeler-Motor Vehicle Crashes: a Path Analysis Modeling Approach**
Abstract	This paper examines injury severity of Two-wheeler (TW) riders with three objectives: 1) identify the main causes of occurrence of run-over; 2) quantify the effect of run-over on the injury severity; and 3) understand how the occurrence of run-over mediates the relationship between the injury severity and other influencing factors. Random-parameter binary logit model, random-parameter ordered logit model, and path analysis are developed based on the China In-Depth Accident Study Database from 2017 to 2020. Model results show that riders' age, crash location, TW length, roadworks influence the occurrence of run-over. Moreover, run-over significantly affects injury severity of two-wheeler riders. When the riders are run over, they are 31.70% more likely to be involved in severe crashes. Additionally, path analysis results reveal the direct and/or indirect effects of various influential factors on injury severity. For example, the motor vehicle collision speed shows only direct effects on injury severity, whereas the presence of roadworks is not directly correlated with injury severity but indirectly increases injury severity through exerting impacts on the occurrence of run-over. Riders' age and TW major crash position show both direct and indirect effects on injury severity. Findings of this study highlight the mediating role of run-over in modeling injury severity of TW riders. Practically, the findings provide insights for the design of road systems and the installation of equipment to avoid occurrence of runover and concomitant severe injuries.

Authors	Kai Kang, Chang'an University Jie Zhang Wenjian Jia Tong Zhu, Chang'an University
Sponsoring Committee	ACS60
Session Number	2037
Session Title	**Advances in Truck and Bus Safety Research**
Paper Number	24-03450
Paper Title	**Text Mining and Reliable Network Analysis of Police Narrative Reports: Understanding Traffic Violations in Severe Truck-involved Crashes**
Abstract	Severe crashes that result in 3 or more deaths, especially when truck drivers commit traffic violations, have been a serious concern in road traffic safety management. However, there is a lack of reliable and comprehensive analyses of severe crashes related to truck violations, largely due to scarce structural crash datasets. This study aims to use police narrative reports to investigate severe crashes related to rule violations of truck drivers based on text mining complemented by reliable network analysis. Text mining results reveal 75 most relevant keywords from 432 police narratives. Networks are constructed subsequently using strong association rules of keywords. The Leiden algorithm is implemented to clarify thematic communities for various violation types. Results indicate that network analysis can identify statistically significant and interpretable thematic communities. Severe crashes with overloading trucks are mainly related to curve-slope road segments of rural highways, provincial and national highways during the afternoon, expressways during nighttime, and braking failure near signalized intersections. In contrast, severe crashes with speeding trucks are more likely to occur with curve-slope road segments during the afternoon, rural highways in autumn seasons, straight road sections during nighttime, work zone areas on four-lane roadways, vulnerable road users at unsignalized intersections on weekdays. Lastly, trucks that are both overloaded and speeding are found in 11% of severe crashes, which are mainly associated with provincial/rural highways, central China, and autumn seasons. According to the findings, prevalent patterns should be incorporated into enforcement schedules, safety education campaigns, and transportation system improvement.

Authors	Subasish Das, Texas State University Monire Jafari Reuben Tamakloe, University of Seoul Show Abstract
Sponsoring Committee	ACS10
Session Number	2236
Session Title	**School Transportation and Planning Research**
Paper Number	24-03757
Paper Title	**Investigating Crashes occurred at School Zones Using Random Parameter Ordered Probit Model**
Abstract	Traffic crashes pose significant challenges, causing immense loss of life and property. School zones emerge as crash-prone areas due to the high concentration of young pedestrians and cyclists who often lack sufficient understanding of traffic rules. Consequently, road authorities face mounting pressure from school representatives and concerned parents to implement improved safety measures in these critical locations. This study aimed to address this pressing issue by analyzing traffic crash data from school zone locations in Louisiana over a five-year period from 2017 to 2021. Several models including random parameters ordered probit model was employed to assess the severity levels of injuries resulting from these crashes. The analysis sought to recognize factors contributing to the severity of crashes and to recommend potential countermeasures to mitigate risks and enhance road safety. The results of this study illuminate the vital factors affecting injury severity in school zone crashes. Factors such as vehicle speed, pedestrian and cyclist exposure, presence of crossing guards, and adherence to traffic signals were analyzed to determine their impact on crash severity levels.

Authors	Monire Jafari Subasish Das, Texas State University Reuben Tamakloe, University of Seoul Md Nasim Khan, Texas State University Ahmed Hossain, University of Louisiana, Lafayette
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03794
Paper Title	**Uncovering Individual Heterogeneity in Pedestrian Crash Severity with Mixed Logit Models**
Abstract	The escalating count of vehicle-pedestrian collisions in the United States has become a growing concern for transportation safety analysts. Pedestrians' immediate exposure to collision forces puts them at an elevated hazard of severe injuries compared to other road users. Considering this as a critical public health issue, this research intends to explore factors that contribute to injury severity in pedestrian crashes. The study focuses on Louisiana State, where there has been a recent increase in pedestrian crashes and gathered pedestrian crash data spanning five years (2017-2021). The database consists of a total of 8,213 unique pedestrian crashes of three severity levels (fatal/severe, moderate, and minor/no injury). To address the complexities and variations in injury types, the study employs a random parameter modeling technique by keeping pedestrian injury severity as the dependent variable in the model. This approach permits the incorporation of unobserved heterogeneity (i.e., variations in the effect of crash contributing factors across the sample population) in the modeling process, providing a more comprehensive and nuanced understanding of injury severity. By analyzing various independent variables (e.g., human, vehicle, roadway, environmental, and temporal factors) and using the random parameter model with heterogeneity in means and variance, the study identifies the factors significantly associated with pedestrian injury types. Understanding these contributing factors can inform targeted interventions and policies to reduce pedestrian injuries and fatalities. Ultimately, this research contributes to the broader goal of creating safer and more pedestrian-friendly transportation environments to protect vulnerable road users and promote public health.

Authors	Riana Tanzen, VHB Ian Hamilton, VHB Michael Spear Scott Himes, VHB
Sponsoring Committee	AKD20
Session Number	3052
Session Title	**Advances in Roadside Safety**
Paper Number	24-03872
Paper Title	**A PRACTICAL ANALYSIS OF RISK FACTORS FOR ROADSIDE BARRIER NEED IN RURAL OREGON**
Abstract	Roadway departure crashes occur when a vehicle crosses an edge line or a centerline, or otherwise leaves the traveled roadway. These crashes often result in severe outcomes due to the high likelihood of the vehicle striking another vehicle or fixed object such as a tree, utility pole, or ditch. The researchers conducted a risk assessment for roadway departure crashes and the need for roadside barrier by analyzing various factors such as crash data, roadway geometrics, roadside slopes, and traffic volume on two corridors. This effort can help to map risk factors associated with run off road and roadway departure fatal, serious injury, and minor injury crashes and therefore, determine the need for roadside barriers. These factors include worse pavement condition, steeper average vertical grade, narrower shoulders, horizontal curve presence, sharper horizontal curves, presence of sight distance limitations, absence of roadside barrier, and steeper sideslopes where barrier is not already present. The paper concludes with recommendations for expanding upon this research and improving the transferability of the findings.

Authors	Chenhui Liu, Hunan University Meiling Su Zhuanzhuan Ma Ke Long, Changsha University of Science and Technology Chaoru Lu
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03876
Paper Title	**Exploration of traffic safety of battery electric vehicles: a case study to Tesla vehicle-involved crashes in Pennsylvania, USA**
Abstract	After decades of efforts, battery electric vehicles (BEVs) have increased greatly in the world. Meanwhile, their unique technical features also bring many new traffic safety challenges. With the traffic accidents data of Pennsylvania from 2018 to 2021, this study aims to identify the characteristics and trends of BEV crashes by analyzing those crashes involving vehicles of Tesla, the premier BEV brand in the auto market of the United States. First, Tesla crashes and internal combustion engine vehicle (ICEV) crashes are compared from accident severity, collision type, spatial & temporal distributions, and environmental features. Tesla crashes show no significant difference from ICEV ones in terms of severity, but they have many more rear-end and angle collisions. Besides, Tesla crashes are found to concentrate in the peak and noon hours, and mainly occur in urban areas, intersections, and state roads. Then, a logistic regression model is built to identify the important factors influencing the severity of Tesla crashes. The findings are expected to provide some new insights to help researchers understand the BEV traffic safety issue better.

Authors	Mohammad Reza Abbaszadeh Lima, Auburn University Md Mahmud Hossain, Auburn University Huaguo Zhou, Auburn University Yukun Song
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-03969
Paper Title	**Data Mining Approach to Explore the Contributing Factors to Fatal Wrong-Way Crashes by Local and Non-local Drivers**
Abstract	Despite wide-ranging research on wrong-way driving crashes, the fatality rate remains high. Being familiar with road conditions can aid drivers in making better driving decisions. However, few studies have concentrated on how the driver's familiarity with the road affects wrong-way driving. This study aims to examine if there is a difference in contributing factors to fatal wrong-way driving crashes by local and non-local drivers by utilizing Fatality Analysis Reporting System (FARS) data from 2016 to 2020. Descriptive statistics were first used to give an insight into the data then the Association Rule Mining method was applied to help uncover the hidden connections between contributing factors to wrong-way driving crashes for both local and non-local drivers. The findings indicated that several factors, including intoxicated drivers, an urban environment, late-night hours from 12 AM to 6 AM, and male drivers, play a significant role in causing local wrong-way driving crashes. On the other hand, non-lighted conditions in a rural setting significantly contributed to fatal wrong-way driving crashes by non-local drivers. Policy-level countermeasures are suggested based on the findings. An essential factor to consider is addressing the issue of intoxicated local drivers participating in wrong-way driving crashes. Additionally, it is crucial to acknowledge the influence of inadequately illuminated conditions in rural regions on non-local drivers.

Authors	Penglin Song, Hong Kong Polytechnic University N.N. Sze, Hong Kong Polytechnic University Sikai Chen, University of Wisconsin, Madison Samuel Labi, Purdue University
Sponsoring Committee	AED60
Session Number	2062
Session Title	**Addressing Statistical Bias and Uncertainties in Transportation Demand and Safety**
Paper Number	24-04171
Paper Title	**Correcting for Endogeneity between Crash Injury Severity and Crash Type at Freeway Ramp Areas Using a Hierarchical Bayesian Bivariate Ordered Approach**
Abstract	Freeway ramp areas are prone to vehicle collisions because of frequent lane-changing events. Crash type is an important factor influencing crash injury severity. However, it is possible that some unobserved factors may affect both the injury severity and crash type at the same time. Hence, crash type is endogenous to crash injury severity. Conventional studies usually model the injury severity and crash type, which can be correlated, of ramp area crashes separately. Such endogeneity issue and its influence on model inferences have rarely been investigated. In this study, injury severity and crash type of ramp area crashes are jointly modeled using a hierarchical Bayesian bivariate ordered approach. Random parameter recursive bivariate ordered probit model is developed to account for the endogenous effect of crash type in the crash injury severity analysis. Crash data at the freeway ramp areas in North Carolina from 2017 to 2018 is used. Results indicate that the proposed hierarchical Bayesian model is capable of capturing possible correlation between crash type and unobserved factors. In particular, the existence of endogeneity associated with crash type is detected by the significant correlation parameter in the crash injury severity analysis. It is also found that other exogenous variables such as gender, vehicle type, road condition, and crash location significantly affect the injury severities and crash types of ramp area crashes. Findings should shed light on the effective traffic management and control strategies that can mitigate crash and injury risk at freeway ramp areas.

Authors	Natalia Barbour Mohamed Abdel-Aty, University of Central Florida Samgyu Yang, University of Central Florida Jaeyoung Lee, Central South University
Sponsoring Committee	ACH10
Session Number	3159
Session Title	**Pedestrian Safety and Behavior**
Paper Number	24-04322
Paper Title	**Temporal changes in the crash trends in Florida during the COVID-19 pandemic: The case of pedestrian related crashes at intersections**
Abstract	While in most places, traffic volumes have returned to the pre-pandemic levels, the pandemic has shifted how and when people travel as well as transformed trends in crash frequencies and severities compared to the pre-pandemic conditions. The current paper has two primary objectives; first is to examine the overall trends in crash frequencies and severities in the state of Florida and how they changed along different phases of the pandemic and second, to examine pedestrian-related crashes at intersections and factors that impacted them before the pandemic as well as in the new norm (defined as the period when traffic volumes returned to their pre-pandemic levels). While, the descriptive statistics and ANOVA are used to study the overall trends, the pedestrian related crashes in two pre-defined time periods (approximately two years each) are evaluated by estimating two mixed logit models with the possibility of heterogeneity in the means and variances of random parameters. Likelihood ratio tests were also conducted to investigate the overall stability of models' estimates across time periods, and marginal effects of each explanatory variable were considered to examine the temporal instability of the effect of individual parameter estimates on the intersection related pedestrian injury-severity probabilities. It was found that the driver's age, gender, lighting conditions, road type, substance use, Florida residency status among other variables were significant in the models. Furthermore, the models' estimation results show statistically significant temporal instability in pedestrian related injuries at intersections between the prepandemic and new norm time periods.

Authors	Pei Li, University of Wisconsin, Madison Sikai Chen, University of Wisconsin, Madison Lishengsa Yue Yuan Xu David Noyce, University of Wisconsin, Madison
Sponsoring Committee	ACS20
Session Number	2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	24-04377
Paper Title	**Analyzing Relationships between Latent Topics in Autonomous Vehicle Crash Narratives and Crash Severity Using Natural Language Processing Techniques and XGBoost**
Abstract	Autonomous vehicles (AVs) are expected to bring huge benefits to society, while safety is one of the most important considerations when evaluating their performance. However, existing studies have only been focusing on general descriptive statistics about AV crashes. The unstructured AV crash narratives have not been investigated comprehensively, mostly due to the additional challenges it involves. This study applied natural language processing techniques to convert unstructured crash narratives into structured latent topics (i.e., combinations of words) among AV crashes using AV crash data provided by The state of California. The structural topic model (STM) is used for extracting topics from crash narratives as it allows the incorporation of metadata (i.e., the severity and year of crashes) while developing the model. In total, 15 topics have been identified from AV crash narratives, which can be divided into behavior-related, party-related, location-related, and general topics. Results suggested that the AVs' ability to interact with vulnerable road users, perform lane-change behavior, and react to other road users' lane-change behavior needs to be further improved. Furthermore, the relationships between the extracted topics and crash severity have been validated using an XGBoost model that has an average precision of 0.931, recall of 0.925, and F1-score of 0.926 in classifying crash severity. Topics containing specific words such as minor, bicyclist, and scooters have been found to have a significant impact on the model's output. Moreover, topics containing general words may not provide enough information for classifying crash severity.

Authors	Nikesh Gyawali Sarthak Khanal Doina Caragea H. M. Abdul Aziz, Kansas State University Eric Fitzsimmons, Kansas State University
Sponsoring Committee	ACS60
Session Number	2037
Session Title	**Advances in Truck and Bus Safety Research**
Paper Number	24-04614
Paper Title	**Predicting Commercial Motor Vehicle Crash Severity in Kansas at District Level using Explainable Machine Learning**
Abstract	The high rate of Commercial Motor Vehicle (CMV) crashes in the U.S., and specifically in Kansas, represents a significant public safety concern and imposes economic and emotional burdens. Kansas Department of Transportation (KDOT) reports 3,534 reported CMV crashes in Kansas in 2021 alone, resulting in 733 injuries and 816 fatalities. There is a critical need for data-driven CMV safety improvement strategies specific to geographic regions at a finer resolution. With limited highway patrol resources, determining where the officers will be assigned is often a critical decision, and with higher spatial resolution models, law-enforcement agencies can quantify predicted risk and take action faster and more efficiently. This study develops machine learning models to predict crash severity in CMVs. It leverages an explainable machine learning technique, specifically model agnostic SHAP analysis, to identify important features for crash severity prediction. The results indicate that ensemble-based models, specifically the Gradient Boosting and CatBoost classifiers, produce the best results on our CMV dataset collected from the Kansas Department of Transportation (KDOT). Furthermore, we perform feature-specific comparisons across different KDOT districts to identify how changes in a specific feature may impact crash severity across the various districts. Our results indicate varying importance across KDOT districts for several features, including light conditions, road surface, and speed limit. Such analysis provides the Kansas Highway Patrol (KHP) with district-specific insights, enabling the agency to make informed decisions regarding the prioritization and distribution of federal funds to enhance enforcement, education programs, and outreach activities.

Authors	Md Nasim Khan, Texas State University Subasish Das, Texas State University Jinli Liu
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-04714
Paper Title	**Predicting Pedestrian-Involved Crash Severity Using Inception-v3 Deep Learning Model**
Abstract	This research leverages a novel deep learning model, Inception-v3, to predict pedestrian crash severity using data collected over five years (2016-2021) from Louisiana. The final dataset incorporated forty different variables related to pedestrian attributes, environmental conditions, and vehicular specifics. Crash severity was classified into three categories: fatal, injury, and no injury. The Boruta algorithm was applied to determine the importance of variables and investigate the contributing factors to pedestrian crash severity, revealing several associated aspects. These include pedestrian gender, pedestrian and driver impairment, posted speed limits, alcohol involvement, pedestrian age, visibility obstruction, roadway lighting conditions, and both pedestrian and driver conditions, including distraction and inattentiveness. To address data imbalance, the study employed Random Under Sampling (RUS) and the Synthetic Minority Oversampling Technique (SMOTE). The DeepInsight technique was then utilized to transform the numeric data into images. Subsequently, five crash severity prediction models were developed with Inception-v3, considering various scenarios including original, under-sampled, over-sampled, a combination of under and over-sampled data, and the top twenty-five important variables. Results indicated that models without data balancing or that used only under sampling did not yield satisfactory results. However, a model applying both over and under sampling achieved prediction accuracies of 93.5%, 77.5%, and 85.9% for fatal, injury, and no injury categories, respectively. Additionally, the comparative analysis demonstrated that traditional machine learning could not outperform the proposed deep learning model. The insights can be harnessed by safety professionals, emergency service providers, traffic management centers, and vehicle manufacturers to enhance their safety measures and applications.

Authors	Jingfeng Ma, Southeast University Gang Ren, Southeast University Shunchao Wang, Southeast University Jingcai Yu, Southeast University Bingtong Wang, Southeast University
Sponsoring Committee	ACS10
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	24-04734
Paper Title	**Modelling the Heterogeneities of Risky Driving Behaviours in Taxi-involved Severities**
Abstract	Although taxis play an important role in daily travels of urban residents, few concerns have been devoted to taxi-involved safety issues related to risky driving behaviours of taxi drivers. This study positions itself at modelling the heterogeneous influences of risky driving behaviours on taxi-involved crash injuries and the injury mechanism. Based on 8327 valid police-reported taxi crashes (2011-2020), the distributions of injury severities and 10 risky driving behaviours are analysed. As an unsupervised approach, latent class clustering (LCC) is applied to identify the number of clusters by maximizing the homogeneities within each cluster and the heterogeneities across clusters. The most suitable number of clusters is determined as four, based on the AIC, BIC, and entropy-based values of the LCC test. Partial proportion odds (PPO) models are employed to characterize the heterogeneity for the whole dataset and each sub-dataset. The model results evidence that sub-models significantly own a better fitness than modelling the whole dataset. Marginal effects are implemented to further quantify the unobserved heterogeneities in 10 risky driving behaviours. The results reveal that the remarkable heterogeneities across clusters do exist. The top three contributing factors are dangerous overtaking, running red lights, and sudden acceleration/ deceleration (maximum marginal effects exceeding +31%). However, there is a great heterogeneity in the top three factors across clusters. Notably, aggressive driving behaviours have greater heterogenous effects, especially the influences of dangerous overtaking (moderate: +16.43%, severe: +36.88%). These findings could support taxi-related policy-making to reduce crash losses.

Authors	Richard Dzinyela, Texas A&M Transportation Institute Bahar Dadashova, Texas A&M Transportation Institute Grant Westfall Subasish Das, Texas State University Chiara Silvestri-Dobrovolny Dominique Lord, Texas A&M University, College Station
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-04774
Paper Title	**Analysis of Motorcyclists Crash Severity using Cluster Correspondence and Hierarchical Binary Logit Models**
Abstract	Crashes involving motorcyclists account for a significant portion of traffic-related injuries and fatalities. Despite motorcycles making only three percent of all registered vehicles, motorcyclists account for 14 percent of all roadway fatalities. As the number of motorcyclists increase, there is an urgent need to understand the factors contributing to crash injuries and severity involving motorcyclists. In this paper, we use the cluster correspondence analysis (CCA) and a hierarchical binary logit model to explore the factors associated with the motorcyclist crash injuries and fatalities in Utah between 2016 and 2020. Cluster correspondence analysis is used to cluster the crash data into seven groups, while hierarchical binary logit model is used to identify the significant factors affecting the KA (severe injuries) and BCO (non-severe injuries) crashes involving motorcyclists. The results of this study indicate that among the crash-contributing factors the motorcyclist age, roadway alignment, roadside safety systems and temporal factors significantly contribute to motorcyclist crash severities. The model results are not only significantly better than results from the binary logit model, but also accounts for the correlation within the clusters found within the crash data. Results from this approach are better and can help decision makers to implement targeted countermeasures to improve motorcyclist safety.

Authors	Jeffrey Bullard, University of Alabama, Tuscaloosa Emmanuel Adanu, Alabama Transportation Institute Jun Liu, University of Alabama William Agyemang, Council for Scientific and Industrial Research- Building and Road Research Institute Steven Jones, University of Alabama
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-04777
Paper Title	**Investigating Pedestrian Groups and Injury Severities in Ghana: A Latent Class Analysis with Mixed Logit Approach**
Abstract	In low- and middle-income countries (LMIC) pedestrians and cyclists account for approximately 26% of the road traffic deaths, which is a considerable amount as it is well known that the majority (90%) of the world's road traffic deaths occur in these countries. In Africa however, pedestrian and cyclist deaths account for 44% of their yearly road related deaths. Ghana is no exception to this trend; in fact, it has been estimated that pedestrian crashes alone account for 36.7% of road related deaths in the country. Therefore, the objective of this study is to use historical crash records from 2018 to 2020 to explore pedestrian-vehicle crashes in Ghana, to identify the groups of pedestrians represented in pedestrian-vehicle crashes by use of a latent class analysis (LCA) model, then conduct injury severity analyses using a mixed logit approach on each pedestrian group found in the LCA modeling. Results indicate that by segmenting the pedestrian crash data into homogenous groups, some variables were found to only be significantly associated with injury severity within some classes. Other variables were found to be significant across multiple classes yet experience different trends within each. For example, no traffic control was found to be significant within three subgroups but affect severity levels differently across classes. Further the darker hours of the day were more likely to be associated with fatal and major injury outcomes across multiple classes. This study provides new direction for studying different types of pedestrian crashes, particularly in LMICs and provides target interventions.

Authors	A. Latif Patwary, University of Tennessee Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACS10
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	24-04785
Paper Title	**Exploring How Urban Form, Demographics, and Disadvantaged Communities are Linked with Pedestrian and Bicycle Safety**
Abstract	With pedestrian and bicycle safety as the main focus, this study investigates the role of urban form, disadvantaged communities (DACs), and demographics at the national level. All three are closely related, e.g., the urban form can lead to segregation and concentration of DACs with limited access to resources such as safe infrastructure, services, and economic opportunities. The study uses the recently released US Department of Transportation data on DACs. This information is available at the census tract level through the Justice40 initiative and aims to address transportation equity issues. Specifically, six comprehensive indicators identify DACs based on economy, environment, equity, health, resilience, and transportation. This study uses these DAC indicators, urban form (e.g., developed area and alternative modes), and demographics (race or gender) to explore their association with pedestrian and bicycle fatal crashes. The study creates a unique database combining ten years of pedestrian-bicycle-involved fatal crashes with data for the 71,729 census tracts. The data are analyzed using descriptives and rigorous zero-hurdle negative binomial models, which account for excessive zeros. The inference-based analysis results reveal that all the disadvantaged indicators are positively associated with pedestrian-bicycle-involved fatal crashes. Furthermore, fatal-crash rates are positively associated with high-intensity development in census tracts. Higher Black, American Indian, or Alaska Native populations are associated with more fatal crashes. The study creates new knowledge about safety in different contexts characterized by urban forms, DACs, and demographics. The information can assist policymakers in allocating resources to improve DACs on a priority basis, promoting transport social justice.

Authors	Mohamed Eldafrawi, University of Rome "La Sapienza" Ken Koshy Varghese Marzieh Afsari Mahnaz Babapourdijojin, Sapienza University, Rome Guido Gentile, Sapienza University, Rome
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04807
Paper Title	**Predictive Analytics for Road Traffic Accidents: Exploring Severity through Conformal Prediction**
Abstract	Road traffic accidents are a significant global health concern with far-reaching economic consequences. In an innovative bid to address this issue, our study predicts accident severity in Rome, leveraging a comprehensive dataset from 2006 to 2022, a first in the literature. We analyzed multiple factors, including weather conditions, road and vehicle conditions, types of accidents, and time-related aspects. Distinguishing our study, we applied one-hot encoding to categorical variables, demonstrating superior model performance over traditional label encoding. Additionally, we employed the Synthetic Minority Over-sampling Technique (SMOTE) to handle data imbalance and provided a detailed analysis of its impacts on model performance. Our key innovation lies in implementing conformal prediction to quantify prediction uncertainty. Given the prevalent skewness in traffic accident datasets, this technique enhances decision-making reliability and precision. We deployed a series of machine learning models, with the Extreme Gradient Boost (XGBoost) algorithm outperforming others in predicting injury severity, boasting a remarkable 77% accuracy rate. Implementing SHapley Additive exPlanations (SHAP) ensured model interpretability, underscoring the type of vehicles involved, the nature of the accident, and road shape as the most influential factors. In conclusion, our approach combining XGBoost, one-hot encoding, SMOTE, and conformal prediction provides a comprehensive, efficient, and transparent method for predicting road accident severity. Incorporating conformal prediction offers critical insights into model uncertainty, significantly aiding decision-making in road traffic safety. Additionally, SHAP analysis highlights the key factors contributing to accident severity, guiding focused preventive strategies.

Authors	Diwas Thapa, University of Memphis Sabyasachee Mishra, University of Memphis Nagendra Velaga, Indian Institute of Technology, Bombay Gopal Patil, Indian Institute of Technology, Bombay
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04843
Paper Title	**A Duration-Based Model for Crash Occurrence and Severity Prediction: Tradeoffs and Stability Analysis**
Abstract	Recent proactive crash prediction models have emphasized data-driven methods, using machine learning and artificial intelligence. However, some researchers argue that statistical models, offering estimations of effect sizes with variable coefficients and elasticity effects, are more suitable from a causal perspective. Most statistical framework-based crash prediction models rely on a case-control approach, matching crashes to non-crash events. Nevertheless, accurately defining the crash-to-non-crash ratio and incorporating crash severities present challenges. Few studies have ventured beyond this approach to explore novel methods, like the duration-based framework. This study extends the duration-based modeling framework to predict crashes and their severity, addressing the computational complexity arising from crash severity inclusion. By striking a balance between model performance and estimation time, a 15% sample drawn at the epoch level achieves satisfactory predictive accuracy while reducing data size. Stability analysis of predictor variables across different samples indicates that certain variables require larger samples for accurate coefficient estimation, while others converge with small sample increases. Additionally, the model performs better in highway segments with more frequent crashes (duration between crashes less than 100 hours or approximately 4 days), as revealed in the validation process.

Authors	Jing Li Shuoyan Xu, University of Toronto Jingqiu Guo, Tongji University Hao Yang, McMaster University
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04857
Paper Title	**Explanatory Prediction of Injury Severity in Traffic Incidents: A Hybrid Approach with Latent Class Clustering and Causal Bayesian Network Model**
Abstract	Understanding the mechanisms of injury severity in traffic accidents is critical to improving road safety. Prior studies have primarily focused on exploring the associations between injury severity (IS) and various features or deployed black-box models for prediction analysis. The field, however, lacks sufficient exploration of explanatory prediction in IS. This research introduces a hybrid methodology integrating Latent Class Clustering (LCC) and Causal Bayesian Network (CBN) models for explanatory prediction of IS and mitigating the impact of unobserved heterogeneity. Traffic incident data from the United Kingdom for 2019, was collected. To alleviate unobserved heterogeneity, the dataset was first segmented into six clusters that represent different accident types using LCC. Following this, individual CBN models were developed for each cluster. The cluster-based CBN model achieved a 17%~37% improvement in fatal injury prediction in comparison with the CBN model based on the entire dataset. Moreover, the causal factors identified within a specific cluster exhibit causal relationships not observable when applying a model to the entire dataset without considering unobserved heterogeneity. A sensitivity analysis was performed on each cluster to identify the most important variables responsible for fatal injuries in traffic incidents. This research can contribute to not only facilitating explanatory prediction of IS but also uncovering distinct causal factors in different traffic accident types, which play a crucial role in reducing traffic-related fatalities and serious injuries.

Authors	Arsalan Esmaili Mohammad Mehdi Oshanreh, University of Washington, Seattle Amelia Regan, University of Washington, Seattle
Sponsoring Committee	ACS20
Session Number	2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	24-04925
Paper Title	**Investigation of Crash Severities Involving ADAS Level 2 and ADS Equipped Vehicles**
Abstract	As the automobile industry progresses toward autonomous vehicles, the incorporation of Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) is increasingly prevalent. This study seeks to examine the severity of crashes involving vehicles equipped with ADAS and ADS, in order to shed light on their potential implications for overall road safety. The dataset used for analysis was sourced from the National Highway Traffic Safety Administration (NHTSA) and is currently the most comprehensive available for ADAS and ADS-equipped vehicles. The results of this research unveiled noticeable differences in the frequency of crashes involving ADAS and ADS technologies. ADAS crashes were found to be more common during unfavorable conditions like wet surfaces, adverse weather, and dark environments, whereas the opposite pattern was observed for ADS crashes. Multinomial and binary logistic regression analyses were employed to examine the impact of different factors on the injury severity of crashes involving ADS and ADAS-equipped vehicles. The results demonstrate that the impact of factors on the severity of crashes involving ADAS and ADS vehicles are different. This study is one of the first attempts to explore the current AV crash data. However, the present study is a preliminary analysis, considering the preliminary nature of the available AV crash data. The findings of this study provide important insights into the current AV crash datasets. Moreover, the proposed models can be reapplied as more data and a deeper understanding of the primary safety factors of AVs becomes available.

Authors	Faria Raha, Northern Arizona University Brendan Russo, Northern Arizona University Steven Gehrke, Northern Arizona University
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-05020
Paper Title	**Assessing the Impact of Vehicle Type on Pedestrian and Bicyclsit Crash Injury Severity**
Abstract	Light-duty vehicles, such as sport utility vehicles (SUVs) and pickup trucks, have become increasingly commonplace on US roads. The size of these vehicles has also increased significantly with time. Given this trend, an improved understanding of the potential safety implications of large vehicles on other road users, especially pedestrians and bicyclists, has become increasingly necessary for informing responsive policies. This study examines the impact of vehicle type and other crash-related indicators of pedestrian and bicyclist injury severity in Arizona between 2017-2021. Adopting a binary logistic regression modeling framework, vehicle type was found to be a significant predictor of both pedestrian and bicyclist injury severity, with an increased likelihood of a fatality or suspected serious injury occurring for pedestrians and bicyclists struck by an SUV or pickup truck compared to a passenger car. The odds of a pedestrian-involved crash resulting in a severe injury were 1.43 times higher for pickup trucks and 1.23 times higher for SUVs in comparison to passenger vehicles. For bicyclist crashes, the odds ratios increased to 1.50 and 1.25, respectively. Other contributing factors such as lighting condition, posted speed limit, crash location, driver action, driver age, and pedestrian and bicyclist age were also found to be significant determinants of increased injury severity. These study findings offer important insights into the seemingly detrimental impacts of increasing vehicle size on vulnerable road user safety that can help provide transportation agencies and policymakers with the empirical evidence needed to support and prioritize roadway safety strategies for protecting pedestrians and bicyclists.

Authors	Md Nasim Khan, Texas State University Subasish Das, Texas State University Ryan Benton Mohammad Jalayer, Rowan University Ahmed Hasan, Rowan University
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-05047
Paper Title	**Uncovering Motorcycle Crash Severity Patterns through Association Rules Mining**
Abstract	Motorcycle crashes have raised significant concerns due to their disproportionate impact on overall vehicle fatalities in the U.S., necessitating in-depth analyses into the complex factors influencing their likelihood. Thus, the primary aim of this study was to employ association rules mining, a robust data mining approach, to examine the contributing factors leading to motorcycle crashes and unveil patterns related to crash severity levels, namely fatal, injury, and property damage only (PDO). To accomplish this objective, a five-year dataset (2016-2020) of motorcycle crash severity data obtained from the Massachusetts Department of Transportation (MassDOT) was utilized. Subsequently, comprehensive rule generation, evaluation, and visualization were conducted for the three crash severity levels, with crash severity levels considered as consequents and other variables as antecedents. The generated rules highlighted aggressive driving as the predominant attribute associated with fatal crashes, along with factors including nighttime riding in unlighted conditions, summer season driving, collisions with barriers, and urban driving. Likewise, the rules identified associations between injury crashes and single motorcycle incidents, daytime riding in the summer, rollover crashes, two-way undivided roadways, middle-aged drivers, and specific road types. Additionally, rules for PDO crashes indicated high associations with adverse weather conditions, winter season driving, collisions with roadside fixed objects, angle crashes, and the absence of traffic control devices on roadways. The study's findings provide valuable insights for policy development, resource allocation, and interventions aimed at mitigating the risks associated with motorcycle crashes.

Authors	I Gede Brawiswa Putra Pei-Fen Kuo, Central Police University Umroh Dian Sulistyah
Sponsoring Committee	ACS10
Session Number	2159
Session Title	**Motorcycle Operation and Safety Research**
Paper Number	24-05071
Paper Title	**Identifying the Related Factors of Food Delivery Motorcycle Crash Severity**
Abstract	The COVID-19 pandemic has resulted in a remarkable upsurge in the popularity of online food delivery services in recent years. This escalating demand has intensified the competition among delivery companies, leading them to prioritize providing the fastest service and incentivizing drivers to prioritize speed over safety. Consequently, this emphasis on speed has doubled the number of injury crashes associated with delivery services compared to typical motorcycles used for daily commuting. While existing research has predominantly focused on the relationship between food delivery bicycles or e-bikes and driving behavior, there remains a noticeable gap in investigating the specific role of food delivery motorcycles and their potential spatial relationships with built environmental factors (e.g., points of interest). Moreover, most food delivery crash severity-related studies have relied on the non-spatial model, potentially biased the estimation results. To address these research gaps, we employed a geographically weighted ordinal regression (GWOR) to identify the factors contributing to the severity of food delivery-related motorcycle accidents while accounting for spatial heterogeneity. Utilizing data from 2020, which included 2,314 food delivery motorcycle crashes in Taipei City, the results indicated that roads with higher speed limits, straight lanes, intersections, and restaurants in sub-urban areas were associated with a higher crash severity level. Similarly, male riders and traffic signal violations exhibited a significant positive association with the severity of food delivery crashes. These findings hold important implications for formulating more effective policies for food delivery drivers in different regions.

Authors	Gou Rui Yanyan Chen, Beijing University of Technology Yunchao Zhang
Sponsoring Committee	ACS20
Session Number	2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	24-05175
Paper Title	**Injury Severity Model of Autonomous Vehicle Involved Incident: A Hybrid model of XGboost and Multinomial Logit Based on A Novel Multi-Source Dataset**
Abstract	Autonomous vehicle (AV) technology is expected to improve road safety by potentially eliminating human error. This study constructed a hybrid method of XGBoost based SHAP algorithm and multinomial logit model. Based on Autonomous Vehicle Operation Incident Dataset Across the Globe (AVOID) to analyze the significant features that affect the driver's injury severity at intersections through five categories of factors: incident time; environment; roadway; incident description, vehicle status. And then explore the interaction between each potential factor. The results show that there are nine characteristics that have an important impact on the driver injury degree. In addition, pre-crash movement, incident scene, pre-crash speed, contact area and automous mode have significant effects on different degrees of injury. At intersections most incident occur when was stopped or driving at low speed (60.72% below 10mph). And in this speed range, the damage severity of the vehicle driver increases when AV goes straight. The proportion of AV in automous mode at the time of the accident was 60.41%. The rear of the AV was the main damage location, accounting for 54.07%. In this case, the driver may suffer more serious damage when the AV is in lane change or manual mode. In an incident steering direction scene, in automatic mode AV drivers also have a higher probability of injury. Although AV can reduce the injury severity of the driver's in most accidents at intersections. However, it is still necessary to make fuller consideration in the current AV technology and security.

Authors	Subasish Das, Texas State University Nazmus Sakib, Ahsanullah University of Science and Technology Xiaobing Li, Kentucky Transportation Cabinet Mohammad Jalayer, Rowan University Srinivas Geedipally, Texas A&M Transportation Institute Zihang Wei, Texas A&M Transportation Institute
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-05240
Paper Title	**Assessing Hit and Run Cases in Pedestrian-Vehicle Collisions using Probabilistic Graphical Method**
Abstract	Walking is an active and sustainable mode of transportation with numerous health and environmental benefits. However, the growing concern over the increasing number of hit and run crashes involving pedestrians poses a significant threat to public health. This research aims to investigate the various factors contributing to the severity of injuries sustained by pedestrians in hit and run crashes. By analyzing data from hit and run incidents involving pedestrians in Louisiana between 2017 and 2021, this study examined the complex relationships between contributing factors, pedestrian actions, driver and pedestrian characteristics, and injury severity. To unravel the intricate web of variables, Bayesian Network (BN) analysis—a powerful probabilistic modeling technique—was employed. The study's findings offer valuable insights into the correlation between crash factors and the severity of pedestrian injuries. With pedestrian safety and sustainable transportation gaining global attention, the results of this research hold significant implications for public health, urban planning, and transportation policy. The integration of BN analysis facilitates a comprehensive understanding of the interconnected factors that influence the severity of pedestrian injuries, thereby paving the way for evidence-based interventions and ultimately contributing to the reduction of hit and run crashes, as well as the promotion of safer walking environments.

Authors	Abdallah Kinero, Florida International University Kabhabhela Bukuru, University of North Florida Enock Mwambeleko, Florida International University Thobias Sando, University of North Florida Priyanka Alluri, Florida International University
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-05398
Paper Title	**Injury Severity of Crashes Involving Golf Carts: A Case Study of The Villages, Florida**
Abstract	Crashes involving golf carts (GCs) are on an increasing trend in recent years, particularly in the United States. This study focuses on analyzing GC crashes in the Florida community known as The Villages, one of the largest GC-oriented communities in the nation and worldwide. The objective was to evaluate the injury severity of crashes involving GCs ia retirement community where GCs are a common mode of transportation. The ordinal logistic regression (OLR) model was used to analyze the injury severity of 616 GC-related crashes. The analysis revealed that GC crash severity is influenced by various factors. Factors found to be significant in determining injury severity include ejection of one or more occupants from the GC, the extent of damage to the GC, GC speed prior to the crash, roadway characteristics (including divided roadways, traffic control devices, paved shoulders, and T-intersections), and roll-over incidents. The OLR model demonstrated an overall accuracy of approximately 71% in predicting injury severity. The model's findings were supported by the chi-square test, which identified estimated speed, occupant(s) ejection from the GC, estimated GC vehicle damage, traffic control devices, and type of shoulder as significant factors influencing GC crash severity. Understanding these factors is vital for transportation agencies to develop effective strategies to reduce the severity of GC crashes, ensuring the safety of GC users.

Authors	Mouyid Islam, Virginia Polytechnic Institute
Sponsoring Committee	ACS60
Session Number	3071
Session Title	**Driver Behavior Analysis for Driving Condition**
Paper Number	24-05405
Paper Title	**An Exploratory Assessment of Driver Injury Severities in Truck Crashes involving Fatigued and Non-Fatigued Driving**
Abstract	Fatigue remains a persistent and significant safety challenge for long-haul truck drivers, increasing the risk of highway crashes and compromising their daily work performance behind the wheel. This study aims to investigate the factors influencing driver injury severity in single-large truck crashes caused by fatigued driving, benchmarked with non-fatigued driving (normal driving). The analysis utilized Florida crash data from 2011 to 2019, encompassing both fatigue and non-fatigue-related crashes. Driver injury severity was examined using random parameters logit models, which consider potential unobserved heterogeneity in means and variances. The data collected covered a wide range of factors known to influence driver injury severity, including spatial and temporal characteristics, vehicle and traffic attributes, roadway conditions, and driver-specific characteristics. The analysis revealed significantly different parameter estimates for fatigue and non-fatigue-related crashes, suggesting fundamental differences in unobserved heterogeneity between these crashes. Most importantly, the estimated model results demonstrated distinct marginal effects between fatigued and non-fatigued driving, especially regarding severe injury crashes. This implies that driver behavior varies significantly depending on their level of fatigue. These findings contribute to the growing body of literature emphasizing the fundamental disparity between fatigued and non-fatigued driving behaviors. Moreover, this research highlights the potential impact of these disparities on the safety performance of commercial trucks, highway-safety technologies, and various policy-related safety countermeasures. Understanding the unique characteristics of fatigued driving can help inform targeted interventions to enhance safety in the commercial trucking industry and minimize the consequences of severe crashes caused by fatigued driving.

Authors	M. Ashifur Rahman, Louisiana Transportation Research Center (LTRC) Ahmed Hossain, University of Louisiana, Lafayette Elisabeta Mitran Julius Codjoe Subasish Das, Texas State University Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	ACS20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-05415
Paper Title	**Exploring the context of roadway geometry and operational characteristics in severe pedestrian crashes: Application of association rule mining**
Abstract	This study explored potential links between pedestrian fatal and severe injury (FSI) crashes and roadway attributes using association rule mining on a highway section dataset. The analysis considered two key perspectives: signalized vs. unsignalized intersections and single vs. multiple FSI incidents. This approach helped pinpoint individual and combined features potentially linked to pedestrian injuries. Incorporating physical and geometric intersection characteristics, the study provides insights into pedestrian FSIs, which are integral for boosting pedestrian safety within a safe system approach. The analysis revealed that higher frequency FSIs at signalized intersections often correlate with a mix of moderate speed limits (30-35 mph), divided medians, and longer crosswalks (>100 ft). Moreover, arterial roads with a higher capacity might be more susceptible to multiple FSIs. For unsignalized intersections, multiple FSIs are often linked to major roads with a higher functional class, crosswalks that are usually longer and vary more, and crosswalks with low-visibility paint markings, like only parallel or traverse lines. These findings illuminate the collective effect of roadway features on pedestrian injury severity, offering actionable strategic countermeasures to curb potential pedestrian injuries. Future studies can formulate effective strategies for enhancing pedestrian safety by understanding these complex relationships.

Authors	Md Mahmud Hossain, Auburn University Mohammad Reza Abbaszadeh Lima, Auburn University Huaguo Zhou, Auburn University
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-05449
Paper Title	**Severity Analysis of Secondary Crashes on High-Speed Roadways: Pattern Recognition from Traditional Crash Data Using Association Rule Mining**
Abstract	Secondary crashes (SCs) are a major concern, posing additional safety threats to both non-involved vehicles and incident responders. The objective of this study was to identify the factors contributing to SCs on roadways with a speed limit of 55 mph or above. Traditional police-investigated crash dataset spanning more than four years (January 2016 to February 2020) for the entire state of Alabama was analyzed. As the crash database did not directly include information on SCs and did not allow for linking a crash with a subsequent SC, a data extraction process was developed to identify SCs and understand their characteristics. Association rule mining (ARM) was applied to identify crash patterns based on injury severity levels. The generated rules were filtered based on support, confidence, and lift, and then validated by the lift increase criterion. The results revealed complex relationships between risk factors and severity of SCs. In relation to SCs with injuries, single-vehicle crashes were frequently observed during peak hours and when drivers swerved to avoid objects/persons/vehicles. In contrast, regarding SCs with possible/no injuries, single-vehicle collisions were more likely to occur when drivers failed to notice objects/persons/vehicles and were involved in speeding. On urban interstates, single-vehicle SCs were frequently associated with injuries, while rear-end SCs were often linked to possible/no injuries. The findings of this study can be helpful in enhancing existing traffic incident management programs to mitigate the occurrence of SCs.

Authors	Josh Roll, Oregon Department of Transportation
Sponsoring Committee	ACH10
Session Number	4049
Session Title	**Pedestrian Safety**
Paper Number	24-05490
Paper Title	**Vehicle Design and Speed: Factors Associated with Pedestrian Injury Severity in the Pacific Northwest**
Abstract	Fatal pedestrian traffic injuries in the United States continue to rise with preliminary data for 2022 likely to be the highest count of pedestrian deaths since 1980. While the frequency of pedestrian fatal injuries has increased, so too has their share of total traffic deaths with pedestrian fatal injuries now nearly 18% of all fatal traffic injuries. This paper documents reports efforts by the Oregon Department of Transportation (ODOT) to quantify the role of vehicle type, weight, and size as well as roadway and road user characteristics in fatal and serious injury crashes involving pedestrians. The results from this analysis above reveal the importance of considering vehicle characteristics finding larger vehicle including pickups, SUVs, CUVs, and vans significantly increase the odds of a pedestrian being seriously or fatally injured in the event of a collision. Detailed vehicle characteristics including curb weight and overall height were also found to increase the odds of pedestrian serious and fatal injury. This research also added to the established knowledge regarding the impact of vehicle speed on pedestrian injury severity finding that the higher the posted speed limit the higher the odds of fatal pedestrian injury. Road authorities including state DOTs should consider the role of vehicle design in traffic safety and mitigate the continued transition of the passenger fleet to larger vehicles by using available taxation, enforcement, and educational tools.

Authors	Ty Holliday, Northern Arizona University Brendan Russo, Northern Arizona University Steven Gehrke, Northern Arizona University
Sponsoring Committee	AJE00, A0010C, ACH10, ACH20, ACH40, ACP20, ACP35, ACP55, ACS30, AED30, AKG90, AKM50, AKM80, AKT40, AMS10, AP055, AR080
Session Number	3108
Session Title	**TRB Minority Student Fellows**
Paper Number	24-05635
Paper Title	**Cyclist-Involved Crashes and Level of Traffic Stress: Evidence from Arizona**
Abstract	Confronted by growing environmental and health concerns, many transportation agencies are instituting new policies and programmatic interventions aimed at further motivating cycling as a mobility option. Yet, in most American metropolitan regions, cycling rates remain relatively low in comparison to other modes despite a suspected desire among many urban residents, workers, and visitors to expand their transportation portfolio. A primary reason for this stagnation in cycling usage relates to continued and mounting concerns regarding the personal safety and security of current and prospective cyclists needing to ride on high-stress facilities to reach their destinations. To help understand the extent of this identified impedance to increased cycling adoption, this study examines the association between cyclist level of traffic stress and cyclist traffic safety measured as segment-level crash frequency and incident-level cyclist injury severity. By estimating a pair of negative binomial and binary logit models, respectively, this study adopts a two-pronged analytic framework to assess the significance of four different tiers in level of traffic stress (LTS) and its components (posted speed limit, number of travel lanes, annual average daily traffic) toward predicting crash frequency and injury severity. Findings from this study of a seven-year crash data set collected across all metropolitan planning organization jurisdictional boundaries in Arizona show that an increase in the LTS classification of a segment is associated with an increase in segment-level cyclist-involved crash frequencies and that cyclists are more likely to experience a more severe injury if involved in a crash with motorists on a higherstress facility.

Authors	Deep Patel, Rowan University Ruqaya Alfaris, Rowan University Mohammad Jalayer, Rowan University
Sponsoring Committee	ACS10
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	24-05730
Paper Title	**Identifying Factors Contributing to the Severity of Injuries for the Intersection Related Crashes in New Jersey**
Abstract	In light of a 2019 report by the Federal Highway Administration (FHWA) indicating that roughly one third of traffic-related fatalities occur at or near intersections, and with special reference to NHTSA statistics (2007-2021) indicating that 35% of traffic deaths in New Jersey occurred at intersections. Given the concerning statistics associated with intersection-related crashes in New Jersey, this research investigated crash data spanning five years (2015-2019). Using machine learning algorithms, such as RandomForest (RF), XGBoost (XGB), LightGBM (LGBM), CatBoost (CB), and an Ensemble model, as well as Shapely Additive Explanations (SHAP) impact value techniques, the study aimed to identify significant contributors to the severity of intersectionrelated crashes. The outcomes of this study stated that the Ensemble Model was the most accurate, with an accuracy of 0.74. SHAP impact value analysis revealed that factors such as angle crash type, posted speed limits (36 to 45 MPH and 46 to 55 MPH), and temporal elements such as summer and fall months, as well as between 6:00 and 18:00 hours, play significant roles in increasing the probability of injury severity in intersection-related crashes. The findings of this study provide essential insights to academics, engineers, and policymakers, opening the way for the development of practical solutions to reduce the crashes and severity of intersection-related crashes.

Authors	Emmanuel Adanu, Alabama Transportation Institute Richard Dzinyela, Texas A&M Transportation Institute Sunday Okafor, University of Alabama, Tuscaloosa Steven Jones, University of Alabama
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-05963
Paper Title	**Injury-severity analysis of crashes involving defective vehicles and accounting for the underlying socioeconomic mediators**
Abstract	Crashes occur from a combination of factors related to the driver, roadway, and vehicle factors. The impact of vehicles on road crashes is a critical consideration within road safety analysis even though not much studies have been conducted in this area. In this study, we assessed how various vehicle and other crash factors are significantly associated with crash outcomes. To do this, historical vehicle defect related crashes were obtained for the state of Alabama for the period covering 2016 to 2020. After data cleaning, a crash injury severity model was developed using the random parameters multinomial logit with heterogeneity in means approach to account for possible unobserved heterogeneity in the data. It was observed that brake defects accounted for a significant proportion, representing 42% of all vehicle defects associated with the crashes, followed by tire blowouts at 22.4%. The model estimation results revealed that crashes that occurred on roads that are curved left with downgrades were likely to result in major injuries. Also, it was revealed that crashes involving drivers between 40-59 years were more likely to result in major and minor injury while younger drivers had lower probability of sustaining major injuries. A spatial analysis was further conducted to better understand vehicle defect crashes as a broader societal issue and potentially explore their connection with socio-demographic characteristics. The findings of the study provide a data-driven evidence for sustained safety campaigns, workshops and trainings on basic vehicle maintenance practices in the low income communities in the state.

Authors	Michael Shea, University of Utah Juan Medina, University of Utah
Sponsoring Committee	ACS20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-05968
Paper Title	**Site-Level Statistical Crash Severity Modeling using Maximum Abbreviated Injury Scale (MAIS) Scores at Signalized Intersections**
Abstract	Crash severity outcomes from police reports and from hospital injury assessments are used in safety research but have yet to be utilized together for crash frequency or severity prediction models. Moreover, detailed site-specific safety assessments using hospital data have not been thoroughly explored, leaving such valuable data aside when it comes to evaluation of roadway geometric characteristics and engineering countermeasures. In addition, crash type can be highly influential on crash severity, but relatively little is known about characteristics influencing crash type and the resulting severity. Part of the difficulty is that the level of analysis using hospital injury data is typically very broad and is performed by region. Additionally, predictive models using injury severity are typically analyzed for the entire intersection, rather than each approach. Because geometric safety countermeasures are often chosen based on recurring crash types and their severity, predictive models for crash frequency and injury severity should also estimate crash frequency by recurring crash types and injury severity. This research leverages geometric, traffic, and crash characteristics at the approach level to analyze 4-leg signalized intersections and generate frequency and severity models by crash type. The research determines probabilistic severity models for hospital injury data using Maximum Abbreviated Injury Scale (MAIS) Scores and police reported fatal and severe injury (KA) data. This method opens opportunities to identify more effective countermeasures at individual sites, particularly in common cases where approaches are not symmetrical or don't have similar treatments. Keywords: MAIS, CODES, probabilistically-linked hospital data, Injury Severity Models

Authors	Hasan Naqvi, National Highways Authority of India
Sponsoring Committee	ACS60
Session Number	2037
Session Title	**Advances in Truck and Bus Safety Research**
Paper Number	24-06018
Paper Title	**Factors Explaining Truck-involved Fatal Crashes on a National Highway in India**
Abstract	Trucks constitute a large and growing segment of traffic on National Highways (NHs) in India. Owing to high share of road transport in transporting goods in India, trucks play an important role and contribute to the economy. However, trucks are considered to be significant contributors of road fatalities in particular on high-speed NHs in India. It is in this context, this paper makes an attempt to uncover characteristics of fatal crashes involving trucks and assess factors contributing to truck-involved fatal crashes on a six-lane NH in India. Three years fatal crash, traffic and highway inventory data for six-lane NH-1 are studied using binary logistic regression method. The truck-involved fatal crash density, i.e. per km per year for six-lane NH-1 is found to be 1.16.Out of the eight variables comprising crash, temporal and road user characteristics considered for the model, two variables are found to be significant. The model results for truck-involved fatal crash showed that the probability of 'striking vehicle' as truck is found to be much higher than car on NH-1; the likelihood of truck-involved fatal crash for variable 'crash type' is observed to be more than sixteen times with attribute as 'rear-end' than 'head-on'. Based on the study findings, road safety measures are recommended to curb the occurrences of truck-involved fatal crashes on the studied NH.

Authors	Ming-heng Wang, Taiwan Police College
Sponsoring Committee	ACH10
Session Number	3159
Session Title	**Pedestrian Safety and Behavior**
Paper Number	24-06095
Paper Title	**Association of intersection geometric and crash-related attributes with elderly pedestrian-involved crashes**
Abstract	This study applies an association rule method, the Apriori algorithm, to determine the critical geometric and crash-related attributes highly associated with the occurrence and fatality of elderly pedestrian-involved crashes at intersections. The results show various characteristics for different age groups, collision occurrence, and fatality. The geometric attributes, such as a lack of median division facility and the presence of crosswalks at the intersections, are highly associated with pedestrians aged 65 to 74 but not significantly associated with pedestrians aged 75 and older. Left-turning vehicles, flash operation intersections, pedestrian position at the endpoint of crossing, and female pedestrian sex are highly associated with crashes involving pedestrians aged 65 to 74. Crashes involving pedestrians aged 75 or older tend to occur at unsignalized intersections, in the spring season, in good weather and daylight conditions, and when pedestrians are at the start of the crossing. Most pedestrians aged 75 or older who are involved in crashes are male. Pedestrians not crossing on the crosswalk and the pedestrian at fault for the collision also contribute to elderly pedestrians' fatality. Implementing the pedestrian phase, pedestrian-actuated signals, refugee islands, and sidewalk extensions are suggested to decrease the conflicts between pedestrians and vehicles. The installation of railings along the sidewalk and more assertive enforcement of pedestrian laws are also strongly recommended to prevent jaywalking, which is the major contributor to crashes and injury severity of elderly pedestrians.

Authors	Abimbola Ogungbire, University of North Carolina, Charlotte Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	AED60
Session Number	2062
Session Title	**Addressing Statistical Bias and Uncertainties in Transportation Demand and Safety**
Paper Number	24-06189
Paper Title	**Effectiveness of Data Imbalance Treatment in Weather-related Crash Severity Analysis**
Abstract	Accurate predictive modeling is often hindered by the prevalent issue of class imbalance within weather-related crash datasets. To address this critical challenge, this study introduces a novel and tailored synthetic data generation technique aimed at effectively handling nominal predictors specific to weather-related factors. The proposed synthetic data generation technique is rigorously evaluated alongside well-established minority oversampling methods, such as the synthetic minority over-sampling technique (SMOTE) and the adaptive synthetic sampling approach for imbalanced learning (ADASYN). A comprehensive comparison of these data treatment techniques is conducted using two prominent machine learning models: the bagging algorithm (Random Forest - RF) and the boosting algorithm (Extreme Gradient Boosting - XGBoost). The findings are expected to contribute crucial insights into the development of more effective road safety strategies, tailored to specific weather scenarios and adverse conditions. The outcomes of this study hold promise in guiding decision-makers and policymakers toward more informed and proactive road safety strategies, better equipped to mitigate the impact of weather-related crashes, and enhance overall transportation safety.

Authors	LIU Xingwei, University of Yamanashi Jian XING, Nippon Expressway Research Institute Kuniaki SASAKI, Waseda University
Sponsoring Committee	ACS20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-06465
Paper Title	**Exploring Contributory Factors to Accident Severity Based on XGBoost Approach: An Application Case Analysis in Tomei Expressway, Japan**
Abstract	Traffic accidents have grave implications in terms of human life and property. Efficient traffic management requires a profound comprehension of the underlying causes of accidents and the ability to predict their severity partially. In this study, we investigated the factors contributing to accident severity by utilizing accident data collected from the Gotenba to Tokyo section of the Tomei Expressway in Japan during 2019. We employed a random forest model on the cleansed dataset to predict traffic accident severity, encompassing a total of 701 cases. Additionally, a grid search was conducted to identify the optimal hyper parameters for XGBoost model. To gain the independent performance and impact of each factor on traffic accident severity, we employed SHAP (SHapley Additive exPlanations) to show the visualization results. This effective tool facilitated the identification of high-risk routes and individuals. Notably, our analysis revealed remarkable findings that variables of geometric design were more prone to accident severity, and vehicles located at the end of congestion also have a high risk of severity when accidents occurred. These compelling findings provide valuable insights for the development of strategies aimed at enhancing expressway management.

Authors	Vahid Bahrami, Michigan State University Mohamed Ahmed, University of Cincinnati Steven Lavrenz, Wayne State University
Sponsoring Committee	ACS10
Session Number	2236
Session Title	**School Transportation and Planning Research**
Paper Number	24-06499
Paper Title	**Severity Analysis of Vehicle-Pedestrian/Bike Crashes in the School Buffer Zones: Investigating Unobserved Heterogeneity and Spatial Instability**
Abstract	Pedestrian and bicyclist safety in school zones has high importance because of children and adult pedestrians' vulnerability to vehicle crashes. There are a few studies that focused on pedestrian's safety in school zones utilizing advanced statistical models to account for spatial instability. This paper aims to explore vehicle-pedestrian/bike crashes severity in a 15-minutes walking time buffer zone around schools in the Cities of Detroit (Michigan) and San Jose (California), which are among the highest pedestrian/bike fatality rates in cities with populations of 500,000 or greater. These two cities were selected to investigate spatial instability, and to identify contributing factors affecting these types of crashes. Using 2016-2020 crash data, this study employed random parameter multinomial logit models with heterogeneity in means and variances to explain unobserved relationships between variables. Spatial stability has also been investigated to determine if the variables' effects are similar across different locations. The analysis results revealed that the parameters are spatially unstable across Detroit and San Jose. Findings show that there are some factors such as Covid lockdown, dark lighting indicator, arterial road indicator, bicycle crashes and number of units involved in the crash, which create stable effects with different magnitude in both cities. Using network buffer zones revealed that the proximity of the crash to a number of schools can affect the injury severity level. Furthermore, estimation results indicate that several driver, roadway, weather, lighting and school related factors influence injury severity in school zones.

6 Crash Modification Factors and Functions

Anurag Pande
California Polytechnic State University, San Luis Obispo

This year, the subcommittee identified 16 **papers/presentations** on research addressing safety evaluation through estimation of crash modification factors (CMF). There is also a Workshop Session #1024 that reviews recent research focused on developing and applying safety performance functions (SPFs) for pavement friction changes on safety performance. This review only includes CMFs estimated using collision data analysis. For studies using surrogate safety measures, the readers are referred to Section 7.

The CMFs estimated in these studies relate to several treatments, including pavement improvements (#24-04881; 01384; 02443; 03313; 00373), measures to avoid lane departure crashes (#24-00131; 01389; 00071), ITS technologies (#24-04686; 04450; 01470), novel intersection treatments and designs (#24-00814; 04338), and pedestrian and bicyclist safety measures (#24-05068). One of the studies reported on the need for estimating combinations of complete street treatments for multimodal traffic based on a review of relevant existing CMFs (#24-03932). Novel intersection design treatments are also addressed in the invited presentation #P24-20045.

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

Following the details of the papers, details of Workshop Session 1024 are provided.

Authors	Tim Nye, North Carolina Department of Transportation Carrie Simpson, North Carolina Department of Transportation
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-00814
Paper Title	**A Safety Evaluation of Dual Left Turn Lane Installations in North Carolina**
Abstract	Crash Modification Factors (CMFs) were calculated for the conversion of a single left turn lane to a dual or double left turn lane (DLTL). Despite their proliferation throughout urban and suburban traffic networks, the safety performance of intersection approaches with DLTLs has not been thoroughly investigated and documented within the library of transportation safety research. To date, no published research has been completed that recommends a CMF for DLTL installations. This research effort lays a foundation for the understanding of the before-after safety effect of this countermeasure. A sample of 36 signalized intersections within North Carolina were investigated that received DLTLs between 2004 and 2021. 18 of these intersections received their DLTLs with no other accompanying geometric changes and were operating with protected left turn phasing along the treated approaches before and after their DLTL installations. A before-after evaluation of these 18 sites using an empirical bayes methodology yielded the following CMFs: 0.974 (total crashes), 0.844 (fatal-and-injury crashes), 1.010 (property damage only crashes), 0.831 (frontal impact crashes), 0.951 (rear end crashes), and 1.241 (sideswipe crashes). This research recommends that the CMFs for fatal-and-injury crashes and property damage only crashes be used in future benefit-cost calculations when planning DLTL installations.

Authors	Shubhankar Chintamani Shindgikar, University of South Florida, Tampa Cong Chen, University of South Florida Pei-Sung Lin, University of South Florida Yaye Keita, University of South Florida Elzbieta Bialkowska-Jelinska, University of South Florida
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-01389
Paper Title	**Evaluating the Safety Effectiveness of Sinusoidal Rumble Strips on Lane Departure Crashes Prevention**
Abstract	Lane departure crashes are among the most common crashes in Florida and in the U.S. To prevent or reduce lane departure incidents, various types of rumble strips have been used. The Florida Department of Transportation (FDOT) adopted a new sinusoidal rumble strip pattern for statewide audible and vibratory treatment (AVT) implementation since recent research found that sinusoidal rumble strip patterns are effective in providing auditory and tactile alert to drivers in lane departure prevention and produces less external noise in comparison to other rumble strip texture patterns. However, there has not been a systematic evaluation on the safety effectiveness of sinusoidal rumble strips in the U.S. This paper focuses on evaluation of the safety effectiveness of sinusoidal rumble strips installed in Florida in recent years through an Empirical Bayes (EB) approach. Crash data at implementation sites and reference sites were collected, and a series of Crash Modification Factors (CMFs) were developed based on the type of rural roads (overall rural roadways, rural two-lane roads, and rural multi-lane roads) and crash severity levels (total crashes, and fatal/severe injury crash only). In addition, the authors used a multinomial logit model to estimate the influence of different variables and parameters that affect lane departure crashes. The research findings quantify the safety effectiveness of sinusoidal rumbles strips in preventing lane departure crashes and provide insights on countermeasure implementation to improve rural road safety.

Authors	Michael Dunn, VHB Angelina Caggiano, VHB Kristin Kersavage, VHB Richard Porter, VHB In-Kyu Lim, Federal Highway Administration (FHWA) Seyedehsan Dadvar, CYFOR Technologies LLC Michael Dimaiuta, GENEX Systems
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-03932
Paper Title	**Complete Streets Treatment Combinations and Safety Analysis Needs Assessment**
Abstract	Complete Streets encompasses policymaking, planning, design, and operations to improve safety, connectivity, and equity for all road users. Existing safety performance analysis and evaluation methods have gaps related to predicting the full safety performance benefits of Complete Streets projects. Specifically, the methods do not fully capture or distinguish expected safety performance improvements for different road users. To set the stage for future method improvements, this paper describes a research effort to identify common Complete Streets treatments and treatment combinations using both empirical and diagnostic analysis approaches. The paper also provides an assessment of available crash modification factors (CMFs) for quantifying the safety performance effects of these treatments and treatment combinations. The research results advance understanding of current capabilities for conducting safety performance analysis of Complete Streets with CMFs. The paper concludes with future research, data, and safety analysis needs for Complete Streets.

Authors	Taha Saleem, UNC Highway Safety Research Center Christopher Cunningham, North Carolina State University Raghavan Srinivasan, University of North Carolina, Chapel Hill Taehun Lee, Korea Expressway Corp
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04338
Paper Title	**Safety Evaluation of Conversion from a Conventional Signalized Intersection to a Continuous Flow Intersection (CFI)**
Abstract	This paper describes the efforts to evaluate the safety impacts of conversion from a conventional signalized intersection to a continuous flow intersection (CFI), with an aim of building on the current knowledgebase of CFIs by answering “Are these intersections expected to reduce crashes compared to other design alternatives?” An empirical Bayes (EB) before-after analysis was conducted on 16 typical CFIs. Overall, CFIs were found to significantly reduce total crashes by 12.2%. The most significant feature impacting safety at CFIs was the use of parallel vs. standard right turns, with parallel right turns having significant safety benefits (29.6% reduction) across the board and standard right turns increasing crashes (15.6% increase) in nearly all categories. Rural locations were significantly safer overall compared to urban/suburban designs (40.3% vs. 26.0% reduction). Although both site types showed improvement in safety, 4-legged sites provide the best overall results for all crash category types and 3-legged sites were only significant in one of the categories. While comparing CFIs with 1-lane and 2-lane crossovers, 2-lane crossovers were found to significantly decrease crashes (34.9% reduction), indicating that moving dual lane left turns upstream from a standard intersection has the greatest benefit.

Authors	Pengxiang Zhang, Pennsylvania State University Asif Mahmud, Kittelson & Associates, Inc. Vikash Gayah, Pennsylvania State University, University Park Eric Donnell, Pennsylvania State University, University Park
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04450
Paper Title	**Comparison of Safety Effect Estimates from Propensity Scores Potential Outcomes Framework and Empirical Bayes Before-After Method: Case Study of Adaptive Traffic Signal Control**
Abstract	Adaptive Traffic Signal Control (ATSC) technologies are applied to high-volume intersections to accommodate changing traffic patterns and ease traffic congestion. In addition to operational efficiencies produced by ATSC, these systems may also influence safety performance at intersections. The objectives of this paper are twofold: (1) quantify the safety effectiveness of ATSC at intersections in Pennsylvania; and, (2) compare safety effectiveness estimates obtained using the empirical Bayes (EB) before-after and propensity scores-potential outcomes (PSPO) methods. The dataset employed in this study consisted of 338 intersections where ATSC technology was deployed in Pennsylvania. The CMF values for total crashes obtained using the EB method are 0.974 for 3-leg intersections, 1.049 for 4-leg intersections, and 1.034 for the combination of both. Meanwhile, the CMF values for total crashes obtained using the PSPO method are 1.114 for 3-leg intersections, 1.096 for 4-leg intersections, and 1.141 for the combination of both. Additionally, when applying the EB method, the CMF values for fatal + injury crashes are 0.874 for 3-leg intersections, 1.034 for 4-leg intersections, and 1.001 for the combination of both. And the fatal + injury crash CMFs with the PSPO method for 3-leg intersections, 4-leg intersections, and the combination of both are 1.003, 1.037 and 1.077, respectively. Overall, these CMF values indicate slight increases in expected crash frequency with the implementation of ATSC, though several of these increases are not statistically significant.

Authors	Mohamed Essa, British Columbia Ministry of Transportation and Infrastructure Joy Sengupta, British Columbia Ministry of Transportation and Infrastructure Emmanuel Takyi, British Columbia Ministry of Transportation and Infrastructure
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04881
Paper Title	**Safety Effectiveness of High Friction Surface Treatment at Signalized Intersections in British Columbia**
Abstract	High Friction Surface Treatment (HFST) is a pavement and safety treatment that dramatically and immediately increases pavement friction to reduce crashes, injuries, and fatalities associated with friction demand issues. Understanding the effectiveness of HFST as a safety measure is crucial for estimating the expected crash reduction and evaluating the cost-effectiveness of future HFST implementations. Existing research on the HFST safety effectiveness evaluation is limited to horizontal curves and ramps, despite the promising safety benefits of installing HFST at other locations, such as signalized intersections. To help fill this research gap, this paper presents a rigorous before-and-after safety effectiveness evaluation of HFST installation at signalized intersections using traffic and crash data obtained from 15 treatment sites and 90 control sites in British Columbia, Canada. To enhance the validity of the safety assessment, two before-after evaluation methods were applied: Empirical Bayes and Full Bayes. The results indicated statistically significant safety benefits of HFST at the treated sites. Specifically, the estimated reductions in serious (fatal and injury) crashes, serious rear-end crashes, and serious wet-pavement crashes, are about 51%, 57%, and 64%, respectively.

Authors	Bhagwant Persaud (bpersaud@ryerson.ca), Toronto Metropolitan University Raghavan Srinivasan, University of North Carolina, Chapel Hill Vikash Gayah, Pennsylvania State University, University Park Kristin Kersavage, VHB Taha Saleem, UNC Highway Safety Research Center Shauna Hallmark, Streetwise Transportation Consultants Cameron Mohammadi, Toronto Metropolitan University
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-04686
Paper Title	**Estimating the Expected Change in Safety for a Potential Application of Three ITS Treatments**
Abstract	The paper documents and illustrates a practice-ready procedure for estimating changes in crash frequency for specific application circumstances for three ITS treatments – Closed Circuit Television Cameras (CCTV), Dynamic Message Signs (DMS) and Road Weather Information Systems (RWIS). The procedure will allow an agency to directly evaluate the change in safety that may be associated with a contemplated treatment. In effect, the approach mimics the application of a Crash Modification Function (CMFunction) in that each potential application will, in principle, have its own Crash Modification Factor (CMF). The procedure uses an empirical Bayes framework with safety performance functions (SPFs) for treatment and non-treatment reference sites. The paper also presents those SPFs, which were developed from Pennsylvania freeway data. In principle, this cross-sectional approach can be applied, as it has been, for other safety treatments where safety effects vary with application circumstance and where that variability cannot be captured with conventional before-after studies.

Authors	Sailesh Acharya, National Renewable Energy Laboratory (NREL) Atul Subedi, Utah State University Michelle Mekker, Utah State University Patrick Singleton, Utah State University
Sponsoring Committee	ACS 20
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	24-01384
Paper Title	**Developing Safety Performance Functions and Crash Modification Factors for Skid Resistance**
Abstract	Pavement friction is a critical factor in determining road safety, especially in adverse weather conditions. This study investigates the relationship between pavement friction, measured as Skid Number (SN), and crash frequency on Utah highways. Utilizing four years of data (2016–2019) from an interstate (I-15) and a non-interstate (US-89) highway, negative binomial models were employed to establish safety performance functions (SPFs) and crash modification factors (CMFs). The models controlled for traffic volume and segment length while examining various crash types, including dry and wet weather, property damage only, and injury-related crashes. Results indicate a significant negative association between SN and crash frequency for all crash types on both highway types. Higher SN values (more friction) were associated with fewer crashes, with a 10-point increase in SN leading to a 12–13% decrease in total crashes. The impact of friction on wet weather crashes and injury crashes on non-interstate highways was even more pronounced. These findings suggest that increasing pavement friction through measures like high friction surface treatments could lead to substantial traffic safety improvements. Overall, the results support the continued collection of skid data by transportation agencies, such as the Utah Department of Transportation (UDOT), to identify high-risk locations and prioritize friction improvement efforts to enhance roadway safety.

Authors	Saif Alarifi, King Saud University Khalid Alkahtani, King Saud University College of Engineering
Sponsoring Committee	ACS 20
Session Number	2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	24-03313
Paper Title	**Developing Safety Performance Functions and Crash Modification Factors for Skid Resistance**
Abstract	This paper aims to contribute to the implementation of the highway safety manual by developing crash modification factors (CMFs) for freeways in Saudi Arabia, which will be useful to enhance the methodology being used in selecting road safety countermeasures on freeways using local data. The CMFs were developed for two types of interventions: shoulder rumble strips and lighting on freeways. The data for this study were obtained from different sources for the period of 2017 to 2019 (3 years) before COVID-19 pandemic and after roads were open to traffic during 2021 and 2022. It was found that shoulder rumble strips reduce fatal and injury run-off-road crashes by 52.7% (CMF=0.473) with a 95% CI (0.325-0.621). Economic analysis of this intervention revealed that shoulder rumble strips were very cost effective with a benefit-cost ratio of 14.12. Regarding Lighting, the treatment has a positive effect on nighttime crashes on freeways since it is expected to reduce nighttime crashes by 24% (CMF=0.760). Economic analysis of this intervention revealed that lighting on freeways was only marginally cost effective with a benefit-cost ratio of 1.24. It should be noted that the benefit-cost ratio for lighting will be higher when using solar powered lights especially in KSA with abundant sunshine.

Authors	Tanveer Ahmed, Pennsylvania State University Asif Mahmud, Kittelson & Associates, Inc. Vikash Gayah, Pennsylvania State University, University Park
Sponsoring Committee	Standing Committee on Roadside Safety Design (AKD20)
Session Number	3052
Session Title	**Advances in Roadside Safety**
Paper Number	24-00071
Paper Title	**Developing Safety Performance Functions and Crash Modification Factors for Skid Resistance**
Abstract	Horizontal curves are known to be more crash-prone than tangent sections particularly with respect to roadway departure crashes. Rumble strips are an effective countermeasure to mitigate various types of roadway departure crashes. While existing studies on the safety effectiveness of rumble strips have primarily used before-after study designs or cross-sectional methods for crash modification factor (CMF) estimation, these methods often suffer from imbalanced datasets and larger standard errors, especially when the sample size is small. To address this, this study applies the propensity score potential outcome (PSPO) framework to estimate CMFs for centerline rumble strips, shoulder rumble strips, and their combined application on horizontal curves. In addition to contributing to the development of CMFs by crash severity, this study also examines the effects of rumble strips on collision types, highlighting their impact on vehicle maneuvering and collision characteristics. The analysis is conducted on horizontal curves on two-lane rural roads in Pennsylvania, utilizing crash data from 2017 to 2021. The PSPO method effectively reduces bias between sites with and without rumble strips, and the resulting statistical models align with engineering judgment. The findings indicate that centerline rumble strips reduce opposite direction sideswipe and head-on crashes but increase run off the road and hit fixed object crashes. Shoulder rumble strips, either alone or in combination with centerline rumble strips, decrease crash frequencies for most types except opposite direction sideswipe and head-on crashes. However, shoulder rumble strips alone are more effective at reducing crash frequencies on horizontal curves than their combined application.

Authors	Jimoku Salum, SRF Consulting Cecilia Kadeha, World Bank Priyanka Alluri, Florida International University Srinivas Geedipally, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Managed Lanes (ACP35)
Session Number	3104
Session Title	**Standing Committee on Managed Lanes**
Paper Number	24-01470
Paper Title	**Safety Performance Functions and Crash Modification Factors for Concurrent Flow Managed Lanes Facilities**
Abstract	Pavement friction is a critical factor in determining road safety, especially in adverse weather conditions. This study investigates the relationship between pavement friction, measured as Skid Number (SN), and crash frequency on Utah highways. Utilizing four years of data (2016–2019) from an interstate (I-15) and a non-interstate (US-89) highway, negative binomial models were employed to establish safety performance functions (SPFs) and crash modification factors (CMFs). The models controlled for traffic volume and segment length while examining various crash types, including dry and wet weather, property damage only, and injury-related crashes. Results indicate a significant negative association between SN and crash frequency for all crash types on both highway types. Higher SN values (more friction) were associated with fewer crashes, with a 10-point increase in SN leading to a 12–13% decrease in total crashes. The impact of friction on wet weather crashes and injury crashes on non-interstate highways was even more pronounced. These findings suggest that increasing pavement friction through measures like high friction surface treatments could lead to substantial traffic safety improvements. Overall, the results support the continued collection of skid data by transportation agencies, such as the Utah Department of Transportation (UDOT), to identify high-risk locations and prioritize friction improvement efforts to enhance roadway safety.

Authors	Vikash Gayah, Pennsylvania State University, University Park Eric Donnell, Pennsylvania State University, University Park Hao Liu, Pennsylvania State University Abhishek Prajapati, Pennsylvania State University
Sponsoring Committee	ACS 20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-00131
Paper Title	**Crash modification factors for high-tension cable median barriers: An empirical Bayes before-after study**
Abstract	Cross-median crashes involve vehicles departing the roadway to the left, crossing the median of a divided highway, and colliding with a vehicle traveling in the opposite direction. These crashes are severe, often resulting in fatal or serious injuries. To mitigate this crash type, transportation agencies may install median barriers. The high-tension cable median barrier is a flexible system that is intended to contain or redirect vehicles entering the median – this barrier type has recently been installed along freeways segments throughout Pennsylvania. The purpose of this study is to develop crash modification factors for this barrier system. An empirical Bayes observational before-after study was used to develop the crash modification factors – various crash types, area types (urban vs. rural), and barrier placement locations were considered. The results indicate that, when considering both urban and rural locations combined, the installation of high-tension cable median barrier is associated with an increase in total, fatal plus injury, property-damage only, and hit-barrier crashes on freeway segments. The expected number of cross-median, fatal plus suspected serious injury, and fatal plus suspected serious injury cross-median crashes are expected to decrease when installing high-tension cable median barriers. The crash modification factor for high-tension cable median barriers is higher for installations along the shoulder of the freeway segment when compared to installations in the center of the median.

Authors	Vikash Gayah, Pennsylvania State University, University Park Eric Donnell, Pennsylvania State University, University Park Pengxiang Zhang, Pennsylvania State University
Sponsoring Committee	ACS 20
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	24-00373
Paper Title	**Crash modification factors for high friction surface treatment on horizontal curves of two-lane highways: A combined propensity scores matching and empirical Bayes before-after approach**
Abstract	Horizontal curves are locations that, as a result of the changing alignment, may be a contributing factor in roadway departure crashes. One low-cost countermeasure to mitigate crashes at these locations is the installation of the high friction surface treatment (HFST), which increases roadway friction and is intended to help keep drivers on the roadway when traversing a horizontal curve. This treatment has been implemented at numerous curves in Pennsylvania, but the overall safety effectiveness is not known. The purpose of this study is to estimate a suite of Crash Modification Factors (CMFs) for HFST applied to curve sections of undivided two-lane roadways. A novel combination of the empirical Bayes observational before-after study design and propensity score matching was used to estimate CMFs for multiple crash types, crash severities, roadway settings (urban and rural), and crash locations (within curve extents only and also including adjacent tangent sections). Propensity score matching was implemented to identify the most appropriate reference group to use within the empirical Bayes methodology. The results indicate that the installation of HFST is associated with a statistically significant decrease in all crash types and severities considered.

Authors	Ross McCarthy, Virginia Polytechnic Institute Gerardo Flintsch, Virginia Polytechnic Institute Edgar de León Izeppi, Virginia Polytechnic Institute
Sponsoring Committee	ACS 20
Session Number	4003
Session Title	**Safety Performance and Analysis Research**
Paper Number	24-02443
Paper Title	**Predicting Crash Reduction with Crash Modification Factors for Friction and Macrotexture**
Abstract	In countries, such as Australia, New Zealand, and the United Kingdom, friction and macrotexture are managed through pavement friction management programs, which are developed, and sometimes implemented as policy, for monitoring and maintaining adequate friction characteristics on pavement surfaces across their roadway network. These programs assign or recommend levels of friction and macrotexture. Recommended levels of friction, also referred to as friction demand, is the amount of friction needed for a vehicle to safely navigate the geometry of the roadway. The Virginia Department of Transportation has funded a multiphase project with cooperation from the Center for Sustainable and Resilient Infrastructure of the Virginia Tech Transportation Institute to investigate the potential benefits of using continuous pavement friction measurement to evaluate the potential benefits of friction enhancement from various safety countermeasures. This paper summarizes the finding of a Phase 3 memorandum that uses crash modification functions derived from safety performance functions to predict the potential reduction in crashes from increasing friction or macrotexture by specific unit amounts for different friction demand categories, referred to in the research as facility site types. The results concluded that continuous friction was a significant factor in the safety performance functions for 12 of 14 facility site types, while macrotexture was only selected for the safety performance function for three site categories under the Rural Multilane Highways. Crash modification functions were successfully derived from the safety performance functions. The results of the crash modification functions showed that increasing friction or macrotexture decreases potential crash risk.

Authors	Raul Avelar, Insurance Institute for Highway Safety Kay Fitzpatrick, Texas A&M Transportation Institute Michael Pratt, Texas A&M Transportation Institute
Sponsoring Committee	ACS 20
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	24-05068
Paper Title	**Developing a Crash Modification Factor for Intersection Corner Radius**
Abstract	This project investigated the impacts of intersection corner radius on pedestrian crashes. The corner radius can be unique to each corner at an intersection; therefore, this study assigned crashes to individual intersection corners within an intersection. The following variables were found to have a direct relationship with corner-level pedestrian crashes: pedestrian volume on the approach leg, pedestrian volume on the receiving leg, vehicle volume on the approach leg, vehicle volume on the receiving leg, corner radius, and shoulder width. The number of pedestrian crashes was higher when both legs at a corner were one-way streets with traffic moving away from the corner or when there was a mix of two-way and one-way operations present at the intersection. Fewer pedestrian crashes occurred when on-street parking existed on the approach leg. The findings from the study support the development of a crash modification factor (CMF) for corner radius. Assuming a baseline condition of 10 ft, the pedestrian CMFs for corner radius for the range of corner radii included in the evaluation went from 1.00 for a 10-ft radius to 1.59 for a 70-ft radius rs is higher for installations along the shoulder of the freeway segment when compared to installations in the center of the median.

Authors	Christopher Cunningham, North Carolina State University
Sponsoring Committee	Standing Committees on Research Innovation Implementation Management (AJE35)
Session Number	2166
Session Title	**Supplemental Research Award Projects**
Paper Number	P24-20045
Paper Title	**Development of a Crash Modification Factor for Conversion of a Conventional Signalized Intersection to a Continuous Flow Intersection: North Carolina Department of Transportation**
Abstract	An Empirical Bayes study was conducted on 16 typical CFIs. Overall, CFIs were found to significantly reduce total crashes by 12.2%. The most significant feature impacting safety at CFIs was the use of parallel vs. standard right turns, with parallel right turns having significant safety benefits (29.6% reduction) across the board and standard right turns increasing crashes (15.6% increase) in nearly all categories. Looking only at sites with parallel right turns, skewed intersections showed significant reductions (29.4% and 30.1% reductions for both no-skew and skew, respectively); however, the findings for the no-skew condition for crash severity and type were better overall. Area type was not found to increase crashes; however, rural locations were significantly safer overall compared to urban/suburban designs (40.3% vs. 26.0% reduction). Although both site types were safe, 4-legged sites provide the best overall results for all crash category types and 3-legged sites were only significant in one of the categories. Last, although the number of crossover lanes did not increase crashes in either category, 2-lane crossovers were the only one that was found to significantly decrease crashes (34.9% reduction).

Workshop Session 1024 Details

Authors/Presenter	Gerardo Flintsch, Virginia Tech Adnan Qazi, Arkansas DOT Shane Underwood, North Carolina DOT John Senger, Illinois DOT Mike Vaughn, Kentucky Transportation Cabinet Alfonso Montella, University of Naples Federico II
Sponsoring Committee	AKP 50; ACS 20; AKP 10
Session Number	Workshop 1024
Session Title	**Pavement Friction Management, Continuous Pavement Friction Measurement, and Safety Analysis**
Abstract	Recent research has focused on developing safety performance functions (SPFs) that include continuous friction and macrotexture measurements on a variety of roadway facility types and categories (i.e., segments, intersections, curves, and ramps). The main objectives were to obtain crash modification factors (CMFs) that make possible the evaluation of pavement friction changes on safety performance and to establish investigatory thresholds for friction based on roadway type and category. The analysis confirmed a strong statistical association between pavement surface frictional properties (friction and macrotexture) and crash rates. As expected, the investigatory levels are higher for higher friction demand sites, such as curves, ramp and access points, and intersections. This workshop will present the approach to developing SPFs and CMFs, establishing investigatory thresholds to improve safety performance, and provide the experience of some DOTs with this process. The workshop will allow attendee interaction and discussion of research needs.

7 Surrogate Measures of Safety

Vamsi Krishna Bandaru and Mario Romero
Purdue University

This year, **sixty-six papers** that use surrogate measures of safety (SMoS) were identified. In these studies, the surrogate measures are used either as the primary approach to safety analysis or as a complement to the traditional crash-based approach.

Broadly, the papers can be classified into the following topics: **intersections, non-motorized users, applications of SMoS** (implementing SMoS or proposing frameworks), **connected and autonomous vehicles (CAV), real time safety monitoring, or safety simulation.**

Sixteen papers analyze safety at **intersections**: 24-00120, 24-00193, 24-00391, 24-01112, 24-01190, 24-01270, 24-01303, 24-01894, 24-02256, 24-03198, 24-03504, 24-03918, 24-04004, 24-05236, 24-06029, 24-06090).

Pedestrians and non-motorized users were investigated in seventeen papers: 24-00120, 24-00193, 24-00391, 24-00693, 24-00927, 24-01190, 24-01198, 24-01270, 24-01894, 24-02153, 24-02362, 24-03198, 24-03918, 24-04264, 24-05236, 24-05520, 24-06029.

Various **SMoS applications** were presented in forty papers: 24-00120, 24-00193, 24-00302, 24-00323, 24-00485, 24-00693, 24-00779, 24-00927, 24-01074, 24-01190, 24-01372, 24-01471, 24-01595, 24-01912, 24-02119, 24-02153, 24-02256, 24-02293, 24-02298, 24-02362, 24-02402, 24-02963, 24-03029, 24-03281, 24-03338, 24-03408, 24-03504, 24-03657, 24-03884, 24-04004, 24-04027, 24-04264, 24-05144, 24-05148, 24-05236, 24-05629, 24-06029, 24-06058, 24-06070, 24-06090.

Real time safety analysis or monitoring is highlighted in six papers: 24-00080, 24-00302, 24-05148, 24-05149, 24-05150, 24-05833.

Safety Simulation was performed in three papers: 24-02362, 24-05299, 24-06302.

Finally, **connected and autonomous vehicles technologies** applications are discussed in twelve papers: 24-00485, 24-00693, 24-00779, 24-01198, 24-01912, 24-02362, 24-02402, 24-03338, 24-05520, 24-06090, 24-06151, 24-06302.

Concerning surrogate measures of safety we found that **traffic conflicts** are used in forty-eight papers: 24-00080, 24-00120, 24-00193, 24-00302, 24-00323, 24-00391, 24-00485, 24-00779, 24-00927, 24-00953, 24-00954, 24-01112, 24-01190, 24-01198, 24-01303, 24-01372, 24-01471, 24-01564, 24-01595, 24-01894, 24-02119, 24-02256, 24-02293, 24-02298, 24-02669, 24-02963, 24-03198, 24-03281, 24-03408, 24-03504, 24-03657, 24-03884, 24-03918, 24-04004, 24-04027, 24-04264, 24-04593, 24-05133, 24-05137, 24-05148, 24-05149, 24-05150, 24-05298, 24-05299, 24-05520, 24-06058, 24-06090, 24-06302.

In terms of conflict indicators, the **time-to-collision (TTC)** and its variants such as modified time to collision (MTTC), generalized time to collision (GTTC) are used in twenty-two papers (24-00080, 24-

00120, 24-00323, 24-00391, 24-00927, 24-00953, 24-00954, 24-01074, 24-01112, 24-01372, 24-01595, 24-01894, 24-03408, 24-03504, 24-03657, 24-03918, 24-05133, 24-05148, 24-05149, 24-05150, 24-05299, 24-05629) while the **post-encroachment time (PET)** is applied in thirteen papers (24-00120, 24-00193, 24-00927, 24-01112, 24-01190, 24-01198, 24-01471, 24-01595, 24-01894, 24-03198, 24-03884, 24-04264, 24-05833). Indicators related to deceleration such as **deceleration** rate, deceleration rate to avoid crash (DRAC) were used in five papers (24-01074, 24-02153, 24-03281, 24-04027, 24-05149). Alternatively, **speed characteristics** were used in (24-00193, 24-02153, 24-02402, 24-03198, 24-03281, 24-03504, 24-04264).

In terms of input data, user **trajectories** derived from **video** was the most common sources of input data used for analysis in twenty-five papers (24-00193, 24-00323, 24-00927, 24-00954, 24-01074, 24-01190, 24-01303, 24-01372, 24-01564, 24-01894, 24-02119, 24-03198, 24-03504, 24-03918, 24-04593, 24-05133, 24-05137, 24-05144, 24-05148, 24-05149, 24-05150, 24-05236, 24-05501, 24-06029, 24-06090). Of these, thirteen papers used **UAVs** to record **video** (24-00323, 24-01074, 24-01303, 24-02119, 24-02256, 24-03281, 24-04593, 24-05133, 24-05137, 24-05144, 24-05148, 24-05149, 24-05150). **LiDARs** were used to collect trajectory data in three papers (24-01112, 24-03918, 24-04593). The other sources of data are: **naturalistic driving studies** in four papers (24-01270, 24-01912, 24-02153, 24-05501), **software simulated trajectories** in four papers (24-00391, 24-05299, 24-05833, 24-06302), and **connected vehicles** data in three papers(24-01198, 24-03338, 24-06151). There was one paper that performed a meta-analysis of several papers that dealt with traffic conflicts in relation to COVID 19 induced traffic disruptions (24-02963).

Some authors target specific maneuvers and driving behaviors using surrogate measures of safety such as **car-following** and **lane changing** maneuvers**. Car following** scenarios which include **rear end** conflicts were analyzed in twelve papers (24-01074, 24-01303, 24-02119, 24-02298, 24-03608, 24-04027, 24-05133, 24-05148, 24-05149, 24-05150, 24-05298, 24-06302). **Lane change** maneuvers were investigated in five papers (24-00954, 24-01564, 24-03281, 24-05137, 24-05144). One paper focused on overtaking maneuver (24-02119) and another focused on driver takeover times in CAV (24-03657).

Regarding data analysis, **statistical regression models** were used in twenty-eight papers (24-00120, 24-00323, 24-00485, 24-00779, 24-00927, 24-00954, 24-01074, 24-01190, 24-01198, 24-01303, 24-01595, 24-01894, 24-01912, 24-02119, 24-02153, 24-02256, 24-02298, 24-03198, 24-03608, 24-03918, 24-04004, 24-05137, 24-05144, 24-05149, 24-05150, 24-05298, 24-05501, 24-06070) whereas **machine learning and deep learning** methods were used in fourteen papers (24-00302, 24-00693, 24-01190, 24-01372, 24-01912, 24-03408, 24-03884, 24-04264, 24-04593, 24-05236, 24-05298, 24-05520, 24-06029, 24-06302).

To conclude, it is relevant to highlight that the **crash risk** or probability of **crash** was estimated in thirty papers (24-00080, 24-00120, 24-00391, 24-00693, 24-00953, 24-00954, 24-01198, 24-01564, 24-01595, 24-01894, 24-01912, 24-02119, 24-02256, 24-02298, 24-02669, 24-03198, 24-03338, 24-03408, 24-03608, 24-03884, 24-03918, 24-04004, 24-04027, 24-05137, 24-05148, 24-05149, 24-05298, 24-05299, 24-05629, 24-06151)

The papers dealing with surrogate measures of safety ordered by their paper number are listed below. For each paper, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Dan Wu, Central South University Jaeyoung Lee, Central South University Ye Li, Central South University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00080
Paper Title	Real-Time Conflict Prediction: Trajectory Data-Driven Approach Incorporating Variable Interaction and Pre-Screening
Abstract	The study aimed to analyze crash risks in the context of increasing traffic demands. It addressed the limitations of historical and trajectory data by investigating the effect of traffic state variables and their interaction terms on real-time conflict prediction. The Smoothly Clipped Absolute Deviation (SCAD) method was applied as a variable prescreening approach. Realistic vehicle trajectory data from HighD were selected and processed, which can be aggregated to extract both traffic state and corresponding conflict data during a specific time interval (10s). As for the conflict detection, the Time-toCollision (TTC) index was utilized to identify risky conditions. For different categories of lanes (i.e., inner, middle and outer lanes), the impact of variables, including interaction terms, on conflicts was explored using the SCAD-logistic regression models. Furthermore, machine learning models were employed to compare the conflict prediction performance before and after considering interaction terms, as well as before and after variable prescreening via the SCAD method. Results indicate that the interaction terms between traffic state variables do have a substantial impact on the conflicts. Besides, considering interaction terms and variable pre-screening based on the SCAD method is significant for enhancing conflict prediction accuracy. Furthermore, it is indicated that the above proposed machine learning models outperform Random Forest (RF) in terms of predicting conflicts for different types of lanes. The findings of this study contribute to the high-precision prediction of real-time conflict in the future.

Authors	Abbas Sheykhfard, Babol Noshirvani University of Technology Farshidreza Haghighi, Babol Noshirvani University of Technology Shahrbanoo Kavianpour, Babol Noshirvani University of Technology Subasish Das, Texas State University Grigorios Fountas, Aristotle University of Thessaloniki
Sponsoring Committee	Standing Committee on Traffic Law Enforcement (ACS30)
Session Number	2237
Session Title	Automated Enforcement and Traffic Crash Investigations
Paper Number	TRBAM-24-00120
Paper Title	Analyzing Pedestrian Red-Light Violations using Surrogate Safety Measures: Risk Levels and Factors Impacting Pedestrian-Vehicle Collisions
Abstract	Pedestrian red-light violation is one of the crucial causes of pedestrian crashes at urban intersections which cause considerable injuries and casualties to this vulnerable road group of road users. The objective of this study is to evaluate the risk of pedestrian-vehicle collisions by clustering the pedestrians' red-light violations using surrogate safety measures. The present study utilized surveillance camera footage to collect data on pedestrians' red-light violations at two urban intersections in Babol City. Based on critical thresholds of post-encroachment time (PET), Time to Collision (TTC), and Gap Time (GT), three different risk levels of red-light violations were identified through the use of a K-means algorithm. Moreover, structural equation models were developed for each of the risk levels considering variables that are associated with four major components: human, environment, road, and vehicle. The findings highlighted the significant role of the human factor, particularly pedestrians themselves, in determining the risk level of violations. Mobile phone use and distractions were found to increase the likelihood of violations, while limited visibility caused by parked vehicles also contributed to higher violation rates. To address these issues, policy insights into amending pedestrian behavior and promoting traffic safety culture were proposed, with an overarching emphasis on the human factor, due to its identified greater influence on the propensity for red-light violations.

Authors	Agnimitra Sengupta, HNTB Corporation S. Ilgin Guler, Pennsylvania State University Vikash Gayah, Pennsylvania State University, University Park Shannon Warchol, Kittelson & Associates, Inc.
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-00193
Paper Title	Evaluating The Reliability of Automatically Generated Pedestrian and Bicycle Crash Surrogates
Abstract	Vulnerable road users (VRUs), such as pedestrians and bicyclists, are at a higher risk of being involved in crashes with motor vehicles, and crashes involving VRUs also are more likely to result in severe injuries or fatalities. Signalized intersections are a major safety concern for VRUs due to their complex and dynamic nature, highlighting the need to understand how these road users interact with motor vehicles and deploy evidence-based countermeasures to improve safety performance. Crashes involving VRUs are relatively infrequent, making it difficult to understand the underlying contributing factors. An alternative is to identify and use conflicts between VRUs and motorized vehicles as a surrogate for safety performance. Automatically detecting conflicts using a video-based systems is a crucial step in developing smart infrastructure to enhance VRU safety. PennDOT conducted a study using video-based event monitoring system to assess VRU and motor vehicle interactions at fifteen signalized intersections to improve VRU safety. This research builds on that study to assess the reliability of automatically generated surrogates in predicting confirmed conflicts using advanced data-driven models. The surrogate data used for analysis include automatically collectable variables such as speeds, movements, post-encroachment time, in addition to manually collected variables like signal states, lighting, and weather conditions. Findings highlight the varying importance and impact of specific surrogates in predicting true conflicts, some being more informative than others. The findings can assist transportation agencies to collect the right types of data to help prioritize infrastructure investments, such as bike lanes and crosswalks, and evaluate their effectiveness.

Authors	Chenwei Wang, Southeast University Jie He, Southeast University Xintong Yan, Southeast University Zhang Changjian, Southeast University Yuntao Ye, Southeast University Pengcheng Qin, Southeastern University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-00302
Paper Title	Real-time Conflict Prediction on Freeways under Different Vehicle Interaction Scenarios using Short-term Vehicle Kinematic Characteristics with temporal variability
Abstract	Real-time conflict prediction is an emerging research perspective of proactive road safety measures, which can prevent potential traffic crashes. Previous research used macroscopic traffic flow data in a long time range while underestimating the short-term vehicle kinematics before the conflict event. This study introduced short-term kinematic-based and status-related characteristics under different vehicle interaction scenarios to explore whether there would be a potential conflict. Sixteen short-term vehicle characteristics were derived from vehicle trajectories of Shanxi Wuyu freeway, China. Three vehicle interaction scenarios (conflicts, normal intersections, and undisturbed passings) and two conflict types (rear-end and sideswipe) were included in conflict prediction. Twelve conflict prediction models based on Random Forest, Support Vector Machine, and Artificial Neural Network were compared and the under-sampling algorithm was employed to solve the sample imbalance. The results indicated that conflict prediction between conflicts and normal interactions based on Support Vector Machine presented the best prediction performance with a higher score of evaluation metrics. Moreover, the most vital kinematic-based characteristic was the mean of longitudinal velocity, and the hour of conflict occurrence was an indispensable status-related characteristic. The discussion of the time window reflected that the shorter time range of vehicle trajectories before conflict events improved the performance of the real-time conflict prediction model. Eventually, the proposed real-time conflict prediction models and contributing factors provide a novel way to estimate conflicts easier than extracting them from complex kinematic relationships among vehicles, which contributes to designing further proactive safety systems for conflict warnings implemented on vehicle dashboards.

Authors	Cai Jing, Kunming University of Science and Technology Rui Zhao, Kunming University of Science and Technology Xiaojing Wang, Kunming University of Science and Technology Fengxiang Guo, Kunming University of Science and Technology
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ACS60)
Session Number	2037
Session Title	Advances in Truck and Bus Safety Research
Paper Number	TRBAM-24-00323
Paper Title	Analysis of Influencing Factors of Highway Traffic Conflicts Considering the Proportion of Large Vehicles Interaction Effect
Abstract	Studying traffic conflict influencing factors is crucial in road traffic safety management policy development and overall safety improvement. This paper aims to investigate the relationship between traffic conflict frequency and short-time traffic characteristics, focusing on the proportion of large vehicles interaction effects on the number of traffic conflicts. To this end, the study is based on the HighD vehicle trajectory dataset, which collects traffic feature indicators at 30-second intervals and detects the number of conflicts using a conflict threshold of TTC of less than 4 seconds. The influence of short-time traffic characteristics on the traffic conflict frequency was analyzed by establishing a zero-inflated negative binomial regression model considering the proportion of large vehicles interaction terms. The results showed that there were significant interaction effects between traffic volume and average speed difference between lanes and large vehicle proportional, in which the interaction term coefficient between large vehicle proportional and average speed difference between lanes was 0.220 ([[EQUATION]]), and the interaction term coefficient between large vehicle proportional and traffic volume was 0.134 (). Further analysis revealed that as the proportion of large vehicles increased, the average speed difference between lanes negatively affected the number of traffic conflicts. In contrast, the proportion of large vehicles increased, and the traffic volume positively affected the number of traffic conflicts. The study's results help further to extend the real-time traffic conflict prediction model for highways and provide an essential reference for traffic management departments to develop real-time early warning systems for highway traffic accidents.

Authors	Pei Li, University of Wisconsin, Madison Huizhong Guo, University of Michigan, Transportation Research Institute Shan Bao, University of Michigan Arpan Kusari, University of Michigan, Transportation Research Institute
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-00391
Paper Title	A Probabilistic Framework for Estimating the Risk of Pedestrian-vehicle Conflicts at Intersections
Abstract	Pedestrian safety has become a critical issue due to the increase in pedestrian crashes every year, while proactive traffic safety management based on surrogate safety measures (SSMs) has been considered one of the key approaches to improving pedestrian safety. However, existing SSMs are developed based on the assumption that road users will maintain constant speed and direction. Risk estimations based on this assumption are less stable and more likely to be exaggerated. Considering the limitations of existing SSMs, this study has proposed a probabilistic framework for estimating the risk of pedestrian-vehicle conflicts at intersections. The proposed framework works by predicting the trajectories of vehicles and pedestrians using Gaussian process regression models and incorporating these results with the probability of vehicles making different maneuvers. The proposed framework has been evaluated using both simulated and real-world data collected at an intersection. The simulation results validated an increased estimated risk given time-critical pedestrian-vehicle conflicts, as well as a higher probability of the vehicle maneuver that led to such conflicts. This observation remained even when multiple conflicts arose from different directions. Moreover, experimental results using real-world data suggested that the proposed framework outperformed traditional time-to-collision (TTC) in terms of conflict prediction, quantification, and localization. For example, the proposed framework had a sensitivity of 0.92 in terms of conflict prediction, while TTC had a sensitivity of 0.62. Furthermore, the proposed framework required much less computation time compared to deep learning methods, which made it an optimal choice for proactive pedestrian safety solutions at intersections.

Authors	Zhankun Chen, Lund University Carmelo DAgostino, Lund University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-00485
Paper Title	Copula method application for the evaluation of road users' interactions severity
Abstract	A difficulty in assessing the safety of road traffic is the scarcity of historical accident data. This is a common problem in contexts where exposure is low, which includes mixed traffic conditions where autonomous vehicles are present, or contexts where a certain level of safety has been reached already, and severe accidents are rare. Recent studies have demonstrated several ways of using Extreme Value Theory (EVT) to extrapolate accidents from traffic conflicts. EVT also has the potential of combining several indicators to enable the extrapolation of severe accidents from severe conflicts. However, a drawback of EVT is that it does not correctly reflect the probability of injury during an accident, as an injury occurs across accidents of all severity while EVT can only capture the most severe events. In this context, this research work proposes a new method based on copula and EVT, which enables a more specific evaluation of interactions at different severity levels. In comparison with pure EVT, this new approach extends the boundary to interactions of all severities. This EVT-copula approach has been validated based on conflicts rather than accident counts, assuming an implicit relationship between them. The method and validation were tested on a medium-small size data set in which there exists no record of historical accidents. We found that the new scheme produced a reasonable estimation of conflicts' frequency using simple assumption-free surrogate measure of safety indicators.

Authors	Gabriel Lanzaro, University of British Columbia Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	3160
Session Title	Automation, Technology, and Pedestrian Interactions
Paper Number	TRBAM-24-00693
Paper Title	Assessing vehicle-pedestrian interaction behavior in different environments using Markov game modeling
Abstract	The rapid progress in Autonomous Vehicles (AVs) requires effective collision avoidance systems capable of identifying crash-risk situations and reacting accordingly. To achieve this, Reinforcement Learning can be used to model AV behavior, where agents make optimal decisions to avoid collisions based on reward functions. However, obtaining these reward functions poses a challenge due to the complexity of human behavior. Inverse Reinforcement Learning offers a solution by recovering reward functions from real-world road user trajectories in conflict interactions. This approach provides valuable insights into road user behavior from the reward functions and optimal sequences of decisions. In addition, there are considerable variations in road user behavior across different traffic environments, which leads to changes in the reward function structure. This study employs Multi-agent Adversarial Inverse Reinforcement Learning (MA-AIRL) to simulate vehicle-pedestrian interactions in four cities: Boston, Las Vegas, Pittsburgh, and Singapore. The findings reveal distinctive behavior patterns depending on the traffic environment, with road users exhibiting diverse preferences during interactions. While MA-AIRL successfully replicates evasive actions by drivers and pedestrians, its prediction accuracy varies across cities due to environmental differences. Finally, transferring agent behavior between locations results in increased risk levels.

Authors	Kun Xie, Old Dominion University Abdalziz Alruwaili, Old Dominion University
Sponsoring Committee	Standing Committee on Human Factors of Vehicles (ACH30)
Session Number	2094
Session Title	Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems
Paper Number	TRBAM-24-00779
Paper Title	Exploring the Impact of Connected Vehicles on Driving Behaviors and Safety Outcomes in Diverse Weather Conditions
Abstract	Equipped with advanced sensors and capable of relaying safety messages to drivers, connected vehicles (CVs) hold the potential to reduce crashes. The goal of this study is to assess the impacts of CV technologies on driving behaviors and safety outcomes in highway crash scenarios under diverse weather conditions, including clear and foggy weather. A driving simulator experiment was conducted and the multigroup structural equation modeling (SEM) was employed to explore the complex interrelationships between the propensity of traffic conflicts, utilization of CV alerts, weather, psychological factors, driving behaviors, and other relevant variables for two different crash locations, namely a straight section and a horizontal curve. Two latent psychological factors including aggressiveness and unawareness were constructed from driving behavior as vehicles passed by crash scenes such as brake, throttle, steering angle, lane offset, and yaw. The SEM can measure latent psychological factors and model interrelationships concurrently through a single statistical estimation procedure. Results of the multigroup SEM showed that CV alerts could significantly reduce the unawareness on a horizontal curve and thus lower the propensity of traffic conflicts. Additionally, the overall effect of foggy weather on conflicts was found to be positive on a horizontal curve, despite the potential benefit of improving situational awareness. In contrast, the single group SEM failed to reveal any significant interrelationships in its structural model by pooling data from both crash locations.

Authors	Md Jamil Ahsan, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Nafis Anwari, University of Central Florida College of Engineering and Computer Science
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-00927
Paper Title	A Detailed Study on the Determinants of Pedestrians' Surrogate Safety Measures at Signalized Mid-block Crossings
Abstract	This study aims to find out the factors related to pedestrian and roadway characteristics that affect vehicle-pedestrian Post Encroachment Time (PET) and Relative Time to Collision (RTTC) under traffic control systems at mid-block pedestrian crossings. 112 hours of video data were collected using multiple cameras from five Pedestrian Hybrid Beacon (PHB) and two Rectangular Rapid Flashing Beacon (RRFB) sites. To extract vehicle and pedestrian trajectories and construct a robust dataset, where each observation corresponds to a specific timeframe, with a recorded speeds of both vehicles and pedestrians, a self-developed cutting-edge Computer Vision (CV) technology was deployed. A bivariate regression approach is employed to capture more complex relationships between variables. The findings reveal that both pedestrian and roadway characteristics significantly influence PET and RTTC. Pedestrian characteristics, such as gender, clothing color, distraction, waiting time, and crossing speed, significantly affect both PET and RTTC. The presence of children, eye contact with drivers and pedestrian signal compliance rate has a significant influence on PET, but not on RTTC. Among roadway characteristics, the presence of a median, hourly traffic flow, and land use diversity of the crossing area were found to be significant determinants of both PET and RTTC. The results indicate that there is no difference in the influence of RRFB and PHB on PET values, but there is a significant difference in the influence of RRFB and PHB on RTTC values. PHB increases RTTC relative to RRFB. Finally, this study enriches existing literature by incorporating unique factors that impact PET and RTTC.

Authors	Xiaohan Xia, Southeast University Jian Lu, Southeast University Jun Zhang, Nanjing Hurys Intelligence Technology Co., LTD Junde Chen, Nanjing Hurys Intelligence Technology Co., LTD Chao Gu, Nanjing Hurys Intelligence Technology Co., LTD
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-00953
Paper Title	Investigating the Features of Risky Driving Behaviors on Expressway Diverge Area Based on Improved Collision-Based Index and Modeling Analysis
Abstract	Driving behaviors are important causes of expressway crash. The purpose of this study is to propse a method to recognize driving behaviors that will be risky, investigating the impact of their velocity and acceleration features. This study put forward an indicator improved from Time to Collision (TTC) by add acceleration into consideration, which is called TTC*, to judge whether the vehicle behavior is risky. The relationships of velocity and acceleration features of different types of driving behavior collected on an expressway diverge area and their judgement were fit by binary logistic regression models and random forests (RF) models, and their feature importance plots and partial dependency plots were ploted. The AUC of 4 RF models for 4 types of driving behaviors, left lane change, right lane change, acceleration and deceleration, are 0.932, 0.845, 0.846 and 0.860 saperately, and their F1 Scores are 0.830, 0.671, 0.662 and 0.652. Study shows that velocity and absolute value of acceleration affect the risk of the driving behaviors. Different driving behaviors under different acceleration condition have their own range of safety speed range, which with the growth of maximum acceleration or deceleration will get narrower, especially that of lane change behavior, and will be nearly non-exist when the acceleration is over 5m/s2. This study provided a method to measure the risk of driving behaviours and establish a model for the estimation and recognition of risky driving behaviors. The results and interpratation can be used to prevent risky drivng behaviors by managing the vehicle speed.

Authors	Xiao-chi MA, Southeast University Jian Lu, Southeast University Jun Zhang, Nanjing Hurys Intelligence Technology Co., LTD Junde Chen, Nanjing Hurys Intelligence Technology Co., LTD Chao Gu, Nanjing Hurys Intelligence Technology Co., LTD
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-00954
Paper Title	Traffic Conflict Risk Assessment in Expressway Diverging Area Based on High-precision Radar-camera Fusion Data
Abstract	To ensure the traffic safety of the expressway diverging area and overcome the shortcomings of current data collection methods, radar-camera fusion device is applied to collect trajectory data to establish a real-time traffic conflict assessment model. Firstly, over 35 million high-precision trajectory data were collected in an expressway diverging area for 55 hours. Then, a new conflict probability metric based on time-to-collision (TTC) and volume is proposed. Various generalized linear and machine learning methods are used to obtain the assessment model. Variable features and their interactions are explained by ANOVA and partial dependency plot(PDP) respectively. In view of the counterintuitive phenomenon in the PDP interpretation, SHAP is used to specifically analyze the driving scenario represented by the outlier data. The results indicate that the regression performance of Gaussian process regression (GPR) model is better than other models on multiple data sets. In the dataset with TTC threshold of 3s, the AUC of GPR reaches 0.886. Furthermore, the model interpretation results using conflict probability metric all show the high risk of lane change behavior, while the traditional binary classification metric ignores that. The PDP and SHAP in GPR suggest that the conflict probability has a peak in three scenarios: congestion state, speed fluctuation and frequent lane change in near-saturation state. In conclusion, radar-camera fusion device collects fine trajectory data, and establishes a Gaussian process regression model based on conflict probability metric, which has both high accuracy and interpretability, and provides a theoretical basis for driving risk scene recognition and assessment.

Authors Qianqian Jin, University of Central Florida
Mohamed Abdel-Aty, University of Central Florida
Zubayer Islam, University of Central Florida
Jorge Ugan, University of Central Florida
Ou Zheng, University of Central Florida

Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)
Session Number 2096
Session Title Safety Performance and Analysis
Paper Number TRBAM-24-01074

Paper Title Identifying the Threshold Discrepancy of Rear-End Conflicts under Clear and Rainy Weather Conditions Using Trajectory Data

Abstract The appropriate threshold selection is pivotal in near-crashes detections. Nevertheless, most cutting-edge warning systems utilize thresholds that are directly derived from general traffic scenarios. However, there is no supportive evidence that the threshold acquired from general scenarios can be applied to specific scenarios. The main purpose of this study is to investigate whether the thresholds of three surrogate measures of safety (SMoS) differ between the general clear scenario and the special rainy scenario, i.e., Modified Time to Collision (MTTC), Deceleration Rate to Avoid a Crash (DRAC), and Single-step Probabilistic Driving Risk Field (SPDRF). A total number of rear-end events (724 in clear conditions and 324 in light rain conditions) on an urban expressway were obtained from vehicle trajectories in the CitySim dataset. Peak Over Threshold (POT) and Bimodal Histogram Threshold Methods were used to propose optimal thresholds. The statistical analysis indicated that only MTTC among three SMoS had a statistical difference in both weather scenarios, hence, a threshold was recommended under each of the two weather conditions. Furthermore, the MTTC threshold was three times larger in rainy conditions than in clear conditions. Contrarily, the threshold was statistically insignificant for the SPDRF and DRAC under two conditions, so one integration threshold per SMoS was recommended, even in two different conditions. As far as the authors knowledge, the risk field indicator SPDRF does not have a designated threshold, so this study also proposed a recommended value. Additionally, this study proposed a more suitable threshold for DRAC compared to the commonly used ones.

Authors Lai Zheng, Harbin Institute of Technology
Shuyu Fan, Harbin Institute of Technology
Shuanghu Ma, Harbin Institute of Technology
Hansheng Jiao, Harbin Institute of Technology

Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)
Session Number 2096
Session Title Safety Performance and Analysis
Paper Number TRBAM-24-01112

Paper Title Multi-type Traffic Conflict Identification at Signalized Intersection Based on LiDAR Point Cloud

Abstract Traffic conflicts have been widely used for proactive road safety evaluation, and this study develops methods to automatically identify different types of traffic conflicts based on LiDAR point cloud data. With the 10h data collected from a signalized intersectrion in Harbin, China, trajectories of motorized vehicles, bicycles, and pedestrians were extracted, and methods to handle the issues of trajectory discontunity, type identification error, and same object with different trajectories were developed. Traffic conflicts between right-turn vehicles and through vehicles, between right-turn vehicles and left-turn vehicles, and between right-turn vehicles and pedestrians were considered, and detailed procedures for calculating the conflict indicators (i.e., TTC and PET) of different types were proposed. The identified traffic conflicts were also compared to the ones that were identified manually. A total of 5352 and 1366 traffic conflicts were identified by PET≤4s and TTC≤4s, respectively. The majority of them are during the through phase, and among them traffic conflicts between right-turn vehicles and through vehicles are the most, followed by conflicts between right-trun vehicles and vulnerable road users. The comparison results show that the automatic method performs well with an average accuracy over 90%.

Authors	Fizza Hussain, Queensland University of Technology Yasir Ali, Loughborough University Faculty of Engineering: Loughborough University Yuefeng Li, Queensland University of Technology Md. Mazharul Haque, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-01190
Paper Title	A hybrid of machine learning and econometric model to estimate pedestrian crash risks by applying Artificial Intelligence-based video analytics
Abstract	Pedestrians represent a group of vulnerable road users who are at a higher risk of sustaining severe injuries than other road users due to their direct exposure to vehicle-related crashes. As such, proactively assessing pedestrian safety becomes paramount to avoid these crashes. Recently, extreme value theory models have been employed for proactive safety assessment using traffic conflicts, whereby the underpinning of these models are two sampling approaches, namely block maxima and peak over threshold. Earlier studies reported poor accuracy and large uncertainty of these models, which has been largely attributed to a limited sample size. A fundamental reason for such poor performance is the improper selection of conflict extremes due to the lack of an efficient sampling mechanism. This study proposes a hybrid of machine learning and extreme value theory models to estimate pedestrian crash risks from traffic conflicts at signalised intersections. In particular, unsupervised machine learning-based anomaly detection techniques such as Isolation forest and minimum covariant determinant techniques were used to identify extreme pedestrian-vehicle conflicts characterised by post encroachment time measure. Video data for four weekdays (6 am to 6 pm) from three fourlegged intersections in Brisbane, Australia was collected and processed using artificial intelligence-based video analytics. Results indicate that mean crash estimates of hybrid models were much closer to observed crashes with narrower confidence intervals as compared with traditional extreme value models.

Authors	Sunny Singh, QUT: Queensland University of Technology Yasir Ali, Loughborough University Faculty of Engineering: Loughborough University Md. Mazharul Haque, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-01198
Paper Title	Estimating Pedestrian Crash Risks from Autonomous Vehicle Sensor Data by applying traffic conflict techniques with extreme value theory models
Abstract	Pedestrian crash risk has traditionally been challenging to model on a corridor or network level accurately. Limitations of current data collection techniques make it difficult to capture detailed pedestrian interaction at the network or corridor level. With autonomous vehicles trialled on public roads generating massive (and unprecedented) datasets capturing all the surrounding road users, utilising such rich information for corridor-wide safety analysis is somewhat limited where it appears most relevant. This study proposes an extreme value theory modelling framework to estimate corridor-wide pedestrian crash risk using autonomous vehicle sensor/probe data. Two models were developed in the Bayesian framework, including the block maxima sampling-based model corresponding to the Generalised Extreme Value distribution and the peak-over threshold sampling-based model corresponding to the Generalised Pareto distribution. The proposed framework was applied to a subset of the Argoverse dataset, focussing on an arterial corridor in Miami, US, to extract pedestrian and vehicle trajectories. From these trajectories, vehicle-pedestrian conflicts were identified and measured using post-encroachment time. The non-stationarity of extremes was captured by vehicle volume, pedestrian volume, average vehicle speed, and average pedestrian speed. Both block maxima and peak-over threshold sampling-based models reasonably estimated historical pedestrian crash frequencies. Notably, the block maxima sampling-based model was more accurate than the peak-over threshold sampling-based model based on mean crash estimates and confidence intervals. This study demonstrates the potential of using autonomous vehicle sensor data for corridor-level safety.

Authors	Huaguo Zhou, Auburn University Humayra Kabir Priyanka, HNTB Corporation
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2004
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	TRBAM-24-01270
Paper Title	Effectiveness of Median Treatments in Enhancing Unsignalized Intersection Safety: A Comprehensive Evaluation of Driver Behavior, Conflicts, and Crash Reduction
Abstract	This study examines the impact of low-cost median opening treatments at unsignalized intersections on rural divided highways. Naturalistic Driving Study (NDS) and field video data are analyzed to understand driver behavior. Traffic conflict analysis and crash data analysis are conducted to evaluate safety effectiveness. A Crash Modification Factor (CMF) was developed to quantify treatment effectiveness, addressing the absence of this type of CMF in the clearing house. NDS data includes 428 trips by 65 participants, highlighting major road traffic volume and speed's influence on driver behavior. Conflict analysis shows that treated intersections have 8% to 40% fewer conflict rates than non-treated intersections. Using the cross-sectional Empirical Bayes (EB) method, CMFs are developed with a combined CMF of 0.70 (30% reduction in expected crash frequency). These findings aid in project-level decision-making, providing insights to improve safety at unsignalized intersections through low-cost median opening treatments.

Authors	Shao-Fu Li, National Yang Ming Chiao Tung University Shou-Ren Hu, National Yang Ming Chiao Tung University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-01303
Paper Title	Thresholds and Contributing Factors for Rear-End Traffic Conflicts at Signalized Intersections under Mixed Traffic Flow Conditions
Abstract	In the past decade, many studies have attempted to collect traffic conflict data to evaluate the safety levels of road designs and traffic operations as a faster alternative to the time-consuming collection of crash data for road safety improvement. Nevertheless, establishing suitable measures and corresponding thresholds to define different patterns of traffic conflicts is a challenging task. In the present study, we developed a peak-over-threshold method involving graphical diagnostics to identify a preliminary threshold range for rear-end traffic conflicts. We then used an automated threshold selection method (ATSM) to confirm the specific threshold value within this range. This capability of the ATSM ensures that the threshold values associated with different traffic conflicts can be accurately determined. The factors that might contribute to different types of traffic conflicts remain to be investigated. To address the aforementioned problems, we used an unmanned aerial vehicle to collect vehicle trajectory data at 19 signalized intersections under mixed traffic flow conditions. We then used these data to identify appropriate rear-end traffic conflict thresholds for different pairs of vehicles. Notably, when the rear vehicle in a vehicle pair was a scooter, the conflict thresholds were significantly smaller than those when the rear vehicle was a car. Moreover, we conducted negative binomial regression analysis to estimate the frequency of rear-end traffic conflicts. According to our findings, compared with unprotected left-turn lanes, protected left-turn phases are more effective in reducing the number of rear-end traffic conflicts.

Authors	Qingwu Liu, Ecole Polytechnique de Montreal Nicolas Saunier, Ecole Polytechnique de Montreal Guillaume-Alexandre Bilodeau, Ecole Polytechnique de Montreal
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-01372
Paper Title	How Good Are Deep Learning Methods for Automated Road Safety Analysis Using Video Data? An Experimental Study
Abstract	Image-based multi-object detection (MOD) and multi-object tracking (MOT) are advancing at a fast pace. A variety of 2D and 3D MOD and MOT methods have been developed for monocular and stereo cameras. Road safety analysis can benefit from those advancements. As crashes are rare events, surrogate measures of safety (SMoS) have been developed for safety analyses. (Semi-)Automated safety analysis methods extract road user trajectories to compute safety indicators, for example, Time-to-Collision (TTC) and Post-encroachment Time (PET). Inspired by the success of deep learning in MOD and MOT, we investigate three MOT methods, including one based on a stereo-camera, using the annotated KITTI traffic video dataset. Two post-processing steps, IDsplit and SS, are developed to improve the tracking results and investigate the factors influencing the TTC. The experimental results show that, despite some advantages in terms of the numbers of interactions or similarity to the TTC distributions, all the tested methods systematically over-estimate the number of interactions and under-estimate the TTC: they report more interactions and more severe interactions, making the road user interactions appear less safe than they are. Further efforts will be directed towards testing more methods and more data, in particular from roadside sensors, to verify the results and improve the performance.

Authors	Lei Zhao, Southeast University Sixuan Xu, Southeast University wei zhou, Southeast University Yuzhi Chen, Southeast University Chen Wang, Southeast University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01471
Paper Title	Multi-agent trajectory prediction at unsignalized intersections: an improved generative adversarial network accounting for collision avoidance behaviors
Abstract	Accurate trajectory prediction for multiple agents (i.e., vehicles, bicyclists, and pedestrians) is the premise of launching proactive interventions, which can serve as an effective way to improve traffic safety at unsignalized intersections. The distinctive characteristic of unsignalized intersections lies in their disorderly traffic organization, prompting traffic agents to be extra vigilant towards other agents to prevent collisions. As such, the primary focus of multi-agent trajectory prediction lies in acquiring a deep understanding of their interactive behavior patterns when encountering potential collisions. To achieve this, this study proposes an improved generative adversarial network (GAN) that can properly model collision avoidance behaviors of multiple agents when predicting their trajectories. Specifically, attention pooling modules are employed to capture pedestrian-pedestrian, vehicle-vehicle and pedestrian-vehicle interactions. A graph convolution network (GCN) based collision extraction module is applied to identify potential collisions and model the collision avoidance behaviors of traffic agents. Experimental results on inD dataset demonstrate that the proposed framework attained a more accurate and reliable performance compared with some baselines. In different interactive scenarios, such as when vehicles yield or don't yield, the results illustrated via the Distance-velocity (DV) diagram display a significant level of robustness. Furthermore, the conflict points and Post-Encroachment Time, as computed from these predicted trajectories, also align well with the ground truth. This indicates that the proposed framework effectively captures the pattern of collision avoidance behaviors of multiple agents, which has potential to serve as an effective way to enhance traffic safety at unsignalized intersections.

Authors	Jinbao Zhang, Central South University Jaeyoung Lee, Central South University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-01564
Paper Title	Investigation of Lane Change Risk at Different Areas of Weaving Segment
Abstract	Improper lane changes significantly contribute to vehicle crash occurrence, with weaving segments on expressways being particularly prone to crashes caused by both mandatory and discretionary lane changes. Mandatory lane changes, in particular, present a challenge due to limited space and time for drivers to execute such maneuvers. Therefore, this study aims to identify safer lane change locations within weaving segments and explore the factors influencing lane change risks. To achieve this, vehicle trajectories for both mandatory and discretionary lane changes are extracted from videos taken at Changsha Airport Expressway, China. Risk variations associated with different lane change locations are then compared using a lane change risk assessment index, considering conflict frequency and severity. Furthermore, random forests and correlation analysis are employed to identify key features, followed by the development of random parameter ordered probit models. The results indicate that conflicts with leading vehicles in the target lane are more likely to occur before entering the weaving segment, while the middle section is comparatively safer for lane changes. In addition, considering both frequency and severity of conflicts, discretionary lane changes pose a higher risk than mandatory ones, and the immediate beginning section exhibits the lowest overall risk. The findings of this study have practical implications for lane change decision-making. They are expected to be useful to enhance traffic safety at weaving sections of expressways, particularly for connected and autonomous vehicles.

Authors	Chuanyun Fu, Harbin Institute of Technology Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-01595
Paper Title	Does r Largest Order Statistics Approach Improve Conflict-based Safety Analysis? A Bayesian Hierarchical Extreme Value Model
Abstract	Existing conflict-based extreme value theory (EVT) safety analysis block maxima models only consider the block maximums as extremes. However, a common issue when developing these models is the scarcity of extremes which typically causes high variances of model estimates. To address this issue, the r largest order statistics (LOS) approach is usually recommended, but its performance compared to block maxima models has not been widely evaluated. This study investigates whether the r LOS approach improves conflict-based safety analysis using a Bayesian hierarchical extreme value model. A Bayesian hierarchical r LOS model is developed and applied to conduct conflict-based crash prediction at signalized intersections in Surrey, British Columbia. The modified time to collision (MTTC) and post encroachment time (PET) were utilized to describe traffic conflicts. For both MTTC and PET, three r values (i.e., r=1,2,3) were employed to develop the Bayesian hierarchical r LOS model, respectively. The models with different r values were compared in terms of deviance information criterion, and their feasibility was further examined by quantitative and graphical diagnostic methods. Meanwhile, all the models with different r values were employed to estimate crashes, which were then compared to the actual crashes. The outcomes indicate that generally, the r LOS approach may enhance the model fitness, but it does not always improve the performance of conflict-based crash prediction. This is probably because of that LOS-based crash prediction from traffic conflicts mainly depends on the distribution of conflict extremes instead of the amount of conflict extremes.

Authors	Deorishabh Sahu, Indian Institute of Technology, Roorkee Kaliprasana Muduli, Indian Institute of Technology, Roorkee Indrajit Ghosh, Indian Institute of Technology, Roorkee
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-01894
Paper Title	A Copula-Based Approach for Modeling Pedestrian Crash Frequency
Abstract	The occurrence of Pedestrian pedestrian road crashes poses a substantial risk to public safety and traffic management due to the potential for severe injuries or fatalities. Pedestrian road crashes frequently occur at unsignalized intersections in urban areas worldwide. The utilization of crash data-based studies as a reactive approach for evaluating road safety is not devoid of limitations, as it is susceptible to random crash incidence and the irregular timing of crash reporting. This study aims to construct a predictive framework that estimates the pedestrian crash frequency at unsignalized intersections through an analysis of the conflicts that emerge from pedestrian-vehicle interactions. Video-based traffic data was collected from statistically justified sites from which the most suitable conflict indicators, (namely, Post-Encroachment Time (PET) and Time to Collision (TTC),) were extracted. The PET and TTC values were subsequently employed in the development of univariate and bivariate Extreme Value Theory (EVT) models, utilizing Copula-based techniques. The univariate models produced inadequate outcomes with regard to pedestrian crash frequency prediction. The study further revealed that the bivariate Copula models demonstrated remarkable outcomes in terms of predictive accuracy, as evidenced by the low Mean Absolute Percentage Error (MAPE) values of 2.164% and 0.60% for both study sites.

Authors	Léah Camarcat, Imperial College London, South Kensington Nicolette Formosa, National Highways UK Mohammed Quddus, Imperial College London
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2213
Session Title	Safety Performance of Connected Automated Vehicles
Paper Number	TRBAM-24-01912
Paper Title	Developing an integrated safety surrogate measure for intelligent vehicles
Abstract	A plethora of safety surrogate measures (SSMs) have emerged as an alternative to historical crash data for traffic safety studies. Despite their efficiency and wide-spread adoption, several limitations endure. Each conflict indicator provides a partial representation of the critical traffic events making the selection of a suitable SSM for a specific application a conundrum due to the vast array available. This paper addresses these limitations by introducing a comprehensive approach to conflict detection through the integration of a new combined metric. The metric is derived from a weighted sum of multiple SSMs including time-based, distance-based, and deceleration-based indicators, which ensures the capture of diverse aspects of potential conflicts. To evaluate its efficacy, a dataset collected by an instrumented vehicle driving on the motorway was used to calculate a variety of indicators and identify conflicts. To address the inherent imbalance in the data, this study compares two balancing techniques: random undersampling and Synthetic Minority Over-sampling Technique (SMOTE). Several optimisation techniques including logistic regression (LR), support vector machine (SVM) and genetic algorithm (GA) were employed and compared to determine the optimal weights that maximises the new index's binary classification capabilities. The GA with SMOTE demonstrated optimal performance with a sensitivity of 93.5% at only a false alarm rate of 3.9%. Although the new index is specific to the motorway, the underlying methodology is transferable to other road environments. The findings of this study hold significant potential for enhancing road safety and providing valuable insights for the development of future intelligent transport systems.

Authors	Wenwen Qin, Kunming University of Science and Technology Huan Li, Kunming University of Science & Technology Xiaofeng Ji, Kunming University of Science and Technology Jinjing Gu, Yunnan University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02119
Paper Title	Dynamic Driving Risk Assessment for Mountainous Two-lane Roads Using Driving Risk Field Model
Abstract	Due to the complex alignments and low-speed heavy trucks, the most frequent and dangerous interaction is in overtaking maneuver along mountainous two-lane roads, where a single vehicle overtakes at least two other ones, creating serious conflicts with opposite-direction vehicles. To manage and reduce a high potential of crash risk on mountainous roads, its quantitative assessment is necessary. However, few studies in the literature deal with this topic and there are no studies quantifying the entire driving risk during car-following and overtaking processes. This paper therefore introduces a novel driving risk assessment model namely driving risk field (DRF) using video-based trajectory data from unmanned aerial vehicles (UAVs), which takes vehicleenvironment and vehicle-vehicle interactions into consideration over different time instants. At each time instant, the driving risk of the vehicle is estimated as the sum of weighted risks over risk fields of obstacle, lane line and road boundary derived from DRF, which can capture the risk patterns corresponding to all collision types, such as rear-end, head-on, and single-vehicle collisions on mountainous two-lane roads. The proposed model is evaluated on 14h traffic videos recorded by UAVs from a typical mountain road in Yunnan, China. The results indicate that comparing to conventional surrogate safety measures, the performance of DRF model in carfollowing and overtaking scenarios can comprehensively identify horizontal and vertical directions of potential risks around the vehicle. Furthermore, the proposed model outperforms current stateof-the-art risk field model in terms of reducing the dependence between relevant parameters and computational complexity.

Authors	Kaiser Mahmood, Beta Group, Inc. Sheikh Ahmed, Steer Group Jiajun Pang, University at Buffalo, SUNY Md Tawfiq Sarwar, East West University Irina Benedyk, University at Buffalo, SUNY Panagiotis Anastasopoulos, University at Buffalo, SUNY
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-02153
Paper Title	In-Depth Assessment of High Visibility Crosswalks: Accounting for Regional and Configuration Characteristics Using a Correlated Grouped Random Parameters Approach with Means Heterogeneity
Abstract	This paper evaluates the effectiveness of High Visibility Crosswalk (HVC) in improving pedestrian safety by using the Second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS) data. A total of 15,379 traversals by 999 drivers across six SHRP2 NDS sites (Florida, Indiana, North Carolina, New York, Pennsylvania, and Washington) for all available HVC configurations (continental, ladder, zebra, and bar pair types installed in un-signalized intersection or mid-block) were analyzed. Four crash surrogate measures, namely, speed, acceleration, throttle pedal actuation (TPA), and brake pedal state, were analyzed through novel linear regression models, binary logit models, and multinomial logit model in the correlated grouped random parameter with means heterogeneity framework. The findings of the study show the overall effectiveness of different HVC configurations (types and installation locations). Based on the study, recommendations are provided on the most effective HVC configurations. Analysis of distracted driving behavior provided evidence of the effectiveness of HVCs even in incidents of distracted driving. This study further validates the use of SHRP2 NDS data not only in pedestrian safety but also in other aspects of transportation safety. Findings from this study can be utilized to design future research in transportation safety using the naturalistic driving study.

Authors	Zhonghua Wei, Beijing University of Technology Shi hao Wang, Beijing University of Technology Yunxuan Li, Beijing University of Technology Houqiang Ma, Beijing University of Technology Mingqian Wang, Beihang University Jingxuan Peng, Beijing University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-02256
Paper Title	A Comprehensive Safety Risk Sensing Method for Intersections Utilizing Vehicle Outline Trajectory Data
Abstract	Due to the absence of well-defined lane markings within the intersection and divergent vehicle trajectories from various approaches, the likelihood of accidents transpiring is considerably elevated. This paper employs aerial footage obtained from unmanned aerial vehicles (UAV) to gather trajectory data encompassing vehicle outline dimensions and established a framework for identifying risk trajectories. Additionally, an intricate analysis is executed on the proportion of risk trajectories and the categorization of risk levels for northbound straight-moving vehicles within a designated signalized intersection. This analysis portrays that the probability and severity of potential traffic conflicts and spatial distribution information of the risk trajectories is explored using density heatmaps. The results indicate that within the three northbound through lanes, 37.41%, 29.49%, and 36.19% of vehicles were classified as risky, with an overall proportion of risky trajectories being 26.47%. Furthermore, during the initial half of the approach to the intersection, there is a dearth of generated risk trajectories for straight-moving vehicles. Nevertheless, as the vehicle speed escalates, a greater density of risk trajectories emerges in the latter half of the intersection, resulting in a heightened probability and severity of traffic conflicts. For the straight-moving lanes nearer to the westbound approach, risk trajectories tend to concentrate near the intersection exit due to trajectory overlap between northbound straight-moving vehicles and westbound right-turning vehicles. The methodology for identifying risk trajectories in this paper can assist pertinent authorities in optimizing intersection infrastructure and offering supplementary guidance for future trajectory planning in the context of autonomous driving environments.

Authors	Harish Saini, IIT Jammu: Indian Institute of Technology Jammu Ankit Kathuria, Indian Institute of Technology, Jammu
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-02293
Paper Title	Can Segregating Motorcyclists Enhances the Safety of Non-urban Highways?
Abstract	Developing countries like India accommodate a significant share of motorized two-wheelers (MTW) in a traffic stream, resulting in increased MTW crashes. Previous research highlighted that separating MTW from the main traffic stream by providing a dedicated lane for motorcyclists effectively reduces crashes. In this study, the safety performance of an exclusive motorcycle lane (EMCL) was evaluated using the traffic conflict technique (TCT). However, EMCLs are not currently operational in India; thus, temporary implementation of EMCLs was carried out on non-urban highways to collect the field data. Safety analysis of EMCL was carried out to assess the conflict severity using surrogate safety measures (SSM). The motorcycle interaction with other vehicles was investigated, and a support vector machine (SVM), a classification algorithm, was used to categorize the interactions into critical, mild, and safe based on SSM. The results indicate that implementing EMCL improves the safety of motorcyclists and other road users by reducing critical interactions. Overall, the research showed that the motorcycle segregation strategy enhances the safety performance of non-urban highways.

Authors	Harish Saini, IIT Jammu: Indian Institute of Technology Jammu Ankit Kathuria, Indian Institute of Technology, Jammu
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-02298
Paper Title	Investigating the Impact of Segregating Motorcyclists on Safety of Non-urban highways: An application of Extreme Value Theory
Abstract	Developing countries like India accommodate a significant share of motorized two-wheelers (MTW) in a traffic stream, resulting in increased MTW crashes. Previous research highlighted that separating MTW from the main traffic stream by providing a dedicated lane for motorcyclists effectively reduces crashes. However, the safety analysis of exclusive motorcycle lanes (EMCL) was missing in the literature. This study applies a conflict-based safety assessment framework to compare the rear-end conflict and crash probability before-after implementing EMCL. Two popularly used surrogate safety indicators, i.e., time-to-collision and deceleration rate to avoid a crash, were used to analyze the safety. Since EMCLs are not currently operational in India; thus, temporary implementation of EMCLs was carried out on non-urban highways to collect the field data. The vehicular trajectory data were extracted and analyzed using traffic conflict techniques. The threshold was identified using a mean residual life plot and threshold stability plot based on the extracted data. Later, the peak-over threshold (POT) model was established for the different thresholds in the suitable ranges for individual conflict indicators. Then, the conflict and crash risk probability of rear-end collision at the mid-block section were analyzed. The POT model suggests low rear-end conflict and crash probability after implementing EMCL compared to before. The findings were consistent for both conflict and crash probability estimates obtained from the surrogate safety indicators used in this study. The significant results of this study will provide valuable insights for transportation planners, government agencies, and researchers.

Authors	Norran Novat, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	3160
Session Title	Automation, Technology, and Pedestrian Interactions
Paper Number	TRBAM-24-02362
Paper Title	Impact of Slip Lanes on Pedestrian Safety at Roundabouts Considering Autonomous Vehicles.
Abstract	The emergence of autonomous vehicles (AVs) has the potential to revolutionize transportation systems, but their impact on the safety of pedestrians in roundabouts is not fully explored. There is a significant gap in understanding the impact of safety on pedestrians in roundabouts under heterogeneous traffic conditions, particularly in the presence of a slip lane. Slip lanes have a significant impact on the speed of right-turning traffic, and vehicle merging behavior and as well they raise the risk of conflicts for pedestrians. The study focused on investigating the impact of slip lane designs on pedestrian safety. Through a combination of field observations and simulation modeling, the results highlighted significant findings. Field observations revealed that slip lane designs influenced the speed of vehicles, with traffic on slip lanes exhibiting higher speeds compared to approach traffic. This behavior had implications for pedestrian safety, particularly at entry and exit crossing points of slip lanes. Additionally, the study used simulation analysis to evaluate the impact of AVs on pedestrian safety at slip lane crossings. AVs were found to have a positive impact on reducing the occurrence of pedestrian conflicts but a negative impact on the severity of conflicts. The study suggests the need for improved speed control at slip lanes and emphasizes the importance of considering AV integration and slip lane design to ensure pedestrian safety.

Authors	Adekunle Adebisi, University of Cincinnati John Ash, University of Cincinnati
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2213
Session Title	Safety Performance of Connected Automated Vehicles
Paper Number	TRBAM-24-02402
Paper Title	Traffic Safety Performance Evaluation in a Connected Vehicle Environment with Queue Warning and Speed Harmonization Applications
Abstract	With connected vehicle (CV) technologies development, safety information is becoming more available to drivers. This study investigates three main questions; (1) Do CV-based traffic management applications improve safety performance on roadways with existing infrastructurebased traffic management systems? (2) Can implementing multiple CV technologies have a greater impact on safety than implementing a single CV technology? and (3) Do geometric and traffic composition factors impact the efficiency of CV technologies? We applied a rarely used CV pilot dataset and conducted a comprehensive analysis with various conditions and CV penetration rates that studies have not considered. Two CV applications (queue warning and speed harmonization) implemented in the Intelligent Network Flow Optimization experiment in Seattle were evaluated. Results showed that the driver safety performance, in terms of speed standard deviation (SSTD) and speed percent of extreme values (SPEV) improved under the CV driving conditions, and by combining conventional variable speed limit systems with queue warning, safety is improved for CV drivers. Further, the implementation of a single CV application (queue warning) provided potential benefits in terms of the SSTD, SPEV, congestion mitigation, and reduction in the number of conflicts. With the two CV applications combined, the results were also similar, suggesting no significant differences. Lastly, with 3 lanes, the results show a decrease in the SSTD under the CV driving condition compared to the non-CV condition. With 4 lanes, no improvement was observed.

Authors	Tao Wang, Guilin University of Electronic Technology Yaxi Han, Guilin University of Electronic Technology Wenyong Li, Guilin University of Electronic Technology Xiaofei Ye, Ningbo University Shurong Huang, Guangxi Road and Bridge Engineering Corporation Guan Lian, Guilin University of Electronic Technology
Sponsoring Committee	Standing Committee on Human Factors of Infrastructure Design and Operations (ACH40)
Session Number	3038
Session Title	Infrastructure Influence on Drivers
Paper Number	TRBAM-24-02669
Paper Title	A takeover risk assessment approach based on an improved ANP-XGBoost algorithm for human-machine driven vehicles
Abstract	This study investigates the risk of driver-vehicle cooperation takeover in a highway environment, with a focus on various non-driving tasks and takeover request scenarios. Using a driving simulator, a 5x5 factor analysis examined non-driving tasks and takeover prompts. These factors are analyzed based on objective data of takeover influencing features and risk indicator features. Considering subjective takeover perception of drivers and expert evaluation opinions, an improved Analytic Network Process (ANP) and XGBoost algorithm-based takeover risk assessment model is proposed. The improved ANP-XGBoost model identifies the minimum time to collision (TTC) as the most influential risk indicator. Results show the takeover scene factor had the highest correlation to risk level (r=-0.78) and minimum TTC (r=-0.76), greatly affecting safety. Despite weak correlations with reaction times, non-driving tasks had a minor effect. The test results demonstrate that the accuracy of this takeover risk assessment model reaches 87.1%, surpassing that of LightGBM and SVM. Findings show that this approach is effective and reliable to identify important features for takeover risk assessment, and achieve an accurate assessment of risk levels.

Authors	Ennis Marshall, University of Maine Mohammadali Shirazi, University of Maine John Ivan, University of Connecticut
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-02963
Paper Title	COVID-19 and Roadway Safety: Review of Studies, Lessons learned, and Research Gaps
Abstract	Transportation safety has substantially been impacted by the COVID-19 Pandemic. To contain the spread of the virus, governments around the world released guidelines (e.g., stay-at-home orders), which reduced or eliminated peoples' daily commutes. These travel restrictions introduced new safety challenges for roadways and drivers. Many cities, states, and countries around the world reported more severe crashes despite fewer drivers on the road. This paper conducts a structured critical review to summarize and discuss studies around the world on roadway safety since the start of the COVID-19 pandemic. We further review studies that examine the direct measures of roadway safety (e.g., crash statistics and models) as well as indirect or surrogate measures (e.g., speeding, aggressive driving, and reduced seatbelt usage). Surrogate measures, although indirectly, can affect the risk of crashes and contribute to the increase in frequency and severity of crashes. Findings are documented and discussed. We then provide suggestions on potential avenues for future research. Particularly, research studies show that the rate of severe injury crashes, as well as aggressive driving (e.g., speeding) increased in most places during the travel restrictions, and continued even after these restrictions were lifted.

Authors	Sunday Okafor, University of Alabama, Tuscaloosa Praveena Penmetsa, University of Alabama Vamshi Annimalla, University of Alabama Elsa Tedla, Alabama Transportation Institute Alexander Hainen, University of Alabama Steven Jones, University of Alabama
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-03029
Paper Title	Connected Vehicle Event Data and Traffic Crashes: A Statewide Correlation Analysis
Abstract	Traditionally, road safety countermeasures are determined through the analysis of historical crash records, which is regarded as a reactive approach since the crash risk is assessed after the occurrence of crash incidents. The emergence of connected vehicle data like hard braking events presents a promising opportunity for proactive traffic safety considerations. As such, some recent studies have been exploring the efficacy of using connected vehicle data as surrogates for traffic crashes. This study contributes to the growing body of literature by presenting a statewide correlation analysis to examine the potential of using hard braking events as a surrogate for crashes on different roadways in Alabama. The study used six months of hard braking events and crashes that occurred during the same period. Spearman’s rank-order correlation results indicated a moderate correlation between hard braking events and crashes on principal arterials, minor arterials, and major collectors. A weak correlation was recorded between hard braking events and crashes on the interstates. Similar correlation results were observed on the different roadways by conducting the analysis at the level of urbanized and rural areas. The findings suggest that hard braking events can serve as crash surrogates for different highway safety screening except for interstates. This study provides valuable preliminary information for traffic safety practitioners and transport agencies to explore practical applications of connected vehicle event data for proactive traffic safety management. Keywords: Connected Vehicle, Hard Braking, Traffic Crashes, Correlation, Proactive Traffic Safety

Authors	Hassan Bin Tahir, Queensland University of Technology Md. Mazharul Haque, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-03198
Paper Title	Estimation of real-time pedestrian crash risk by severity at signalized intersections using a non-stationary bivariate extreme value model
Abstract	Pedestrian-vehicle interactions are deemed severe due to the vulnerability of pedestrians compared to the occupants of vehicles. As such, the severity of pedestrian crash risks has not been addressed in proactive safety evaluations based on traffic conflicts derived from video analytics. This study proposed a novel analytical framework to estimate real-time pedestrian crash risk by severity at the signal cycle level while incorporating the effect of time-varying exogenous variables. Specifically, the study proposed a non-stationary bivariate extreme value model to jointly model the Post Encroachment Time and Delta-V indicators for real-time pedestrian crash risk by severity estimation at individual signal cycles. The proposed framework is tested on 144 hours of video data collected from three signalized intersections in Queensland, Australia. The developed model showed that the increased frequency of pedestrian conflicts per cycle increases severe injury crash risk per cycle. Similarly, medium to high average pedestrian speeds per cycle have a high associated severe injury pedestrian crash risk compared to low average pedestrian speeds per cycle. Moreover, the developed model precisely predicted the mean severe and non-severe pedestrian crash frequencies over a period of five years when compared with the observed severe and non-severe pedestrian crash frequencies over the five years (2014 - 2018). In conclusion, the developed framework can precisely estimate the pedestrian crash risk by severity at the signal cycle level. Such proactive estimation of pedestrian crash risk by severity can help mitigate the risk of severe injury crashes to vulnerable road users.

Authors	Chunqing Liu, Wuhan University of Technology Mengfei Liu, Shandong Hi-Speed Group Innovation Research Institude Chao Liu, DongFeng Motor Corporation Technology Center Xinpeng Yao, Shandong Hi-Speed Group Innovation Research Institude Nengchao Lyu, Wuhan University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03281
Paper Title	Exploring Traffic Conflict Characteristics and Factors in Short Weaving Section of Expressway
Abstract	In order to explore the characteristics of traffic conflicts in short weaving section on expressways and the reasons for their occurrence, this study conducted long-term and large-scale traffic flow observations specifically for the weaving areas of urban expressways, vehicle trajectory data and key parameters were extracted. This study proposes a set of methods for extracting rear-end and lateral conflicts. At the objective level, conflicts are calculated using surrogate safety measures, and false conflicts are filtered using the vehicle width virtual envelope rule and sliding time window method. At the subjective level, conflicts are verified through expert judgment. Considering individual vehicle, traffic flow, and longitudinal region factors, we construct a Bayesian-based random parameters logistic regression model to analyze the mechanism of traffic conflict influence. The research results indicate: The speed and deceleration-related indicators of individual vehicles and segments, as well as the traffic volume and longitudinal region, often have a significant impact on the occurrence of conflict events; Surprisingly, contrary to previous assumptions, the speed of individual vehicles is often lower when conflicts occur compared to when conflicts do not occur; Additionally, conflicts are concentrated in the weaving section and its upstream affected area when traffic density increases and interval average vehicle speed decreases. The conclusions of this study provide a certain theoretical support for the safety management and accident prevention in short weaving section of expressways.

Authors	Yuzhi Chen, Southeast University Chen Wang, Southeast University Yuanchang Xie, University of Massachusetts, Lowell
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03338
Paper Title	Modeling the Risk of Single-Vehicle Run-off-Road Crashes on Horizontal Curves Using Connected Vehicle Data
Abstract	Surrogate safety measures (SSM) are widely used in safety analysis to complement crash reports. However, none of the existing SSM are specifically designed for modeling the risk of single-vehicle run-off-road (SVROR) crashes, especially those on horizontal curves. This paper proposes a novel SSM for modeling SVROR crash risk (SVROR-SSM) using connected vehicle data. The proposed SVROR-SSM is based on the concept of tetraquark in particle physics. It utilizes the adjusted position deviation risk force (Friskposi) and adjusted attitude deviation risk moment (Γriskatti) to quantify SVROR crash risk. The SVROR crash risk is then estimated by the joint probability of Frisk posi and Γriskatti using a peak-over threshold approach. The risk threshold is automatically determined via a mean absolute error (MAE) computation function. The SVROR-SSM is validated using connected vehicle and crash data from 16 curves on Interstate 80 in Wyoming. The results suggest that the estimated crash risks well match historical crash records. The proposed approach bridges an important gap in SSM research and can be used to estimate SVROR crash risk and identify safe trajectories for highway horizontal curves.

Authors	Zhizhi Yang, Changsha University of Science and Technology Lu Xing, Changsha University Siqi Zhong, Changsha University of Science and Technology Yi Fei, Changsha University of Science and Technology Xi Li, Changsha University of Science and Technology Kongning Jin, Changsha University of Science and Technology Ou Zheng, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03408
Paper Title	Estimating collision risk of toll plaza diverging area using traffic cross-sectional data
Abstract	Although the cross-sectional traffic flow data has the advantages of being simple to access and more indicative of the general state of traffic, previous studies have rarely considered using cross-sectional data to investigate traffic safety. This study focuses on the extraction of cross-sectional traffic flow data and its application in predicting traffic safety in the diversion area of toll plazas. First, aggregation technology is used to obtain cross-sectional data, and ETTC is employed as a surrogate safety measure, while TOPSIS method and the entropy weighting method are utilized to propose a regional risk assessment indicator. Then, multiple machine learning methods are applied to build a collision risk evaluation model, which is evaluated using the random forest method and achieves a score of 90.03%, thereby confirming the validity of using aggregated section data. Furthermore, a Regional Risk Prediction Model is proposed using the BPNN AdaBoost algorithm, achieving an accuracy of 86.71% and demonstrating the best performance in predicting high-risk levels. The results show that the vehicle's location within the diversion area is the most influential feature variable in the collision risk evaluation model. Moreover, it is evident that upstream traffic conditions have a stronger impact on safety compared to the downstream segment, indicating varying safety conditions at different sites. The research's conclusions offer insightful information for proactive traffic safety management.

Authors	Anamika Yadav, Indian Institute of Technology, Jammu Ankit Kathuria, Indian Institute of Technology, Jammu
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03504
Paper Title	Assessing the Severity of Conflicts at Unsignalized Intersection under Heterogeneous Traffic Conditions
Abstract	In a developing country like India, with a dynamic traffic environment characterized by heterogeneous and non-lane-based traffic, effectively managing traffic and reducing collisions at unsignalized intersections presents a significant challenge. Consequently, the primary objective of this study is to comprehensively analyze various types of conflicts and their corresponding severity levels. Additionally, the study seeks to gain a comprehensive understanding of the speeds at which various categories of vehicles choose to ride at intersections by comparing the speeds of different vehicle classes. Vehicle speed serves as a crucial indicator, providing valuable insights into the safety dynamics at unsignalized intersections. In the present study, automated trajectory data is utilized for extracting vehicle speeds and surrogate safety indicators such as time to collision (TTC). Using the trajectory data, the study first compares different vehicle speeds at the intersection to understand which category of vehicle chooses to ride at higher speeds at the intersection. Further, the study understands the different types of conflicts arising due to possible left-turning and right-turning maneuvers at three-arm intersections based on the geometry of study locations used in the current study. Furthermore, severity dimensions are proposed for three types of frequently observed conflict, namely crossing conflict, rear-end conflict and merging conflict. Based on the severity dimensions of these conflicts, a comparison is drawn for the most severe conflict occurring at the three-arm unsignalized intersection. Overall, the research provides an essential insight into the safety at unsignalized intersections under heterogenous traffic conditions.

Authors	Shivasai Samalla, IIT: Indian Institute of Technology Guwahati Pranab Kar, No Organization Suvin Padinjare Venthuruthiyil, Indian Institute of Technology, Hyderabad Mallikarjuna Chunchu, Indian Institute of Technology, Guwahati
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03608
Paper Title	Determination of Conflict Thresholds and Crash Risk of Powered Two-wheelers in Mixed Traffic Conditions: An Extreme Value Theory Approach
Abstract	In low and middle-income countries (LMICs), powered two-wheelers (PTWs) are widely used because of their low maintenance costs and ease of usage. There is a growing concern for the safety of PTWs, but safety studies are still lacking in LMICs. The present study investigates the crash risk of PTWs involved in multiple conflict types, with different vehicle classes constituting a mixed traffic stream. A state-of-art surrogate safety measure (SSM) called Anticipated Collision Time (ACT) was used to evaluate the crash risk. This study uses the extreme value theory to estimate the crash risk by establishing the conflict thresholds for potential rear-end and side-swipe conflicts. The conflict thresholds for rear-end conflicts were found to be higher than side-swipe conflicts except for the PTW-PTW vehicle pair. Further, the conflict thresholds corresponding to rear-end and side-swipe conflicts increase with the interacting vehicle size. The findings indicate the necessity to determine the conflict thresholds corresponding to each conflicting vehicle type for PTWs-dominated urban traffic. The crash risk of PTW varies depending on the type of conflict and conflicting vehicle type. Further, the crash risk of side-swipe conflicts is relatively higher for all PTW-vehicle pairs than the rear-end conflict, except for the PTW-Bus pair. Hence, to improve PTWs' safety, filtering and swerving maneuvers of PTWs should be restricted in mixed and weak lane-disciplined driving conditions.

Authors	Haolin Chen, Beijing University of Technology Xiaohua Zhao, Beijing University of Technology Zhenlong Li, Beijing University of Technology Haijian Li, Beijing University of Technology Jianguo Gong, Southeast University Qiuhong Wang, Research Institute for Road Safety of MPS
Sponsoring Committee	Standing Committee on Human Factors of Vehicles (ACH30)
Session Number	2094
Session Title	Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems
Paper Number	TRBAM-24-03657
Paper Title	Safe Time for Driver Takeover in Automated Driving: A Methods for Calculating Takeover Time Thresholds
Abstract	The time required for drivers to assume control is a critical factor in takeover behavior. This study aims to calculate takeover time thresholds and validate their appropriateness. A driving simulation experiment was conducted, incorporating non-driving related tasks, takeover request time, takeover scenes, and traffic flow as external variables, resulting in 18 takeover events. Takeover time data were collected from 42 drivers across 18 takeover events. Firstly, the distributional differences of takeover time were analyzed. The results reveal that takeover time varies across different driver attributes and external environmental conditions. Secondly, the Hill estimation and data fitting methods were employed to identify the takeover time threshold. The results indicated that the best fit for the data distribution was achieved at 3.88 s. Lastly, the threshold of 3.88 s is validated using takeover failure events and minimum time to collision, the result show that 3.88 s can explain 95.35% of the takeover failures are caused by unsafe takeover times. In accident takeover scenes, the minimum TTC is used as a safety validation indicator. We found that the 3.88 s have distinct discriminative accuracies (91.67%) for safe and unsafe behavior. The contribution of this paper is that the calculation methods of the takeover time thresholds can provide a reference for determining critical takeover time, the takeover time threshold can be utilized to evaluate and train the driver's takeover ability. Moreover, this study provides valuable support for driver regulatory authorities to enhancing the driving qualification management of drivers in automated vehicle.

Authors	Maryam Hasanpour, Toronto Metropolitan University Bhagwant Persaud, Toronto Metropolitan University Robert Mansell, Toronto Metropolitan University Craig Milligan, Miovision
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-03884
Paper Title	Investigation of a machine learning sampling method for estimating the frequency of severe and non-severe crashes using traffic conflicts
Abstract	Extreme value theory allows for identifying traffic conflicts most likely to lead to crashes and is considered state-of-the-art in proactive safety analysis. However, the first main issue is that estimating severe crash frequency using traffic conflicts has not been thoroughly explored. Moreover, the statistical-based sampling methods suffer from complexity of defining the dependence structure for the safety indicators. Yet, a considerable body of research has used conventional statistical sampling techniques, while data-driven methods have received relatively little attention. This research, built on an earlier study, aims to address this gap and develop a data-driven-based methodology to estimate total and fatal plus injury crashes utilizing traffic conflicts. After thoroughly reviewing recent advances, the paper explores a candidate data-driven sampling model based on conflicts between left-turning vehicles and opposing through vehicles at signalized intersections. To develop this approach, a database of these traffic conflicts was assembled from video observations. Then, extreme conflicts in different severity levels were determined by jointly modeling the indicators of crash frequency, post-encroachment time, and crash severity, predicted post-collision change in velocity, using autoencoder neural network. Linear regression models were then developed to relate crashes at the same intersections to the correspondingly classified extreme conflicts. Given the promise of the results, it is suggested that they can be used in practice with due caution. To facilitate this application, at least as an approximation, equations defining the boundary between consecutive anomaly score levels were developed for jurisdictions without resources for training an autoencoder to classify conflicts for their datasets.

Authors	Renfei Wu, Southeast University Ziwei Yi, Southeast University Yikang Rui, Southeast University Bin Ran, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-03918
Paper Title	Enhanced Risk Assessment in Pedestrian-Vehicle Interactions at Un-signalized Sections Using the Modified DSF Model
Abstract	Pedestrian-vehicle interactions play a crucial role in traffic safety concerns. In recent years, this topic has garnered significant attention from both academia and the industry due to its pressing challenges. In the pursuit of enhancing pedestrian-vehicle risk assessment, we introduce a modified Driving Safety Field (DSF) model that evaluates the risk between pedestrians and vehicles at un-signalized intersections. This model is distinct due to its emphasis on predicting a pedestrian's future trajectory. Firstly, we leverage pedestrian motion and environmental features which feed into dynamic Bayesian network (DBN). These features help infer crossing intentions. Subsequently, particle filtering refines these trajectory predictions based on the crossing-intention. For calibration, we employed driving data, gathered from real-world traffic settings. The real-world driving data was collected from multi-sensor, notably from LiDAR and monocular cameras, sets the stage for verifying performances in intention inference and trajectory prediction. Furthermore, an integral part of the modified DSF model is the uncertainty trajectory defined via an attenuation coefficient grounded in the Bellman equation. To gauge the effectiveness of risk assessment, we relied on metrics such as mean braking times, and two variants of TTC−1. Monte Carlo simulations, executed a thousand times, showcased our model's prowess in reducing braking operations by 18.73%. Further, there was a marked reduction in both TTC−1 average values (28.83%) and peak values (33.91%). The proposed model, with its dynamic risk assessment capabilities, stands as a promising tool for integration into enhancing vehicles' driving safety.

Authors	Reza Aminghafouri, University of Waterloo Liping Fu, University of Waterloo
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-04004
Paper Title	An Automated Threshold Selection Framework for Conflict-Based Road Safety Analyses
Abstract	Extreme Value Theory has been commonly applied for extrapolating the risk of severe but rare events (crashes) from that of low severe but more frequent events (traffic conflicts). The challenge is however how to determine the threshold that can be used to delineate the events of low severity. This paper presents an automated framework for threshold selection based on a peak-over-threshold extreme value model with the goal of maximize the accuracy of crash risk prediction from traffic conflicts. The proposed methodology evaluates the goodness-of-fit of the generalized Pareto distribution to identify the suitable threshold level for exceedances. The selection process controls the False Discovery Rate for ordered hypotheses, utilizing the Anderson-Darling goodness-of-fit test. The approach is demonstrated through a case study using a set of conflict data collected at ten signalized intersections in the city of Toronto. The results show that the proposed method could be effectively applied for determining the conflict threshold for improved crash risk prediction.

Authors	Wenxuan Wang, Chang'an University Bo Yan, Xidian University Ying Yan, Chang'an University Yanqiu Cheng, Chang'an University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-04027
Paper Title	Development and Performance of a Deceleration-Based Surrogate Safety Measure for Rear-End Collision Risk
Abstract	A surrogate safety measure can be used to evaluate the safety level and prevent the potential risk in driving events. In this paper, a surrogate safety measure, namely the risk deceleration(DR), is proposed based on Field theory to describe drivers' risk-perceiving and decision-making process in car-following scenarios to evaluate the rear-end collision risk. The ability of DR in identifying the perceived risk of drivers in car-following scenarios has been verified through vehicle trajectories of three different risk groups. Results show that the DR has a good performance on the prediction accuracy, timeliness and the similarity to drivers' behavior. The parameter values of DR can be calibrated and acquired based on drivers' real operation performance and with the calibrated reaction time value helps to enhance the prediction accuracy. The research findings suggest that the DR can reflect the mechanism by which drivers operate vehicles based on perceived risk levels during the car-following process. DR has great potential for the application in collision warning systems, which can improve drivers' satisfaction and compliance.

Authors	Alejandro Perez Villasenor, McGill University Luis Miranda-Moreno, McGill University Lynn Scholl, Inter-American Development Bank Eduardo Adame Valenzuela, McGill University Cansu Alakuş, McGill University Faculty of Engineering
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others
Paper Number	TRBAM-24-04264
Paper Title	Application of an XGBoost Approach for Pedestrian Surrogate Safety Analysis: A Case Study in Intersections with BRT Stations and Bus Stops in Mexico City
Abstract	In Latin America, transit corridors often challenge pedestrian safety due to the high pedestrian activity, high traffic volumes, and inappropriate designs at intersections that reach BRT boarding stations or bus stops. Unfortunately, these conditions often translate into dangerous vehiclepedestrian interactions and pedestrian injuries. We present a surrogate safety methodology to investigate the pedestrian injury-risk contributing factors at intersections with transit facilities - BRT stations or bus stops. First, seven locations are selected from which hundreds of hours of video data are collected and processed using an automated software tool. Then, trajectory and conflict data identify the most common scenarios between pedestrians and motor vehicles. Next, risk measures like post-encroachment time (PET), speed, and traffic violations are measured for pedestrians involved in interactions and illegal crossing events. Finally, an eXtreme Gradient Boosting model identifies the important features of how critical a vehicle-pedestrian interaction is. Results show that the most hazardous interactions happen when motorcycles are involved. We observed no difference in how critical a conflict near a BRT facility was from those near a bus stop, despite BRT stations having smaller PETs. This research helps better understand how transit facilities' planning and design impact pedestrian safety and identifies which interactions entail the most risk for vulnerable users, providing a ground for further interventional study. Keywords: Bus Rapid Transit, BRT, Pedestrian Safety, Transit, Bus Stops

Authors	Ahmed Mohamed, University of Cincinnati Lizhe Li, University of Cincinnati College of Engineering and Applied Science Mohamed Ahmed, University of Cincinnati
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2213
Session Title	Safety Performance of Connected Automated Vehicles
Paper Number	TRBAM-24-04593
Paper Title	Automated Traffic Safety Assessment Tool Utilizing Monocular 3-D Autonomous Vehicle Algorithm at Signalized Intersections
Abstract	Traffic conflict analysis has gained significant attention over the last few years. Recent research has made significant progress in the development of detection and tracking systems, utilizing various technologies such as closed-circuit televisions, unmanned aerial vehicles, and sensor fusion exploiting light detection and ranging. By examining the challenges facing the widespread of real-time traffic conflict detection and analysis techniques, this study utilized CenterTrack Convolutional Neural Network (CNN) based algorithm, that is essentially developed for autonomous vehicle systems, to detect and track road users at signalized intersections. The primary advantage of this algorithm lies in its ability to depict road users through the utilization of three-dimensional bounding cuboids. In an effort to refine the precision of the tracking process, this study further incorporates a suite of post-processing algorithms. These are specifically designed for data augmentation, the reconstruction of seamless trajectories, and the accurate estimation of vehicle states and indicators. This representation method simplifies the entire traffic data processing procedure and improves the detection for better establishment of an automated safety assessment tool utilizing Artificial Intelligence. The algorithm has been examined on various video footages and proved its detection superiority for high traffic volumes at intersections with an overall precision of 95.08%, and a recall of 92.81%. It exhibited exceptional accuracy and efficacy in identifying a range of crucial conflict scenarios, achieved through the application of four unique traffic conflict indicators.

Authors	YUXUAN WANG, Southeast University Pan Liu, Southeast University Chengcheng Xu, Southeast University Qingyun Li, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05133
Paper Title	The validity and application of Time-to-Collison based on real-world crash trajectory data
Abstract	The validity of surrogate safety measure (SSM) holds paramount importance since numerous previous studies of traffic safety analysis relied on traffic conflict events identified by SSMs. This paper aims to assess the effectiveness of conflicts to be an alternative to crashes. To achieve this goal, we conducted a drone video survey on a Chinese expressway from 2021 to 2022. The recordings consistently capture the morning peak hours (2 hours) on every sunny weekday. An automatic algorithm is employed to extract vehicle-level trajectories from each video. In total, we obtain 200 hours of trajectory data, which includes 20 rear-end crashes. A sliding window approach is first proposed to segment the whole oneyear survey into a series of field observations. In each field observation, a widely used SSM known as Time-to-Collision (TTC) is utilized to identify all traffic conflicts. The ratio between the number of conflicts and actual crash frequencies is calculated to represent their relationship. The validity of TTC is reflected by the variance of ratios across these field observations. Our results highlight that the TTC has the optimal relationship with crashes when the TTC thresholds range from 0.4s to 0.8s. According to the proposed ratio, we further investigate the impact of the observation period of conflicts, TTC thresholds, and the estimation period of crashes on the validity of TTC. These results can guide us in effectively applying TTC in different scenarios. Finally, the transferability test demonstrates that our conclusions are valid and replicable under different locations and traffic conditions.

Authors	Ke quan Chen, Southeast University Hao Yu, Southeast University Pan Liu, Southeast University Zhibin Li, Southeast University Yuxuan Wang, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	Safety Performance and Analysis of Freeways
Paper Number	TRBAM-24-05137
Paper Title	Can we predict freeway lane-changing crashes before the insertion?
Abstract	Previous research has primarily applied surrogate safety measures to identify potential conflicts during LC and investigated the factors contributing to such risky LC. Indeed, the results obtained from conflict LC samples may differ from those obtained from real crash LC samples. As a result, it could lead to misjudgments in several aspects, such as risk evaluation, automatic crash avoidance, and trajectory planning. To address this serious issue, the research team obtained real LC crash samples by recording videos with drones from 2021 to 2022 at a merging bottleneck in Nanjing, China. We then develop two binary logit models to identify the variables significantly influencing: (a) LC conflict likelihood; and (b) LC crash likelihood. Furthermore, we design experiment to provide insights into the occurrence mechanism of LC crashes by considering the dynamic characteristic before the insertion (anticipation). Comparison results reveal that various factors affect the probability of LC crashes, but some of them are found to be insignificant or exhibit opposite effects when predicting the LC conflict likelihood. When directly applying the model developed with LC conflict samples to predict real LC crash, the accuracy reduces to 10% for both the anticipation stage and LC decision moment.

Authors	Qingyun Li, Southeast University Pan Liu, Southeast University Kequan Chen, Southeast University YUXUAN WANG, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05144
Paper Title	Comparing Lane-changing Behavior and Safety During Daytime and Evening Using Vehicle Trajectory on Expressway
Abstract	This study aims to compare the differences in driving behavior and safety performances of lane-changing events on expressways between daytime and evening. Drone video data were collected during the morning and evening peaks on the same expressway segment in Nanjing, China, with the extraction of 1133 and 1355 lane-changing events, respectively. Based on these events, we first analyzed two key features of lane-changing: duration and gap acceptance under different traffic states. The empirical results indicated that the lane-changing events have a significantly longer duration under the congested flow state in the evening. In terms of gap acceptance, it is usually larger in the evening under the free flow state, while the lag gap is significantly smaller in the evening under the steady flow state. Next, surrogate safety measures were applied to evaluate lane-changing safety, and the results suggested that lane-changing events are more dangerous in the evening, particularly under the congested flow state. Finally, binary logistic models were established to investigate the critical factors influencing lane-changing crash risk. Our findings revealed that compared to daytime, the duration of relaxation, lateral speed, and the gap with the leaders on the current lane show additional significant impacts on the lane-changing events in the evening. This is the first time to study lane-changing events in a real evening driving scenario. We hope these findings can be applied to promote the development of connected and automated vehicles in the evening and improve road safety.

Authors	YUXUAN WANG, Southeast University Pan Liu, Southeast University Chengcheng Xu, Southeast University Zhibin Li, Southeast University Ke Quan Chen, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05148
Paper Title	A new rear-end crash risk indicator for traffic oscillation
Abstract	Traffic oscillation is known to be closely related to rear-end crashes. However, little attention has been given to understanding the underlying mechanisms between oscillation and crash risk due to the lack of real crash data at the microscopic level. To address this data gap, we recorded drone videos over one year at two busy freeways in China during the morning peak hours on sunny weekdays. 20 rear-end crashes and their corresponding trajectories are obtained. Based on this crash dataset, this paper aims to investigate the impact of oscillation-related features on the probability of rear-end crashes and establish a novel indicator to assess the potential evolution of an oscillation into a rear-end crash. Our empirical results suggest that once an oscillation forms, its amplitude and the follower's reaction behavior significantly affect the likelihood of a rear-end crash. Subsequently, we incorporate these findings into the framework of Time-to-Collision (TTC), yielding a new crash risk indicator called Oscillation Risk Indicator (ORI). We evaluate the performance of the ORI by comparing it with five commonly used Surrogate Safety Measures (SSMs). The results show that the ORI outperforms the selected SSMs in trading off the recall and the false alarm rate. We introduce a variant of the ORI to predict crash risk continuously once the oscillation forms, offering a real-time crash risk prediction tool. This study makes the first attempt to explain the oscillation risk at the microscopic level. The results can serve as a backbone for developing and testing more sophisticated traffic control strategies.

Authors	Yuxuan Wang, Southeast University Pan Liu, Southeast University Kequan Chen, Southeast University Chengcheng Xu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05149
Paper Title	Evaluating the predictability of surrogate safety measures using real-world crash trajectory data
Abstract	There is still no consensus on the effectiveness of these SSMs. This study aims to address this issue through the following objectives: (1) to propose a method for estimating and comparing the predictability of SSMs and (2) to investigate factors contributing to their predictability. To achieve these goals, we collect 20 rear-end crashes by drones in Nanjing, China, during a year of video collection. A computer vision algorithm is used to extract trajectory data from real-world crashes. Then, we define the real-time predictability of SSMs by considering the SSM threshold and the early warning time (i.e., how far in advance to predict crashes) based on Bayes' theorem. Subsequently, we establish a ridge regression model to explore factors affecting the SSMs' predictability, including the predefined threshold, early warning time, and dynamic interaction variables between two consecutive vehicles. Four commonly used SSMs for rear-end crashes are investigated in this research. It is found that the predictability of SSMs could be estimated as the product of the prior crash probability and ratio between recall and false alarm rate. Among the selected SSMs, time-to-collision (TTC) and modified time-to-collision (MTTC) performance well with comparable results considering overall effectiveness. The deceleration rate to avoid a crash (DRAC) follows closely behind TTC and MTTC, whereas the Potential index for collision with urgent deceleration (PICUD) significantly underperforms these three indicators. Moreover, the ridge regression results indicate that different SSMs are affected by different factors. These findings provide valuable insights for evaluating and improving SSMs.

Authors	Yuxuan Wang, Southeast University Pan Liu, Southeast University Chengcheng Xu, Southeast University Ke quan Chen, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05150
Paper Title	Assessing and guiding conflict techniques for real-time crash detection using extreme value theory and real-world crash trajectories
Abstract	Surrogate safety measures (SSMs), serving as a promising alternative approach for estimating crash frequency, has been widely explored in the literature. As the Intelligent Transportation System rapidly advances, many efforts turn to integrate SSMs into vehicle-level crash risk estimation. The reliability of these results depends on the robust predictive capacity of SSMs in real-time conditions. To date, how to evaluate whether the SSMs possess this predictive ability remains an unclear issue. Hence, this article extends Extreme Value Theory (EVT) to investigate the performance of current SSMs when used as microscopic evaluation metrics and guides on their application. Our research team conducted a drone video recording survey on every sunny weekday for one year at a bottleneck segment in Nanjing, China. This survey produced a unique trajectory dataset that covers the formation process of 20 rear-end crashes. We propose an EVT model with block maxima sampling approach to investigate the distribution of extreme events in the non-crash and crash conditions, respectively. The crash condition is further divided into different forecast windows to unveil the predictability of SSMs as the time approaches the crash moment.We test the proposed framework into two widely used and accepted SSMs: Time-to-Collision (TTC) and Absolute value of Derivative of Instantaneous Acceleration (ADIA). We find that TTC outperforms ADIA across various forecast windows. With the forecast window widening, the performance of both TTC and ADIA diminishes. Furthermore, we report optimal threshold curves for TTC and ADIA, offering guidance on their usageunder different forecast windows.

Authors	Panick Kalambay, University of Washington, Tacoma Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	3160
Session Title	Automation, Technology, and Pedestrian Interactions
Paper Number	TRBAM-24-05236
Paper Title	Modeling Adjacent Levels of Pedestrian-Vehicle Conflict Severity at Fixed-Cycle Intersections Using Computer Vision
Abstract	This research focuses on object detection and tracking algorithms, specifically YOLOv4 and DeepSORT, to examine pedestrian safety at a signalized intersection with a fixed cycle time. An adjacent-category approach was used to model the effects of pedestrian, vehicle, and signal timingrelated factors on the severity of pedestrian-vehicle conflicts at a fixed-cycle intersection. Compared with a non-conflict situation, pedestrian red-light violations increase the likelihood of a slight conflict by 5.9%. Jaywalking is more likely to increase the severe conflict situation by 9.5% compared with a slight conflict situation. Driving at a speed greater than 25 mph increases the likelihood of a slight conflict by about 24.7% compared with a non-conflict situation. Similarly, the likelihood of a severe conflict increases by 13.1% compared with the slight conflict situation. A one-second extension of the yellow time can decrease the likelihood of a slight conflict situation by 17.2% compared with a non-conflict situation. On the other hand, a one-second extension of the yellow time can decrease the likelihood of a severe conflict situation by about 20.9% compared with a slight conflict situation. The findings revealed the importance of the yellow time as an integral measure for enhancing pedestrian safety and minimizing potential conflicts with vehicles at fixed-cycle intersections.

Authors	Weilin Ren, Southeast University Chengcheng Xu, Southeast University Yongcheng Shao, Southeast University Changshuai Wang, Southeast University Hao Tong, Southeast University Chang Peng, Southeast University Weilin Ren, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05298
Paper Title	A String Stability-based Safety Assessment for Rear-end Conflict in A Platoon
Abstract	The primary objective of this paper is to investigate the impact of string stability on crash risk, and to develop a rear-end conflict prediction model incorporating string stability indicators. The string stability criterion is used to investigate the transition between instability and crash. Multinomial logistic regression model is leveraged to analyze the impact of factors associated with string stability on the transition process of a platoon state from no-crash instability to crash. The results show that platoon size, maximum acceleration, desired time gap, driver's reaction time and string stability criterion have significant effects on crash risk. The contributing factors to crash risk are used as inputs to support vector machines (SVM) for constructing a rear-end conflict prediction model. Validation results revealed that rear-end conflict prediction model incorporating string stability criterion exhibits higher accuracy in identifying rear-end conflict compared to the surrogate safety measure (SSM) based model.

Authors	Chuang CUI, Southeast University Bocheng An, Southeast University Linheng Li, Southeast University Xu Qu, Southeast University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2004
Session Title	Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session
Paper Number	TRBAM-24-05299
Paper Title	A Vehicle Safety Early Warning Method Based on Risk Map
Abstract	Traffic safety has always been a focal point of concern, especially on highways where vehicles travel at high speeds, and the harm caused by traffic accidents is more severe. To evaluate the driving risks of highway vehicles and reduce the accident rate on highways, this study proposes a highway vehicle safety warning method based on a risk map. Firstly, a two-dimensional feature indicator MTTC (Modified Time to Collision) is selected to describe the driving risk between vehicles, and it is subjected to probabilistic processing. Then, the probabilistic risk values are mapped onto road segments. The risk map is obtained by overlaying them, which is used to depict the driving risks around vehicles. After that, highway vehicle warning is performed based on the risk map. When the risk value is higher than the warning threshold, high-risk vehicles are given a warning alert. Finally, the effectiveness and timeliness of the proposed method are verified through simulation in VISSIM. The experimental results show that the proposed method is effective and timely. This study constructs a vehicle warning risk map in the connected vehicle environment and provides a research foundation for enhancing highway driving safety, which is not only suitable for the current stage of manual driving and assisted driving but can also be applied to future autonomous driving.

Authors	Manmohan Joshi, University of Connecticut Anshu Bamney, University of Connecticut Kai Wang, University of Connecticut Shanshan Zhao, University of Connecticut John Ivan, University of Connecticut Eric Jackson, University of Connecticut School of Engineering
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-05501
Paper Title	Analyzing the Suitability of Vehicle Telematics Data as Surrogate Safety Measure for Short Term Crashes
Abstract	Traffic safety analysis heavily relies on the comprehensiveness of traffic crash data; however, the crash occurrence is a rare event. Researchers have sought alternative measures closely linked to crash occurrences, known as surrogate safety measures, to address this challenge. The advent of vehicle telematics has introduced a valuable source of data, consisting of time-stamped positional information of vehicles, facilitated through telecommunication networks. Wejo Data Services Inc. collects vehicle telematics data through collaboration with various automotive OEMs (original equipment manufacturers) to furnish connected vehicle data along with driver event variables, such as braking and accelerations. This study seeks to investigate the relationship between hard braking events and the incidence of total crashes and peak period crashes across different facility types using analysis of variance and negative binomial models. The results show a strong correlation between harsh braking and crash frequency. Further, significant differences are observed in the relationship across time periods and across facilities. The model performance of different short period models improved better than the extent of improvement in total crash model after hard braking was introduced as explanatory variable. The marginal effects of hard braking on crash frequency in freeways are consistently higher than those in non-freeway segments.

Authors	Maged Shoman, University of British Columbia Tarek Sayed, University of British Columbia Suliman Gargoum, University of British Columbia
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	3160
Session Title	Automation, Technology, and Pedestrian Interactions
Paper Number	TRBAM-24-05520
Paper Title	Transformer-Based Model for Predicting Trajectories in Autonomous Vehicle-Pedestrian Conflicts: A Proactive Approach to Road Safety
Abstract	In the rapidly evolving landscape of autonomous vehicles (AVs), accurate prediction of pedestrian trajectories remains a critical concern for conflict detection and prevention. Current methods, including Constant Velocity and LSTM Models, exhibit limitations in accurately discerning pedestrians' intents. This paper proposes a novel approach using Transformer Networks, initially developed for Natural Language Processing tasks like ChatGPT, for predicting AV and pedestrian trajectories in urban conflict scenarios. Leveraging attention mechanisms, the model dynamically assigns weights to different features of AV and pedestrian behavior, enabling nuanced predictions that cater to real-world situations. Performance comparison with traditional models demonstrates superior accuracy of the proposed Transformer model. Our findings suggest potential applications of the model in conflict analysis, collision warning systems, and algorithm fine-tuning in AV manufacturing. The model's versatility suggests scope for future research, including applying the technique to diverse driving cultures, examining interactions with different road users, and developing multi-agent transformers. This study offers a significant stride towards a safer integration of autonomous vehicles into human-centric urban spaces.

Authors	Dachuan Zuo, New York University Zilin Bian, New York University Fan Zuo, New York University Kaan Ozbay, New York University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	Analytical Methods of Safety Performance
Paper Number	TRBAM-24-05629
Paper Title	Risk Estimation for Vehicles and Road Sections Using a Data-driven Risk Field Model
Abstract	This study proposes a new safety metric to estimate the driving risks of vehicles and road sections on the basis of vehicle risk field model and the concept of power of the work done by the field force (PWF). The proposed metric based on PWF is not only able to estimate the risk associated with specific vehicle interactions like previous studies, but can also be aggregated to capture the overall risk imposed by the entire surrounding traffic on a vehicle and quantify the total risk on a specific road section. Case studies involving three different scenarios compared to time-to-collision (TTC) were conducted to validate the properties of the proposed PWF-based metric and demonstrate its effectiveness in assessing driving risks of vehicles in chaotic traffic and quantifying the overall risks for an entire road section.

Authors	Yu Wu, McMaster University Hao Yang, McMaster University Harith Abdulsattar, McMaster University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-05833
Paper Title	Development of A Novel Real-time road safety evaluation system
Abstract	This research aims to develop a real-time, comprehensive, practical, and reliable safety performance evaluation system for road segments, taking into account various types of potential collisions. The system considers potential rear-end collisions on straight roads and side-impact collisions within intersections. The probability and severity of potential collisions are estimated using real-time vehicle trajectories, and a real-time risk score is defined to assess the safety performance of road segments. In this paper, we propose a predicted PET based on the anticipated trajectories of vehicles at intersections. Simultaneously, this research also takes into account near-side and far-side impact collisions. Furthermore, model justifications based on simulation data are conducted to demonstrate the system's effectiveness in identifying potential conflicts near intersections. An empirical analysis of two real-world intersection datasets is performed to evaluate the system's performance with actual data. The developed system lays the groundwork for municipalities and government agencies to adopt a safety-based road management approach and identify vulnerable locations within specific areas.

Authors	Panick Kalambay, University of Washington, Tacoma Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Pedestrians (ACH10)
Session Number	3160
Session Title	Automation, Technology, and Pedestrian Interactions
Paper Number	TRBAM-24-06029
Paper Title	Modeling Pedestrian Near-Crash Events at Rectangular Rapid Flasing Beacons (RRFBs)Controlled Intersection Using Video Analytics and Long Short-Term Memory Neural Networks
Abstract	Pedestrian safety has long been a concern in urban areas, with a higher frequency of pedestrian near-crash events than in suburban areas. This is primarily attributed to the concentration of many intersections to facilitate pedestrian travel in urban environments. This study adopts a proactive approach to assess and predict the severity of pedestrian near-crash events, as they are valuable surrogates for potential crashes. The study employed object detection and tracking techniques to establish the temporal relationship of pedestrian near-crash events involving vehicles at an intersection controlled by rectangular rapid flashing beacons (RRFBs). The objective is to predict the severity of these events. A long short-term memory (LSTM) neural networks model is proposed to give drivers a warning 2 seconds before the vehicle reaches the conflict zone. The results highlight the effectiveness of the proposed LSTM neural networks model, with an area under the curve (AUC) value of 78.5% on the training data and an overall recall of 71.1% on the test data. The significance of the proposed LSTM neural network model lies in its ability to provide timely insights into potential near-crash events by continuously monitoring and analyzing pedestrian and vehicle movements at a point of interest. Keywords , Post-Encroachment Time, Detection, Tracking, Rectangular Rapid Flashing Beacon, Long Short-Term Memory, Pedestrian Safety.

Authors	Song Wang, Chongqing Jiaotong University Zhixia Li, University of Cincinnati
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-06058
Paper Title	Quantification of Safety Improvements and Human-Machine Trade-Offs in the Transition to Automated Driving
Abstract	The assumption of reduced human error-related crashes with increasing levels of automation in the pursuit of Level 5 automation lacks empirical evidence. As automation levels rise, human error-induced safety hazards are anticipated to decrease while machine error-induced hazards increase. However, a quantitative index capturing this trade-off is absent. Theoretical modeling of safety improvements during the transition to automated driving, particularly concerning the reduction of human error-related hazards, remains unexplored. These limitations impede the understanding of safety from human and machine perspectives for Automated Vehicle (AV) specialists and manufacturers. This research addresses these gaps by investigating safety performance associations between human and machine factors using the "Human-Machine conflict reduction ratio" (H-M ratio). The study aims to establish safety improvements related to human errors under various automation levels. Sixty participants completed driving tasks at Levels 0, 4, 3, and 2 on a driving simulator. Safety performance measures, including conflict frequency and severity, were computed. As a result, Level 4 exhibits the largest decrease (93.3%) compared to manual driving, followed by Level 2 (70.7%) and Level 3 (40.5%). The H-M ratio measures the trade-off between reducing human and machine error-induced hazards, with Level 2 demonstrating the highest ratio, followed by Levels 4 and 3. Safety performance is evaluated by considering all possible types of human errors at each automation level. Theoretical models from a human factor's perspective are employed to estimate safety improvements at each level. This research contributes to a comprehensive understanding of safety in the "human-machine cooperative driving" phase.

Authors	Brianna Lawton, Iowa State University Shauna Hallmark, Iowa State University Guillermo Basulto-Elias, Iowa State University Daniel Obeng, Kwame Nkrumah University of Science and Technology Williams Ackaah, CSIR-BRRI
Sponsoring Committee	Standing Committee on Human Factors of Infrastructure Design and Operations (ACH40)
Session Number	3038
Session Title	Infrastructure Influence on Drivers
Paper Number	TRBAM-24-06070
Paper Title	Understanding the Relationship Between Road Users and Roadway Infrastructure in Ghana: A Quantitative Video-Driven Study
Abstract	Ghana exemplifies the contribution of road crashes to mortality and morbidity in Africa, partly due to a growing population and increasing car ownership, where fatalities have increased by 12 to 15% annually since 2008 [22]. This study focused on understanding driver behavior at unsignalized junctions in Ghana. Understanding driver behavior at unsignalized junctions is particularly important since failure to stop or yield can seriously affect vulnerable road users leading to crash fatalities and serious injuries. This study's objectives were to develop relationships between driver behavior and junction characteristics. The type of stop and location of the stop in relation to the stop bar were selected as two surrogate measures of safety. Logistic regression was used to model these two behaviors at the selected junctions. The analysis showed drivers were more likely to stop based on various factors such as vehicle turn movement, vehicle type, number of approaches, and certain safety countermeasures. While vehicles were more likely to stop before or at the stop bar based on approach type, and when roadway countermeasures such as lighting, on-pavement signage, speed humps, or channelizers were present. The results from this research contribute valuable insight and recommendations to local Ghanaian road safety agencies. This provides guidance for safety professionals to select solutions and use as a valuable tool to predict the economical effectiveness of solutions addressing junction safety in low- and middle-income countries (LMICs) like Ghana.

Authors	Zhangcun Yan, Tongji University Lishengsha Yue, University of Central Florida Nicolas Saunier, Ecole Polytechnique de Montreal Jian Sun, Tongji University
Sponsoring Committee	Standing Committee on Human Factors of Infrastructure Design and Operations (ACH40)
Session Number	3039
Session Title	Pedestrians, Bicyclists, and Driver Interactions
Paper Number	TRBAM-24-06090
Paper Title	Investigating and Modeling Motorized and Non-Motorized Interaction Behavior in Shared Spaces of Intersections
Abstract	Motorized and non-motorized vehicles (NMVs) are mixed together within the shared space of intersection, and the interaction rules between the vehicles are uncertain, significantly affecting traffic efficiency and operational safety, also representing a major challenge for autonomous vehicles. In order to have an accurate understanding of the interaction mechanisms between motorized and NMVs in a shared space. In this study, two intersections with high density of machine non-interaction behaviors were investigated, videos were recorded, and 8160 vehicle trajectory data were extracted by processing the videos using YOLOV7+Deepsort algorithm. We extracted 183 complete chains of motorized and NMV interaction events by computing the agent safety index TTC. Latent variables affecting the interaction course that influence the occurrence of conflicts were defined in terms of six aspects: vehicle driving purpose at the intersection, vehicle motion state, surrounding traffic environment, signal timing, interaction behavior, and NMV type.The conflict model is built with the ordered logit model. The results found that there are 10 significant influencing variables affecting the risk of vehicle conflict, vehicle traveling direction, vehicle speed, distance to potential conflict points, phase green light time, and vehicle type. The study provides a reference basis for the development of active safety control and driver assistance strategies.

Authors	Alican Karaer, Iteris Masoud Hamedi, Iteris
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2213
Session Title	Safety Performance of Connected Automated Vehicles
Paper Number	TRBAM-24-06151
Paper Title	Intersection Safety Risk Scoring using Connected Vehicle Data and Machine Learning: A Case Study in Atlanta Region
Abstract	Signalized intersections are often considered critical crash hotspots due to the presence of multiple conflicting movements. Traditional intersection safety studies have been conducted using historical crash data which is a reactive approach as it requires multiple years of crash records. The advancements in connected vehicle (CV) technology introduced a wealth of vehicle motion data, such as hard acceleration/braking events, highly granular trajectories, and segment-wise speeding proportions. This study proposes a framework utilizing these emerging data sources to demonstrate their viability on network screening for signalized intersection safety assessment even in the absence of up-to-date crash data. As proof of concept, CV event data and intersection characteristics are linked and compared with two years of crash data in the metropolitan area of Atlanta, GA covering 3,853 intersections. Exploratory analysis revealed that hard acceleration is the most significant factor followed by hard braking and traffic volume. To predict the number of crashes using this emerging dataset at each intersection, Negative Binomial Regression (NBR) and two Machine Learning (ML)-based models, namely Random Forest (RF) and Extreme Gradient Boosting (XGBoost), are employed. All models ranked the intersections with a relatively high ranking-order correlation coefficient, While ML models outperformed the NBR model. The XGBoost model predicted the number of crashes with an error margin of ±22 per intersection. By reducing reliance on historical crash data, the proposed methodology empowers stakeholders to efficiently rank signalized intersections based on safety performance and prioritize critical locations for future investments or policy development.

Authors	Yuhe Bai, Tongji University Ling Wang, Tongji University Zicheng Su, Tongji University Yingying Xing, Tongji University Wanjing Ma, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	Safety Performance and Analysis
Paper Number	TRBAM-24-06302
Paper Title	Rear-End Conflicts Prediction based on Vehicle and Roadside Data
Abstract	The frequent occurrence of expressway traffic crashes not only greatly affects the efficiency of road traffic, but also seriously damages people and property. The conflict prediction of the expressway is a hot topic in the field of traffic safety research. Traditional research mainly uses fixed detector data, and the spatial-temporal dimension is highly aggregated, which greatly limits the precision and accuracy of prediction. The increasing deployment of connected vehicles (CVs) offers spatiotemporally continuous trajectory data, and it is important to note that the effectiveness of conflict prediction varies with different CV penetration rates. An expressway conflict prediction model based on convolutional neural networks (CNNs) is established using data combining both CVs and roadside from the Shanghai Inner Ring Expressway. The findings reveal a positive correlation between the increasing penetration rate of CVs and the model's predictive performance, demonstrating a continuous rise in effectiveness, ultimately achieving an AUC of 0.92. As the CV penetration rate reaches approximately 50%, the effectiveness of the model based on both data sources stabilizes, showing minimal difference from the model using CVs data alone. The SHAP method identifies key influential factors of rear-end conflicts, including differences in vehicle speeds, longitudinal acceleration, distances, and traffic flow, enhancing the model's interpretability. The results of this study can be used as a key input for active road safety control, to effectively improve road traffic safety and prevent crashes.

8 Real-Time Safety Prediction

Mohamed Abdel-Aty, Heesub Rim, Md Rakibul Islam, and Samgyu Yang
University of Central Florida

Studies related to real-time safety prediction aim to improve traffic safety by identifying locations with a high probability of crashes in the near future. The prediction of crash-prone locations could contribute to establishing and operating active traffic management (ATM) to reduce the likelihood of crashes. The subcommittee identified **twenty-seven papers** related to real-time safety prediction. The papers are classified by the outcomes of the predictive models, data sources, methodologies, and types of facilities.

Considering the **outcomes of predictive models**, multiple papers analyzed real-time crash risk and roadway safety based on traffic conflicts (24-05149, 24-05150, 24-00302, 24-00954, 24-04593, 24-05833, 24-00080, 24-01982, 24-03281, 24-03408). Papers (24-01380, 24-03288, 24-05116, 24-00465, 24-01789, 24-02111, 24-03253, 24-03198) focused on real-time traffic incident detection/prediction. Additionally, paper (23-04915) focused on predicting traffic restoration time following a crash occurrence considering crash types, severities, and weather conditions. Further, paper (24-05133) studied the relationship between conflict and actual crash frequencies in real-time traffic safety. Moreover, paper (24-01282) analyzed the crash influencing variables in terms of different advanced traffic management (ATM) strategies.

Some studies introduced **distinct data sources** into the real-time safety prediction. Specifically, studies (24-05149, 24-05150, 24-05133, 24-04593, 24-03198) utilized vehicle trajectory data extracted from video image processing algorithms to assess real-time traffic safety. One study (24-00954) adopted radar-camera fusion devices to collect high-precision trajectory data, employing it as a primary input source of conflict assessment model. Further, floating car data (FCD) was leveraged in paper 24-03288 to address the spatial-temporal traffic dynamics in predicting crash potential. The trajectories from connected vehicles (CV) or connected and automated vehicles (CAV) environments were also incorporated into several papers (24-04419, 24-04593, 24-01136, 24-04924) to develop safety prediction models. Furthermore, in paper 24-05833, both traffic simulation and actual data were employed to develop and evaluate real-time road safety evaluation system respectively. One paper (24-01789) collected individual vehicle maneuver data (Digital Tachograph data) from commercial vehicles to classify risky traffic conditions and develop a crash prediction model.

Multiple **methodologies** were proposed to predict safety parameters in real-time. Most of the studies adopted machine learning and deep learning techniques such as Artificial Neural Network (ANN) (24-01380, 24-00302, 24-00465, 24-00998), Support Vector Machine (SVM) (24-00302, 24-00465, 24-01789), Long Short-term Memory (LSTM) (24-03288), Graph Convolutional Network and Long Short-term Memory (GCN-LSTM) (24-05116), Convolutional

Neural Network (CNN) (24-04593), Dynamic Bayesian Network (DBN) (24-04924), K-means clustering (24-01789), Time Series Generalized Regression Neural Network and binomial Weighted Convolutional Neural Network (TSGRNN-WCNN) (24-02111), Spatio-Temporal Composite Multi-Graph Convolutional Neural Network (STCM-GCN) (24-03253), and Bidirectional LSTM (Bi-LSTM) (24-00998). In addition, some studies adopted tree-based data-driven methods such as eXtreme Gradient Boosting (XGBoost) (24-01282), Random Forest (RF) (24-00302, 24-01789, 24-03408), CatBoost (24-03351), and BPNN AdaBoost (24-03408). On the other hand, some studies proposed statistical approaches such as rigid regression model (24-05149), Extreme Value Theory (EVT) (24-05150), Gaussian Process Regression (GPR), Weibull distribution model (24-03068), Smoothly Clipped Absolute Deviation (SCAD) logistic regression model (24-00080), logistic regression and multinomial logistic regression models (24-01982), Bayesian-based random parameters logistic regression model (24-03281), non-stationary bivariate extreme value model (24-03198).

Moreover, in addressing heterogeneity of traffic conditions across each segment in a large-scale network, the paper 24-01380 introduced spatial ensemble and knowledge distillation concepts. Further, one study (24-00465) introduced the strategy of just-in-time-learning (JITL) to improve the performance of the base learner prediction model on the premise of diluting prior knowledge allowing the model to simultaneously train and predict online.

In terms of roadway **facility types**, some studies focused on the specific segment types such as expressway diverging area (24-00954), weaving section of expressway (24-03281), mountainous freeways (24-05116), mountainous two-lane roads (24-02119), elevated expressway (24-00465), and toll plaza diverging area (24-03408). Furthermore, two papers focused on the pedestrian safety on signalized intersections (24-03198) and mid-blocks without crossing facilities (24-00998). Otherwise, most of the studies focused on the traffic safety on generic freeways.

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

Authors	Yiran Shao Junhua Wang, Tongji University Ting Fu, Tongji University Qiangqiang Shangguan, University of Waterloo Hao Song, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-01282
Paper Title	**Exploring the Traffic Flow Parameter Optimization Method of Freeway based on Real-time Crash Prediction Model and Interaction of Crash Influencing Variables**
Abstract	The results of crash prediction and traffic flow parameter optimization can assist the management department to carry out active traffic management and ensure the freeway driving safety. However, most previous studies did not consider the interaction between multiple influencing variables in the traffic flow parameter optimization, which made it difficult to guarantee the practicability and effectiveness of the active traffic management method by adjusting the influencing variables. In order to fill the gaps in the above research, this study proposes a traffic flow parameter optimization method considering the interaction effects of the crash influencing variables. The eXtreme Gradient Boosting (XGBoost) model was introduced to build the crash prediction model, and the Shapley Additive exPlanations (SHAP) algorithm was used to analyze the interaction between the crash influencing variables. The results show that three active traffic management and control modes can be divided according to the different interactions between variables. The optimized crash rates are reduced by 56%, 35% and 65% respectively, and the optimization effect is better than the original optimization method. The findings from this study are expected to have significant implications for active traffic management, which can improve the safety level of expressway operation.

Authors	Md Rakibul Islam, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Dongdong Wang, University of Central Florida Zubayer Islam, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-01380
Paper Title	**Spatial Ensemble Distillation Learning for Large-scale Real-time Crash Prediction**
Abstract	Large-scale real-time crash prediction is critical to traffic safety planning, but very challenging, even for machine learning models because the observation data are not independent and identically distributed (non-IID) due to its spatial heterogeneity. We propose a generic framework, which blends spatial ensemble learning and knowledge distillation, to address this non-IID problem. Spatial ensemble learning leverages zonal expert modeling to alleviate the non-IID issue for more accurate crash prediction, while knowledge distillation reduces the model size and improves false alarm rate. We justify the effectiveness of this method on I-75 freeway in Florida for large-scale real-time crash prediction by comparing it with the current benchmark models. Our method successfully improves sensitivity and false alarm rate to 90.35% and 24.21%. With this more accurate prediction model, we analyze the prediction variability across this region. We found that: 1. across segments, false alarm rate exhibits more heterogenous pattern than sensitivity; 2. more rear-end crashes are more accurately predicted compared to sideswipe/angle crashes; 3. urban segments show better prediction performance compared to rural segments. 4. Developing models with desired accuracy needs special attention in higher traffic fluctuation zones. These observations are very useful to develop more accurate prediction model and traffic safety decision making. To the best of our knowledge, this is the first study to integrate spatial ensemble learning and knowledge distillation to predict large-scale real-time crashes and apply it to analyze crash prediction variability.

Authors	Yuxuan Wang, Southeast University Pan Liu, Southeast University Kequan Chen, Southeast University Chengcheng Xu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-05149
Paper Title	**Evaluating the predictability of surrogate safety measures using real-world crash trajectory data**
Abstract	There is still no consensus on the effectiveness of these SSMs. This study aims to address this issue through the following objectives: (1) to propose a method for estimating and comparing the predictability of SSMs and (2) to investigate factors contributing to their predictability. To achieve these goals, we collect 20 rear-end crashes by drones in Nanjing, China, during a year of video collection. A computer vision algorithm is used to extract trajectory data from real-world crashes. Then, we define the real-time predictability of SSMs by considering the SSM threshold and the early warning time (i.e., how far in advance to predict crashes) based on Bayes' theorem. Subsequently, we establish a ridge regression model to explore factors affecting the SSMs' predictability, including the predefined threshold, early warning time, and dynamic interaction variables between two consecutive vehicles. Four commonly used SSMs for rear-end crashes are investigated in this research. It is found that the predictability of SSMs could be estimated as the product of the prior crash probability and ratio between recall and false alarm rate. Among the selected SSMs, time-to-collision (TTC) and modified time-to-collision (MTTC) performance well with comparable results considering overall effectiveness. The deceleration rate to avoid a crash (DRAC) follows closely behind TTC and MTTC, whereas the Potential index for collision with urgent deceleration (PICUD) significantly underperforms these three indicators. Moreover, the ridge regression results indicate that different SSMs are affected by different factors. These findings provide valuable insights for evaluating and improving SSMs.

Authors	Yuxuan Wang, Southeast University Pan Liu, Southeast University Chengcheng Xu, Southeast University Ke quan Chen, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-05150
Paper Title	**Assessing and guiding conflict techniques for real-time crash detection using extreme value theory and real-world crash trajectories**
Abstract	Surrogate safety measures (SSMs), serving as a promising alternative approach for estimating crash frequency, has been widely explored in the literature. As the Intelligent Transportation System rapidly advances, many efforts turn to integrate SSMs into vehicle-level crash risk estimation. The reliability of these results depends on the robust predictive capacity of SSMs in real-time conditions. To date, how to evaluate whether the SSMs possess this predictive ability remains an unclear issue. Hence, this article extends Extreme Value Theory (EVT) to investigate the performance of current SSMs when used as microscopic evaluation metrics and guides on their application. Our research team conducted a drone video recording survey on every sunny weekday for one year at a bottleneck segment in Nanjing, China. This survey produced a unique trajectory dataset that covers the formation process of 20 rear-end crashes. We propose an EVT model with block maxima sampling approach to investigate the distribution of extreme events in the non-crash and crash conditions, respectively. The crash condition is further divided into different forecast windows to unveil the predictability of SSMs as the time approaches the crash moment. We test the proposed framework into two widely used and accepted SSMs: Time-to-Collision (TTC) and Absolute value of Derivative of Instantaneous Acceleration (ADIA). We find that TTC outperforms ADIA across various forecast windows. With the forecast window widening, the performance of both TTC and ADIA diminishes. Furthermore, we report optimal threshold curves for TTC and ADIA, offering guidance on their usage under different forecast windows.

Authors	Yuxuan Wang, Southeast University Pan Liu, Southeast University Chengcheng Xu, Southeast University Qingyun Li
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2096
Session Title	**Safety Performance and Analysis**
Paper Number	TRBAM-24-05133
Paper Title	**The validity and application of Time-to-Collison based on real-world crash trajectory data**
Abstract	The validity of surrogate safety measure (SSM) holds paramount importance since numerous previous studies of traffic safety analysis relied on traffic conflict events identified by SSMs. This paper aims to assess the effectiveness of conflicts to be an alternative to crashes. To achieve this goal, we conducted a drone video survey on a Chinese expressway from 2021 to 2022. The recordings consistently capture the morning peak hours (2 hours) on every sunny weekday. An automatic algorithm is employed to extract vehicle-level trajectories from each video. In total, we obtain 200 hours of trajectory data, which includes 20 rear-end crashes. A sliding window approach is first proposed to segment the whole one-year survey into a series of field observations. In each field observation, a widely used SSM known as Time-to-Collision (TTC) is utilized to identify all traffic conflicts. The ratio between the number of conflicts and actual crash frequencies is calculated to represent their relationship. The validity of TTC is reflected by the variance of ratios across these field observations. Our results highlight that the TTC has the optimal relationship with crashes when the TTC thresholds range from 0.4s to 0.8s. According to the proposed ratio, we further investigate the impact of the observation period of conflicts, TTC thresholds, and the estimation period of crashes on the validity of TTC. These results can guide us in effectively applying TTC in different scenarios. Finally, the transferability test demonstrates that our conclusions are valid and replicable under different locations and traffic conditions.

Authors	Chenwei Wang, Southeast University Jie He, Southeast University Xintong Yan, Southeast University Zhang Changjian, Southeast University Yuntao Ye, Southeast University Pengcheng Qin, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-00302
Paper Title	**Real-time Conflict Prediction on Freeways under Different Vehicle Interaction Scenarios using Short-term Vehicle Kinematic Characteristics with temporal variability**
Abstract	Real-time conflict prediction is an emerging research perspective of proactive road safety measures, which can prevent potential traffic crashes. Previous research used macroscopic traffic flow data in a long-time range while underestimating the short-term vehicle kinematics before the conflict event. This study introduced short-term kinematic-based and status-related characteristics under different vehicle interaction scenarios to explore whether there would be a potential conflict. Sixteen short-term vehicle characteristics were derived from vehicle trajectories of Shanxi Wuyu freeway, China. Three vehicle interaction scenarios (conflicts, normal intersections, and undisturbed passings) and two conflict types (rear-end and sideswipe) were included in conflict prediction. Twelve conflict prediction models based on Random Forest, Support Vector Machine, and Artificial Neural Network were compared and the under-sampling algorithm was employed to solve the sample imbalance. The results indicated that conflict prediction between conflicts and normal interactions based on Support Vector Machine presented the best prediction performance with a higher score of evaluation metrics. Moreover, the most vital kinematic-based characteristic was the mean of longitudinal velocity, and the hour of conflict occurrence was an indispensable status-related characteristic. The discussion of the time window reflected that the shorter time range of vehicle trajectories before conflict events improved the performance of the real-time conflict prediction model. Eventually, the proposed real-time conflict prediction models and contributing factors provide a novel way to estimate conflicts easier than extracting them from complex kinematic relationships among vehicles, which contributes to designing further proactive safety systems for conflict warnings implemented on vehicle dashboards.

Authors	Xiao-chi MA, Southeast University Jian Lu, Southeast University Jun Zhang Junde Chen Chao Gu
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-00954
Paper Title	**Traffic Conflict Risk Assessment in Expressway Diverging Area Based on High-precision Radar-camera Fusion Data**
Abstract	To ensure the traffic safety of the expressway diverging area and overcome the shortcomings of current data collection methods, radar-camera fusion device is applied to collect trajectory data to establish a real-time traffic conflict assessment model. Firstly, over 35 million high-precision trajectory data were collected in an expressway diverging area for 55 hours. Then, a new conflict probability metric based on time-to-collision (TTC) and volume is proposed. Various generalized linear and machine learning methods are used to obtain the assessment model. Variable features and their interactions are explained by ANOVA and partial dependency plot (PDP) respectively. In view of the counterintuitive phenomenon in the PDP interpretation, SHAP is used to specifically analyze the driving scenario represented by the outlier data. The results indicate that the regression performance of Gaussian process regression (GPR) model is better than other models on multiple data sets. In the dataset with TTC threshold of 3s, the AUC of GPR reaches 0.886. Furthermore, the model interpretation results using conflict probability metric all show the high risk of lane change behavior, while the traditional binary classification metric ignores that. The PDP and SHAP in GPR suggest that the conflict probability has a peak in three scenarios: congestion state, speed fluctuation and frequent lane change in near-saturation state. In conclusion, radar-camera fusion device collects fine trajectory data, and establishes a Gaussian process regression model based on conflict probability metric, which has both high accuracy and interpretability, and provides a theoretical basis for driving risk scene recognition and assessment.

Authors	Xuesong Wang, Tongji University Yifan Wang Mohammed Quddus, Imperial College London Tonggen Wang, Shanghai Electric Vehicle Public Data Collecting, Monitoring and Research Center
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-03288
Paper Title	**Real-time Expressway Crash Prediction using Floating Car Data**
Abstract	The likelihood of traffic crashes is significantly affected by short-term turbulence of traffic flow, which is increased on expressways due to high traffic volume and speed. Real-time traffic safety models have potential to capture this variation in traffic flow to accurately predict crashes, but data collection methods used in previous studies cannot effectively acquire the necessary spatio-temporal traffic dynamics. Floating car data (FCD), using the kinematics information collected by multiple single vehicles, provides a way to acquire this information on traffic flow before crashes occur. This study aims to develop a real-time crash prediction model based on FCD from the Urban and Outer Ring Expressway in Shanghai, China. Because new algorithms have more power to extract time-varying characteristics, a long short-term memory network (LSTM) was used with added bidirectional mechanism and attention mechanism to improve the model's performance. The approach involved segmenting the roads; map matching FCD and crash data; aggregating FCD into three pre-crash time periods for the current, upstream, and downstream adjacent segments; crash and non-crash sampling by matched case-control; and conducting a Mann-Whitney U test. By analyzing speed, speed standard deviation, and FCD volume, it was discovered that drivers tended to take measures to escape complex traffic situations to arrive at relatively safe places downstream. The bidirectional LSTM model with attention mechanism reached 87.98% accuracy, 76.38% recall, and 78.23% precision, significantly higher than comparable models without those mechanisms. This model can be applied in detecting dangerous traffic flow, evaluating real-time intervention measures, and providing alerts to drivers.

Authors	Raghupathi Kandiboina, Iowa State University Varsha Mouli, Iowa State University Guillermo Basulto-Elias, Iowa State University Skylar Knickerbocker, Iowa State University Neal Hawkins, Iowa State University Anuj Sharma, Iowa State University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-04419
Paper Title	**A Real Time Freeway Crash Detection Framework using Connected Vehicle Waypoint Data**
Abstract	Accurate and timely detection of traffic accidents is of crucial for transportation agencies seeking swift responses and effective traffic management, particularly on freeways where crash severity and traffic flow disruptions are amplified. While several methods have been developed using cameras or infrastructure-mounted sensors, these approaches may face challenges in geographical scalability. To address this, we present a novel approach using real-time connected vehicle data, collecting continuous information at the journey-level with a market penetration rate of 4-7%. The results demonstrate promising outcomes, achieving an overall accuracy of 63.5% with 4.1% false detections and 33.4% non-detections by extracting five key features from individual journeys. This accuracy surpasses the speed-alone model using the same data by 24%. Furthermore, higher traffic volumes lead to even greater accuracy, exceeding 80% at levels of service D and 90% at level of service E. The developed algorithm also exhibits precision in crash detection, with a mean latency of only 2.5 minutes after the actual incidents. This study highlights the potential of connected vehicle data in enhancing crash prediction methods and underlines its value for future transportation systems' efficiency and safety.

Authors	Yesihati Azati, Tongji University Xuesong Wang, Tongji University Mohammed Quddus, Imperial College London Xuefang Zhang, Tongling University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-05116
Paper Title	**Graph Convolutional LSTM Algorithm for Real-time Crash Prediction on Mountainous Freeways**
Abstract	Accurate real-time traffic crash prediction is crucial for proactive traffic safety management. Currently, most real-time models predict crashes at 15-minute intervals to apply their results toward intelligent transportation systems, but the intervals may be too short to be useful for manual proactive traffic safety management to deploy traffic law enforcement and emergency rescue resources. Therefore, this study conducts hourly crash prediction to provide relevant departments with enough time to take measures in advance. A section of a mountainous freeway in Guizhou province was divided into homogeneous segments, with crash data, traffic operations data, and meteorological data collected hourly. As the result was an imbalanced dataset of crash and non-crash instances, the training dataset was resampled using synthetic minority over-sampling technique (SMOTE) to address the issue. To fully capture the complex spatiotemporal relationships in the data and achieve high crash prediction accuracy, a GCN-LSTM model was constructed for the first time, combining a graph convolutional network (GCN) and long short-term memory (LSTM) neural network. For comparison purposes, LSTM, Extreme Gradient Boosting (XGBoost), and logistic regression (LR) models were developed. The results showed that the GCN-LSTM model outperforms other models in hourly traffic crash prediction, and the optimal prediction performance was achieved with the crash-to-non-crash ratio of 1:4. The GCN-LSTM method was found to effectively capture the complex spatiotemporal relationships in prediction data and to handle imbalanced traffic crash data.

Authors	Ahmed Mohamed, University of Cincinnati Lizhe Li, University of Cincinnati Mohamed Ahmed, University of Cincinnati
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-04593
Paper Title	**Automated Traffic Safety Assessment Tool Utilizing Monocular 3-D Autonomous Vehicle Algorithm at Signalized Intersections**
Abstract	Traffic conflict analysis has gained significant attention over the last few years. Recent research has made significant progress in the development of detection and tracking systems, utilizing various technologies such as closed-circuit televisions, unmanned aerial vehicles, and sensor fusion exploiting light detection and ranging. By examining the challenges facing the widespread of real-time traffic conflict detection and analysis techniques, this study utilized Center Track Convolutional Neural Network (CNN) based algorithm, that is essentially developed for autonomous vehicle systems, to detect and track road users at signalized intersections. The primary advantage of this algorithm lies in its ability to depict road users through the utilization of three-dimensional bounding cuboids. In an effort to refine the precision of the tracking process, this study further incorporates a suite of post-processing algorithms. These are specifically designed for data augmentation, the reconstruction of seamless trajectories, and the accurate estimation of vehicle states and indicators. This representation method simplifies the entire traffic data processing procedure and improves the detection for better establishment of an automated safety assessment tool utilizing Artificial Intelligence. The algorithm has been examined on various video footages and proved its detection superiority for high traffic volumes at intersections with an overall precision of 95.08%, and a recall of 92.81%. It exhibited exceptional accuracy and efficacy in identifying a range of crucial conflict scenarios, achieved through the application of four unique traffic conflict indicators.

Authors	Songha Lee, Hanyang University Juneyoung Park, Hanyang University Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-03068
Paper Title	**Hazards-based Duration Time Model with Priorities Considering Unobserved Heterogeneity Using Real-time Traffic and Weather Big Data**
Abstract	Because non-recurrence congestion on expressways is more difficult to predict compared with repetitive congestion, strategies are needed to reduce the severity of accidents by responding in advance. In this study, we define a model to analyze accident duration on highways using dynamic (e.g., vehicle detection and weather sensor) and static (e.g., historical accident database and roadway geometry designs) datasets. The model includes the parametric distribution of the accelerated failure time model (e.g. Weibull, log-logistic, log-normal), temporal stability and unobserved heterogeneity, which can parametrically estimate the time to hazard to provide the conditional probability that the crash will be resolved. The results show that the Weibull distribution model with random parameters was suitable for both injury and non-injury crashes, and differences in truck, rain, rollover, and temporal traffic characteristics increase the duration time. Also, when the weighted to the length of the response time and detection time are applied to the duration time, the shorter the response time, the shorter the duration time for injury crash, and without injury crashes, the faster it should be detected and arrived at the scene. It is therefore necessary to establish a traffic safety management strategy that includes periodic highway patrol programs and emergency vehicle support services to minimize the risks of secondary accidents and extreme congestion.

Authors	Haozhan Ma, Southeast University Linheng Li, Southeast University Bocheng An, Southeast University Ziwei Yi, Southeast University Xu Qu, Southeast University Bin Ran, Southeast University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-01136
Paper Title	**Mass-based Omni-directional Risk Indicator (MORI): A Novel Approach for Quantifying Risk in Multi-Participant, Two-Dimensional Traffic Scenarios**
Abstract	Real-time quantified risk indicators are crucial for improving driving safety and must be tailored to the specific characteristics of the CAV environment. To this end, this paper introduces the concept of "risk pair" to decompose the joint actions of multiple traffic participants into pairwise interactions. First, an Omnidirectional Risk Indicator (ORI) is developed to describe the effect of "risk pairs", and the superposition of ORI based on quality is proposed as the Mass-based Omni-directional Risk Indicator (MORI). Furthermore, in the context of car-following scenarios, a comparison between MORI and existing risk substitute indicators shows that MORI has good performance in quantifying one-dimensional scenarios. Finally, in two-dimensional scenarios involving multiple participating entities, MORI provides two quantitative results: vector summation (VS) and scalar summation (SS). The results show that both VS and SS of MORI demonstrate strong risk quantification capabilities with different directions. Although some limitations of MORI still exist, it is expected that this approach will provide a scientifically effective means of risk quantification for two-dimensional complex scenarios.

Authors	Haiyi Yang, Beijing University of Technology Xiaohua Zhao, Beijing University of Technology Sen Luan, Beijing University of Technology Hang Qi, Beijing University of Technology Yujia Xiang
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-03351
Paper Title	**Analysis of Factors Affecting Traffic Safety Risks in National Trunk Highway System: Using Interpretable Machine Learning Framework**
Abstract	The prevailing approach to traffic safety risk assessment relies on scarce and challenging-to-access accident-related data. Aggressive Driving Behaviors (ADBs) are a significant cause of accidents, but few studies have explored risk assessment methods based on ADBs and traffic status data. In this study, Non-negative Matrix Factorization (NMF) extracts latent risk variables to compute the Traffic Risk Score (TRS). Prominent machine learning algorithms establish the relationship between traffic risk levels and traffic status, road, environment, and periods characteristics. The Partial Dependence Plots (PDP) algorithm identifies influencing factors. Results indicate: 1) TRS effectively distinguishes high and low-risk roads, with more fatal accidents associated with higher TRS; 2) The CatBoost algorithm demonstrates superior performance, with traffic status characteristics having the most significant impact on identifying safety risk levels, followed by road characteristics; 3) Main effects show risk variables positively associated with safety risk include the difference between average speed and speed limit, speed standard deviation, and the number of roadway entrances and exits. Conversely, risk variables negatively correlated with safety risk include the proportion of trucks, inclement weather, and the number of median openings; 4) Interaction analysis shows that when the difference between average speed and speed limit exceeds 17.5 km/h, an increase in road section entrances and exits intensifies traffic safety risk. Additionally, with two or fewer median openings, the negative impact of speed standard deviation on safety risk diminishes as it increases. The proposed analysis framework provides valuable insights for further research on real-time traffic safety evaluation.

Authors	Sultana Rajia, Tokyo Institute of Technology Yasunori Muromachi, Tokyo Institute of Technology Moinul Hossain, Islamic University of Technology
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-04924
Paper Title	**Safety Assessment of Automated Vehicle (AV) Driving Logics under Mixed Traffic Using Real-Time Crash Prediction Model**
Abstract	Successful implementation of automated vehicle (AV) technology can be achieved through proper safety evaluation which in the future will be required for informative decision-making during large scale deployment of automated vehicles (AVs). The focus of this paper is two folds: understanding appropriate parameter setting for AVs by examining the behavioral models from preceding studies, and evaluate the corresponding crash risks under mixed traffic operation. After reviewing the preceding studies and two large scale real-world projects: CoEXist Project and UK Auto drive, parameters were set for three driving environments - normal, cautions, and all-knowing. Safety assessment for these driving environments were conducted using a Dynamic Bayesian Network (DBN) based real-time crash prediction model. The safety assessment showed that crash risk can be reduced by 21.9%, 22.3%, and 17.6% under normal, cautious, and all-knowing driving behaviors, respectively, with mixed scenarios. Results also exhibited that with higher market penetration rates, some of the driving volatility measures were reduced such as less lane changing, maintaining homogeneous speed and headways. Furthermore, difference of up and downstream speed has significant impact on crash risk estimation and its reduction was found to be associated with lower levels of risk.

Authors	Yu Wu Hao Yang, McMaster University Harith Abdulsattar, American University of Beirut
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-05833
Paper Title	**Development of A Novel Real-time road safety evaluation system**
Abstract	This research aims to develop a real-time, comprehensive, practical, and reliable safety performance evaluation system for road segments, taking into account various types of potential collisions. The system considers potential rear-end collisions on straight roads and side-impact collisions within intersections. The probability and severity of potential collisions are estimated using real-time vehicle trajectories, and a real-time risk score is defined to assess the safety performance of road segments. In this paper, we propose a predicted PET based on the anticipated trajectories of vehicles at intersections. Simultaneously, this research also takes into account near-side and far-side impact collisions. Furthermore, model justifications based on simulation data are conducted to demonstrate the system's effectiveness in identifying potential conflicts near intersections. An empirical analysis of two real-world intersection datasets is performed to evaluate the system's performance with actual data. The developed system lays the groundwork for municipalities and government agencies to adopt a safety-based road management approach and identify vulnerable locations within specific areas.

Authors	Dan Wu, Central South University Jaeyoung Lee, Central South University Ye Li, Central South University
Sponsoring Committee	Standing Committee on Transportation Safety Management Systems (ACS10)
Session Number	2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-00080
Paper Title	**Real-Time Conflict Prediction: Trajectory Data-Driven Approach Incorporating Variable Interaction and Pre-Screening**
Abstract	The study aimed to analyze crash risks in the context of increasing traffic demands. It addressed the limitations of historical and trajectory data by investigating the effect of traffic state variables and their interaction terms on real-time conflict prediction. The Smoothly Clipped Absolute Deviation (SCAD) method was applied as a variable prescreening approach. Realistic vehicle trajectory data from HighD were selected and processed, which can be aggregated to extract both traffic state and corresponding conflict data during a specific time interval (10s). As for the conflict detection, the Time-to-Collision (TTC) index was utilized to identify risky conditions. For different categories of lanes (i.e., inner, middle and outer lanes), the impact of variables, including interaction terms, on conflicts was explored using the SCAD-logistic regression models. Furthermore, machine learning models were employed to compare the conflict prediction performance before and after considering interaction terms, as well as before and after variable prescreening via the SCAD method. Results indicate that the interaction terms between traffic state variables do have a substantial impact on the conflicts. Besides, considering interaction terms and variable pre-screening based on the SCAD method is significant for enhancing conflict prediction accuracy. Furthermore, it is indicated that the above proposed machine learning models outperform Random Forest (RF) in terms of predicting conflicts for different types of lanes. The findings of this study contribute to the high-precision prediction of real-time conflict in the future.

Authors	Xiao-chi MA, Southeast University Jian Lu, Southeast University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-00465
Paper Title	**Application of Just-in-time-learning Strategy on Machine-learning-based Crash Risk Prediction of Elevated Expressway**
Abstract	Crash risk prediction system effectively supports risk management and travel guidance. To achieve the accuracy of complex machine learning prediction models and overcome the defects of verbose parameter adjusting required for complex models, the strategy of just-in-time-learning (JITL) was introduced to improve the performance of the base learner prediction model on the premise of diluting prior knowledge. JITL builds the subset of similar samples of the data to be tested via similarity, and simultaneously models and predicts online. Two base learners including artificial neural network and support vector machine were developed. Principal component analysis (PCA) was used to reduce the data dimension and time cost. Taking the crash data of Shanghai elevated expressway as a case, the crash risk prediction model was established by regressing traffic flow data, and the performance of the prediction models with or without JITL strategy was compared. The result shows that the performance of base learners was improved after the JITL has been applied, specifically in AUC, sensitivity, and false alarm rate. Meanwhile, the performance of JITL-based model is closely related to the size of subset of similar samples. The number of subset samples and the performance of the model show a concave function shape. Furthermore, by combining PCA and JITL strategy, the performance of base learner models is further improved, and the running time of a single prediction is on the order of milliseconds, which can be applied to real-time prediction system with high data sampling frequency.

Authors	Nuri Park, Hanyang University Juneyoung Park, Hanyang University Ling Wang, Tongji University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-01789
Paper Title	**Digitalized Vehicle Maneuver-based Real-time Crash Risk Prediction using Multi-Stage Machine Learning Approach**
Abstract	The selection of indicators that can catch risky traffic flow is important to predict crash risk on highways. Unsupervised machine learning techniques can be a new approach to deriving important crash risk indicators. This paper applies a multi-stage methodology using both unsupervised and supervised machine learning techniques systematically to evaluate crash risks. The proposed multi-stage methodology is composed of three stages. In the first stage, select variables that can classify risky traffic flow well using K-means clustering and Random Forest. The second stage is making a combination of selected variables. Lastly, the third stage is developing the support vector machine-based crash prediction models using selected variable sets. For the real-time crash prediction model, individual vehicle maneuver data (Digital Tachograph data) collected from the commercial vehicle were used. As a result of this study, new key variables required for the prediction model were derived through unsupervised learning, and the multi-stage models improved the predictive performance. This study proposes a new approach to selecting key variables when developing a crash prediction model.

Authors	Bowen Cai Léah Camarcat, Imperial College London, South Kensington Mohammed Quddus, Imperial College London
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-02111
Paper Title	**A new spatio-temporal causal inference-based CNN model for short-term crash prediction**
Abstract	Short time crash prediction is challenging for having extremely imbalanced dataset of excessive zeros, random crash occurrence, strong correlation with dynamic traffic variables, and being heterogeneity in nature. This paper puts forward a combined method of time series generalized regression neural network and binomial weighted convolutional neural network (TSGRNN-WCNN) model to capture both temporal and spatial features simultaneously in short time crash prediction. The model is trained and tested by employing real-world data that is collected with loop detectors for the M1 motorway in the UK in 2019 and the crash data is extracted from the STATS19 database for the same year with more than 99.99% data is non-crash. The joint TSGRNN-WCNN model conducts crash prediction by updating crash and traffic data in every period of 30 minutes. In the southbound direction, 75.3% crash events are correctly predicted, and 81.6% non-crash events are also identified accurately. In the northbound direction, 78.1% crash event are accurately predicted, and 80.2% non-crash events are predicted. Although GRNN and CNN models have been widely used in crash analysis respectively, the introduction of autocorrelation and seasonality temporal structure to GRNN, the innovative fitting procedure of binomial weighted CNN model to capture crash data distribution, and the combination of both methods to deal with time series and spatially correlated imbalanced crash data are novelties involved in this study. Causal inference is also applied to analyze explanatory variable importance. Results show that speed variances and speed are the most influential factors contributing to crash occurrence.

Authors	Pengfei Gao, Southwest Jiaotong University Bin Shuai, Southwest Jiaotong University Rui Zhang, Southwest Jiaotong University Bao Wang, Southwest Jiaotong University
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03253
Paper Title	**STCM-GCN: A Spatio-Temporal Prediction Method for Urban Road Traffic Accidents under Road Network Constraints**
Abstract	To further enhance the fusion and coordination of multi-source data for more accurate spatio-temporal prediction of urban road traffic accidents, this paper proposes a new method called Spatio-Temporal Composite Multi-Graph Convolutional Neural Network (STCM-GCN). The method integrates heterogeneous data with three attributes, i.e., spatial, temporal and spatio-temporal data. The spatial module utilizes residual-connected GCN blocks to capture spatial features based on road network topology and traffic pattern similarity. The temporal module employs a combination of multilayer bi-directional GRUs and self-attention mechanisms to extract temporal features. The spatio-temporal module combines residual-connected GCN blocks with GRUs to capture dynamic spatio-temporal information and incorporates spatio-temporal distribution information of traffic violations for the first time. The feature fusion module utilizes an attention mechanism to adjust the weights of the three feature components before fusion to obtain the final output. In addition, in order to reduce the sparsity of accident data, this paper also introduces accident police data as official data expansion. Experiments utilizing real-world data collected from Shenzhen, China, show that our model outperforms other baseline models in terms of overall prediction performance, robustness under various spatio-temporal conditions, and ability to capture positive instances. The ablation experiments further validate the rationality and necessity of our model design and structure.

Authors	Tianheng Zhu, Purdue University Ling Wang, Tongji University Yiheng Feng, Purdue University Wanjing Ma, Tongji University Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-01982
Paper Title	**Vehicle-group-based Crash Risk Formation and Propagation Analysis for Expressways**
Abstract	Studying crash risk on expressways is crucial for travel safety and efficiency. Previous studies primarily linked the number or likelihood of crashes on a road segment to traffic parameters or geometric characteristics of the segment, usually neglecting the impact of vehicles' continuous movement and interactions with surrounding vehicles. Meanwhile, limited-resolution input data posed challenges to capture the microscopic features of vehicles. Based on high-resolution vehicle trajectory data, this research set vehicle groups as study objects and analyzed risk formation and propagation mechanisms considering features of vehicle groups and road segments. Logistic regression models were built to predict the risk status of vehicle groups using variables from different time windows prior to risk occurrence. The findings revealed that proximity to on-ramps, past risky vehicle-group status, complex vehicle behaviors and compositions within vehicle groups, and congested traffic conditions would result in high crash risks. Conversely, smooth traffic flow conditions appear to help mitigate risks. Furthermore, a multinomial logistic regression model was developed to analyze the spatial risk propagation patterns, which were classified based on the trend of the occurrences of risks higher than a predefined threshold within vehicle groups. The results indicated that prolonged high-risk status, growth in vehicle-group size, and frequent lane changes are associated with adverse risk propagation patterns. Meanwhile, smooth driving state and high-risk vehicle-group initial state are linked to risk dissipation. This study's findings would facilitate researchers' and practitioners' understanding and prediction of vehicle-group safety, ultimately improving active traffic safety management and operations of Connected and Autonomous Vehicles.

Authors	Wenwen Qin, Kunming University of Science and Technology Huan Li, Kunming University of Science & Technology Xiaofeng Ji, Kunming University of Science and Technology Jinjing Gu
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-02119
Paper Title	**Dynamic Driving Risk Assessment for Mountainous Two-lane Roads Using Driving Risk Field Model**
Abstract	Due to the complex alignments and low-speed heavy trucks, the most frequent and dangerous interaction is in overtaking maneuver along mountainous two-lane roads, where a single vehicle overtakes at least two other ones, creating serious conflicts with opposite-direction vehicles. To manage and reduce a high potential of crash risk on mountainous roads, its quantitative assessment is necessary. However, few studies in the literature deal with this topic and there are no studies quantifying the entire driving risk during car-following and overtaking processes. This paper therefore introduces a novel driving risk assessment model namely driving risk field (DRF) using video-based trajectory data from unmanned aerial vehicles (UAVs), which takes vehicle environment and vehicle-vehicle interactions into consideration over different time instants. At each time instant, the driving risk of the vehicle is estimated as the sum of weighted risks over risk fields of obstacle, lane line and road boundary derived from DRF, which can capture the risk patterns corresponding to all collision types, such as rear-end, head-on, and single-vehicle collisions on mountainous two-lane roads. The proposed model is evaluated on 14h traffic videos recorded by UAVs from a typical mountain road in Yunnan, China. The results indicate that comparing to conventional surrogate safety measures, the performance of DRF model in car following and overtaking scenarios can comprehensively identify horizontal and vertical directions of potential risks around the vehicle. Furthermore, the proposed model outperforms current state-of-the-art risk field model in terms of reducing the dependence between relevant parameters and computational complexity.

Authors	Chunqing Liu Mengfei Liu Chao Liu Xinpeng Yao Nengchao Lyu, Wuhan University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03281
Paper Title	**Exploring Traffic Conflict Characteristics and Factors in Short Weaving Section of Expressway**
Abstract	In order to explore the characteristics of traffic conflicts in short weaving section on expressways and the reasons for their occurrence, this study conducted long-term and large-scale traffic flow observations specifically for the weaving areas of urban expressways, vehicle trajectory data and key parameters were extracted. This study proposes a set of methods for extracting rear-end and lateral conflicts. At the objective level, conflicts are calculated using surrogate safety measures, and false conflicts are filtered using the vehicle width virtual envelope rule and sliding time window method. At the subjective level, conflicts are verified through expert judgment. Considering individual vehicle, traffic flow, and longitudinal region factors, we construct a Bayesian-based random parameters logistic regression model to analyze the mechanism of traffic conflict influence. The research results indicate: The speed and deceleration-related indicators of individual vehicles and segments, as well as the traffic volume and longitudinal region, often have a significant impact on the occurrence of conflict events; Surprisingly, contrary to previous assumptions, the speed of individual vehicles is often lower when conflicts occur compared to when conflicts do not occur; Additionally, conflicts are concentrated in the weaving section and its upstream affected area when traffic density increases and interval average vehicle speed decreases. The conclusions of this study provide a certain theoretical support for the safety management and accident prevention in short weaving section of expressways.

Authors	Zhizhi Yang Lu Xing, Changsha University Siqi Zhong Yi Fei, Changsha University of Science and Technology Xi Li Kongning Jin Ou Zheng, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03408
Paper Title	**Estimating collision risk of toll plaza diverging area using traffic cross-sectional data**
Abstract	Although the cross-sectional traffic flow data has the advantages of being simple to access and more indicative of the general state of traffic, previous studies have rarely considered using cross-sectional data to investigate traffic safety. This study focuses on the extraction of cross-sectional traffic flow data and its application in predicting traffic safety in the diversion area of toll plazas. First, aggregation technology is used to obtain cross-sectional data, and ETTC is employed as a surrogate safety measure, while TOPSIS method and the entropy weighting method are utilized to propose a regional risk assessment indicator. Then, multiple machine learning methods are applied to build a collision risk evaluation model, which is evaluated using the random forest method and achieves a score of 90.03%, thereby confirming the validity of using aggregated section data. Furthermore, a Regional Risk Prediction Model is proposed using the BPNN AdaBoost algorithm, achieving an accuracy of 86.71% and demonstrating the best performance in predicting high-risk levels. The results show that the vehicle's location within the diversion area is the most influential feature variable in the collision risk evaluation model. Moreover, it is evident that upstream traffic conditions have a stronger impact on safety compared to the downstream segment, indicating varying safety conditions at different sites. The research's conclusions offer insightful information for proactive traffic safety management.

Authors	Hassan Bin Tahir, Queensland University of Technology Md. Mazharul Haque, Queensland University of Technology
Sponsoring Committee	Standing Committee on Safety Performance and Analysis (ACS20)
Session Number	4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-24-03198
Paper Title	**Estimation of real-time pedestrian crash risk by severity at signalized intersections using a non-stationary bivariate extreme value model**
Abstract	Pedestrian-vehicle interactions are deemed severe due to the vulnerability of pedestrians compared to the occupants of vehicles. As such, the severity of pedestrian crash risks has not been addressed in proactive safety evaluations based on traffic conflicts derived from video analytics. This study proposed a novel analytical framework to estimate real-time pedestrian crash risk by severity at the signal cycle level while incorporating the effect of time-varying exogenous variables. Specifically, the study proposed a non-stationary bivariate extreme value model to jointly model the Post Encroachment Time and Delta-V indicators for real-time pedestrian crash risk by severity estimation at individual signal cycles. The proposed framework is tested on 144 hours of video data collected from three signalized intersections in Queensland, Australia. The developed model showed that the increased frequency of pedestrian conflicts per cycle increases severe injury crash risk per cycle. Similarly, medium to high average pedestrian speeds per cycle have a high associated severe injury pedestrian crash risk compared to low average pedestrian speeds per cycle. Moreover, the developed model precisely predicted the mean severe and non-severe pedestrian crash frequencies over a period of five years when compared with the observed severe and non-severe pedestrian crash frequencies over the five years (2014 - 2018). In conclusion, the developed framework can precisely estimate the pedestrian crash risk by severity at the signal cycle level. Such proactive estimation of pedestrian crash risk by severity can help mitigate the risk of severe injury crashes to vulnerable road users.

Authors Ziqian Zhang
Haojie Li, Southeast University

Sponsoring Committee Standing Committee on Safety Performance and Analysis (ACS20)
Session Number 4070
Session Title **Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number TRBAM-24-00998
Paper Title **Prediction of jaywalker-vehicle conflicts based on encoder-decoder framework utilizing multi-source data**

Abstract Given the unexpected and sudden essence of jaywalking activity, it is important to develop predictive models for J-V conflicts to offer pre-conflict warnings for road users. This study introduces a novel encoder-decoder framework utilizing multi-source data for the prediction of J-V conflict severity. We define three encoders to represent three types of input data, (1) J-V interaction encoder (Bi-LSTM) extracting J-V interactive features, (2) jaywalker motion encoder (Bi-LSTM) representing jaywalker's historical motion pattern, (3) background information encoder (MLP) encoding features of jaywalker characteristics, traffic condition and environmental factors. Finally, features extracted by these three encoders are concatenated and transferred to the conflict severity decoder (MLP) to obtain the predicted severity level. We further conduct a case study using the surveyed video data at three mid-blocks without crossing facilities in Nanjing, China. The experimental results indicate that, compared to classical models, our Proposed encoder-decoder (Proposed ED) model yields the best and stable predictive metrics, i.e. Precision, Recall, F1 score and Accuracy. Moreover, the results of ablation study suggest that, with the incorporation of background information, the four evaluative metrics of the Proposed ED model have been greatly improved, with an average improvement of 24.291%. Additionally, the results of transferability analysis suggest that, when the ratios of samples from the new mid-block reaches 40% to 50%, the four metrics of the updated models could stabilize around 80% to 95%. Eventually, we also derive several practical suggestions from the above findings, in order to help with J-V conflict prediction and jaywalking safety improvement.

9 Safety Effects of Connected and Automated Vehicles

Stefano Coropulis and Vittorio Ranieri
Polytechnic University of Bari

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

The subcommittee identified **60 papers** related to the Safety Effects of Connected and Automated Vehicles. Among these 60 papers, 29 are sponsored by the ACS10 and ACS20 Committees; the other papers dealing with the topic of Safety Effects of CAVs are 31 and they are sponsored by other Committees, as follows:

- The ACP30 Committee sponsored 10 out of 31 papers (one out of ten together with other Committees).
- The ACH30 Committee sponsored 7 out of 31 papers.
- The ACH50 Committee sponsored 6 out of 31 papers.
- The ACH10 Committee sponsored 4 out of 31 papers (one out of four together with other Committees).
- The ACP50 Committee sponsored 2 out of 31 papers.
- The AED30 Committee sponsored 2 out of 31 papers.

Among these papers it is possible to identify 5 macro groups:

1. Papers dealing with the **safety improvement of CAVs (16 papers)**
2. Papers dealing with **performance comparison of CAVs with human-driven vehicles (HDV) or fully CAVs with ADAS-equipped vehicles (9 papers)**
3. Papers dealing with **surrogate safety measures (5 papers)**
4. Papers dealing **new safety features of CAVs (16 papers)**
5. Papers dealing with **CAV crash-related factors and causes (14 papers)**

As regards to **safety improvement of CAVs**, it is possible to highlight the number of works based on real condition datasets (5 studies). It is evident from the papers that highly automated CAVs (Level 4 of SAE) can reduce crashes (24-06058) especially if they have

cautious behavior and they are widely deployed (24-04924). It is estimated that 60.91% of crashes can be avoided by CAVs and the remaining crashes are of course mitigated (24-00318). Moreover, if CAVs exchange safety info in real-time (24-02402) or they can provide alerts, safety increases since the awareness increases even under inclement weather conditions, except for fog (24-00779). Safety can be improved thanks to CAVs, also on interchanges, with high CAVs penetration rate (24-05905), on roundabouts, redesigning slip lanes (even though in current conditions, CAVs still have beneficial impacts, 24-02362), and at intersections, optimizing the right-of-way (24-06166). Regarding the CAVs interacting with vulnerable road users (VRUs), new urban design strategies can enhance the trust of pedestrians towards CAVs, leading to great effects on safety (24-00577). CAVs, if implemented with adequate ADAS, can protect VRUs from vehicles that are becoming bigger and heavier, reducing their negative impacts (P24-20989). Among the ADAS, even if the effect of Automated Emergency Breaking (AEB) is still debatable on safety (24-05762), it is found that AEB optimized for pedestrians (P-AEB) stopped 63.6% of crashes and reduced crash speed in 33.1% of cases (24-02568).

Regarding lower level of CAVs (SAE Level 2 and 3), it is possible to state that Level 2 vehicles (L2) are involved in more severe crashes than Level 3 vehicles (L3). Even if low severe crashes due to L3 are accounted for a great number of rear-end crashes, they might be severe for VRUs or on highways (24-03250). Considering abnormal conditions, such as the case of subpar conditions, it is seen that CACC is still working efficiently reducing crash occurrences (24-03239).

In the optic of having CAVs deployed, it is useful to get their interactions with other vehicles. Investigating Human Driven Vehicles (HDV) and CAV interactions, it is evident that car-following behavior of CAVs is safer than the one of HDV, that also shows greater Time To Collision (TTC), according to 24-04406. Nonetheless there are several studies about safety improvements of CAVs, their overall benefits, and implementation, are still challenging (P24-02871).

One possible way to assess the CAV benefits is **comparing performance of CAVs with HDVs and ADAS vehicles** to get all the limitations, challenges, and improvements. This approach is possible thanks to available crash datasets for all these types of vehicles (8 papers). CAV and HDV crashes are compared to understand how to deal with them and the features in common (24-02913). In California, driverless cars have a Miles per Crash value comparable to the one of Uber ride crashes, even though calculated on a smaller sample (24-05951). Among these crashes, it is important to note that a huge percentage is non-fatal (24-00397). This aspect can be highlighted by the investigation of the most frequent crash type of AVs (rear-end) and the associated severity (very low), compared to HDV crash severity (24-00697).

While CAVs interact with bikes, they show a more cautious behavior than HDVs, characterized by very low speed and great headways, in 63.6% of cases (24-00599). Comparing the lane changing of these two vehicle types (CAVs and HDVs), it is evident that CAVs perform safer lane changing maneuvers even if they are not homogenous among all the investigated trajectories (24-02167). In fact, lane changing of CAVs compared to the one of HDVs, appears

to be more defensive on the driving lane, more aggressive on the opposite lane and similar on the target lane (24-04908). If the comparison becomes between fully CAVs and ADAS-equipped vehicles, it is possible to note that ADAS systems fail with dark light and adverse weather conditions, fully CAVs no (24-04925). Also, in terms of numbers, ADAS-equipped vehicles are more prone than CAVs to be involved in collisions. Collision numbers were found to be stable for fully CAVs in a period over 12-24 months (24-06086).

Another approach towards the **CAVs is studying the Safety Surrogate Measures (SSMs) to assess the potential collisions.** The papers dealing with this topic were based on investigation of datasets (4 papers) or on road tests (1 paper). Using CAVs as data collectors, thanks to their sensors, it is possible to determine new SSMs (24-01912), as hard breaking that was found to be influential to determine crashes on highways only (24-03029). Other driving events potentially useful for crash frequency assessment are cornering, braking, and accelerating. They can be used as SSMs (24-05717). CAVs were also used to define a new SSM of single-vehicle-run-off-road event on curve. The investigation was based on 16 curves and validated by crash datasets and CAV data (24-03338). Also, the CAV attitude of being involved in crashes with pedestrians can be investigated by SSMs, using the Post Encroachment Time, PET (24-01198).

Not only new SSMs can be defined using CAVs, but there are also several **new safety features of CAVs** being widely investigated. One blatant example can be the definition of real-time risk map to warn the CAV of the possible risky situations during their trips (24-05299), or the use of improved crash prediction methods in real-time thanks to the CAV data, efficient also at low CAV penetration rates of about 4-7% (24-04419). Real-time risk assessment provides also better stability and safety than other tested models, like the ACC model or the IDM one (24-02176). Another efficient real-time feature is the prediction model of trajectories that emerged to improve safety by 46% (24-06205). Takeover management through behavioral inoculation (24-04537) or lane-changing prediction in real-time (24-02495) are other two real-time measures to enhance CAV safety, thanks to the elaboration of data collected during the CAV travelling. CAV data can be also used for increasing road perceptions and prevent secondary crashes in real-time, by sharing data (24-00490). One important feature of CAVs, that enables a good awareness of the driving condition, is the Human Machine Interface (HMI). Improving it, can make roads safer. HMI, in fact, helps during non-emergency situations with just simple messages, but during the emergency the message by the HMI must be precise and detailed (24-01573) and with different inputs (voice, description, and so forth). Hybrid HMI warnings are also beneficial on curve safety (24-02449). CAV warnings combined with optimized HMI reduce acceleration and jerk, improving drastically the safety of travels (24-02872). Also, considering interactions with VRUs, CAVs must communicate with them to prevent dangerous situations and make VRUs comfortable and trustful. In this optic, external-HMI (E-HMI) are crucial to improve VRUs safety (24-03212), as well as information signals from the CAVs (24-06132). In the interactions of light vehicles with track platoons (that uses CACC) the signals on tracks are found to have negligible effects on safety. Crucial for safety during

this interaction are new roadside signals (24-02316). Not only roadside elements are beneficial but also CAV on-board equipment, like speed guidance information (24-03279), Lidar scans, as the TScan (24-05208), or in-built cameras to manage warnings and timely interventions as soon as abnormalities and anomalies are detected (24-5043). These studies were mostly based on simulations (5 papers) and dataset investigation (2 papers).

The analysis of **CAV crash-related factors and causes** was investigated in 10 papers thanks to the available datasets, and in 2 cases (papers) thanks to simulations. Investigating the dataset, it was immediately evident the necessity of a new narrative for describing CAV accidents to get the causes and factors beneath each event (24-04377). The dataset was used for understanding the influence of environment and road characteristics on CAV accidents, highlighting that stop signs and sign density influence crash occurrence (24-05434). Moreover, the dataset showed how snow and work-zones are related to fixed-object collisions. Crashes are due to dark light conditions, wet surfaces, and rain (24-03775). Dark light was also the main factor for collisions at intersections, while daytime and parked vehicles for non-intersection collisions (24-01915). Adverse weather conditions were a crash-related factor for both intersections and non-intersections, such that breaking distance studies during inclement weather were run to calculate safety breaking distances (24-03180). Another contributing factor for intersection collisions is the hard acceleration, followed by hard braking and traffic volume (24-06151). Intersections were also found to be the vulnerable spots in mixed traffic conditions, together with some specific maneuvers affecting both longitudinal and lateral safety (24-00694). Other factors can be identified in technological causes, as it emerged by CAV crash analysis (24-02571). However, this cause can be addressed to cybersecurity attacks in sensor perception, for example (24-06036), but also to disengagements. Disengagements happen also due to recognition errors on curves (63.3%) where greater radii implied lower disengagement frequency but at greater speeds (24-00423). However, disengagements seem to be attributable to human drivers rather than to technological failures (24-03964). For example, L3 vehicles experienced high takeover time after the disengagement due to driver distractions (24-06042). High disengagements resulted in a great percentage of collisions (42%), even though these collisions happened at low speeds. When the disengagement is coupled with unlawful behavior, the collisions happened with great speeds (24-02656). 60.72 % of collisions with CAVs happened with low speeds but with great CAV damages and limited damages to drivers (24-05175).

Below, for each of **the 60 papers** regarding **Safety Effects of Connected and Automated Vehicles**, the following information is provided: authors, sponsoring committee, session number, session title, paper number, paper title, and abstract.

Authors	Chuang CUI Bocheng An, Southeast University Linheng Li, Southeast University Xu Qu, Southeast University
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	**Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session**
Paper Number	TRBAM-24-05299
Paper Title	**A Vehicle Safety Early Warning Method Based on Risk Map**
Abstract	Traffic safety has always been a focal point of concern, especially on highways where vehicles travel at high speeds, and the harm caused by traffic accidents is more severe. To evaluate the driving risks of highway vehicles and reduce the accident rate on highways, this study proposes a highway vehicle safety warning method based on a risk map. Firstly, a two-dimensional feature indicator MTTC (Modified Time to Collision) is selected to describe the driving risk between vehicles, and it is subjected to probabilistic processing. Then, the probabilistic risk values are mapped onto road segments. The risk map is obtained by overlaying them, which is used to depict the driving risks around vehicles. After that, highway vehicle warning is performed based on the risk map. When the risk value is higher than the warning threshold, high-risk vehicles are given a warning alert. Finally, the effectiveness and timeliness of the proposed method are verified through simulation in VISSIM. The experimental results show that the proposed method is effective and timely. This study constructs a vehicle warning risk map in the connected vehicle environment and provides a research foundation for enhancing highway driving safety, which is not only suitable for the current stage of manual driving and assisted driving but can also be applied to future autonomous driving.

Authors	Song Wang, Chongqing Jiaotong University Zhixia Li, University of Cincinnati
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-06058
Paper Title	**Quantification of Safety Improvements and Human-Machine Trade-Offs in the Transition to Automated Driving**
Abstract	The assumption of reduced human error-related crashes with increasing levels of automation in the pursuit of Level 5 automation lacks empirical evidence. As automation levels rise, human error-induced safety hazards are anticipated to decrease while machine error-induced hazards increase. However, a quantitative index capturing this trade-off is absent. Theoretical modeling of safety improvements during the transition to automated driving, particularly concerning the reduction of human error-related hazards, remains unexplored. These limitations impede the understanding of safety from human and machine perspectives for Automated Vehicle (AV) specialists and manufacturers. This research addresses these gaps by investigating safety performance associations between human and machine factors using the "Human-Machine conflict reduction ratio" (H-M ratio). The study aims to establish safety improvements related to human errors under various automation levels. Sixty participants completed driving tasks at Levels 0, 4, 3, and 2 on a driving simulator. Safety performance measures, including conflict frequency and severity, were computed. As a result, Level 4 exhibits the largest decrease (93.3%) compared to manual driving, followed by Level 2 (70.7%) and Level 3 (40.5%). The H-M ratio measures the trade-off between reducing human and machine error-induced hazards, with Level 2 demonstrating the highest ratio, followed by Levels 4 and 3. Safety performance is evaluated by considering all possible types of human errors at each automation level. Theoretical models from a human factor's perspective are employed to estimate safety improvements at each level. This research contributes to a comprehensive understanding of safety in the "human-machine cooperative driving" phase.

Authors	Sultana Rajia, Tokyo Institute of Technology School of Environment and Society: Tokyo Kogyo Daigaku Kankyo Shakai Rikogakuin Yasunori Muromachi Moinul Hossain, Islamic University of Technology
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-04924
Paper Title	**Safety Assessment of Automated Vehicle (AV) Driving Logics under Mixed Traffic Using Real-Time Crash Prediction Model**
Abstract	Successful implementation of automated vehicle (AV) technology can be achieved through proper safety evaluation which in the future will be required for informative decision-making during large scale deployment of automated vehicles (AVs). The focus of this paper is two folds: understanding appropriate parameter setting for AVs by examining the behavioral models from preceding studies, and evaluate the corresponding crash risks under mixed traffic operation. After reviewing the preceding studies and two large scale real-world projects: CoEXist Project and UK Autodrive, parameters were set for three driving environments - normal, cautions, and all-knowing. Safety assessment for these driving environments were conducted using a Dynamic Bayesian Network (DBN) based real-time crash prediction model. The safety assessment showed that crash risk can be reduced by 21.9%, 22.3%, and 17.6% under normal, cautious, and all-knowing driving behaviors, respectively, with mixed scenarios. Results also exhibited that with higher market penetration rates, some of the driving volatility measures were reduced such as less lane changing, maintaining homogeneous speed and headways. Furthermore, difference of up and downstream speed has significant impact on crash risk estimation and its reduction was found to be associated with lower levels of risk.

Authors	Shi Dong Zhiwei Cui, Chang'an University Daniel (Jian) Sun, Chang'an University Liming Ye Shengxuan Ding
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-03775
Paper Title	**How Does Environmental and Road Factors Impact Automated Vehicle (SAE Level 2) Crash Results? A Network and Coupling Analysis**
Abstract	In recent years, extensive on-road testing has been conducted to monitor the safety of automated vehicles (AVs) in real-world conditions. Environmental and road (ER) factors notably contribute to AV crashes. However, the effects of ER factors on AV crash events remain unclear due to the limited number of studies conducted in this area. This study aims to explore their influence mechanisms through investigating AV at SAE Level 2. First, empirical data from the Autonomous Vehicle Operation Incident Dataset (AVOID) were obtained to cleansing and processing, resulting in a refined dataset comprising 709 crashes. Five categories of ER factors were extracted, along with two types of crash results. Next, a combination of two-mode social network analysis and N-K model was employed to analyze the relationships and coupling interactions. The results indicate that: snow and traffic incident/work zone are exclusively associated with collisions involving fixed object and vehicle, respectively. Dark-lighted, rain and wet road surface have a stronger impact on crash results. Ten ER core factors and three core crash results were revealed, which the ER core risk factors includes rain, wet, dark-lighted and intersection. The risk associated with coupling modes involving rain and wet conditions is higher than that of other. The four high-risk combinations can be addressed through improvements in sensors, target recognition algorithms and the promotion of dedicated AV lanes. Finally, safety recommendations for AV based on ER factors were proposed based on the findings, which may be improved as AV safety guidelines and applied in high-level scenarios.

Authors	Sunday Okafor, University of Alabama, Tuscaloosa Praveena Penmetsa, University of Alabama Vamshi Annimalla Elsa Tedla, Alabama Transportation Institute Alexander Hainen, University of Alabama Steven Jones, University of Alabama
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-03029
Paper Title	**Connected Vehicle Event Data and Traffic Crashes: A Statewide Correlation Analysis**
Abstract	Traditionally, road safety countermeasures are determined through the analysis of historical crash records, which is regarded as a reactive approach since the crash risk is assessed after the occurrence of crash incidents. The emergence of connected vehicle data like hard braking events presents a promising opportunity for proactive traffic safety considerations. As such, some recent studies have been exploring the efficacy of using connected vehicle data as surrogates for traffic crashes. This study contributes to the growing body of literature by presenting a statewide correlation analysis to examine the potential of using hard braking events as a surrogate for crashes on different roadways in Alabama. The study used six months of hard braking events and crashes that occurred during the same period. Spearman's rank-order correlation results indicated a moderate correlation between hard braking events and crashes on principal arterials, minor arterials, and major collectors. A weak correlation was recorded between hard braking events and crashes on the interstates. Similar correlation results were observed on the different roadways by conducting the analysis at the level of urbanized and rural areas. The findings suggest that hard braking events can serve as crash surrogates for different highway safety screening except for interstates. This study provides valuable preliminary information for traffic safety practitioners and transport agencies to explore practical applications of connected vehicle event data for proactive traffic safety management.

Authors	Noah Goodall, Virginia Department of Transportation
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-02913
Paper Title	**Comparability of Automated Vehicle Crash Databases**
Abstract	Advanced driving assistance systems are available on many late-model vehicles, and automated driving systems are testing on public roads. Regulators and developers continue to assess the safety of these vehicles by comparing automated vehicle crash rates to baseline, human-driven crash rates. While there are several widely-cited automated vehicle and conventional vehicle crash databases, these databases have different underlying assumptions and inclusion criteria. Crash rates among databases may be directly comparable only with significant filtering and normalization, if at all. This paper reviews current automated vehicle and baseline human-driven crash databases and evaluates their comparability. Recommendations are presented to improve their comparability, both in terms of normalization and contextualization, as well as additional data fields that can be incorporated into existing databases. These findings may assist researchers, regulators, and automated vehicle developers attempting to evaluate the safety of driving automation systems.

Authors	Sangjae Lee, Hanyang University Young Jo, Hanyang University, Ansan Juneyoung Park, Hanyang University, Ansan Cheol Oh, Hanyang University
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-00694
Paper Title	**Prioritizing Safety-Vulnerable Interrupted Road Facilities for Mixed Car-Following Situations: Methodology and Application**
Abstract	With the advancement of autonomous driving technology, it is expected that autonomous vehicles (AVs) and manually driven vehicles (MVs) will coexist and operate soon. The different driving behaviors of AVs and MVs can potentially impact the driving safety on existing road infrastructure. This study tries to evaluate the driving safety of AVs and MVs in the context of following events on urban roads and determine priority for evaluation and improvement. The multi agent driving simulator (MADS) was utilized to simulate AV manuevering control algorithms and urban road, enabling the derivation of longitudinal, lateral, and inter-vehicle driving safety indicators. To provide a relative comparison of driving safety, the change rate in safety indicators for each road section was compared against the tangent section on a level road. The analysis revealed that longitudinal safety decreased by 11 times and inter-vehicle safety decreased by 150 times compared to the tangent section on a level road, particularly in signalized and unsignalized intersections that require frequent acceleration and deceleration. Furthermore, the lateral driving safety in roundabout and U-turn sections, which necessitate significant steering controls, was found to be 17 times lower. Additionally, by applying the developed safety evaluation methodology to a real-world mobility testbed to find urban road sections requiring safety improvement. The analysis results indicated that sections with a high number of signalized intersections showed lower driving safety. Based on the prioritization of urban road sections derived from this analysis, vulnerable sections for AV mixed traffic can be identified in terms of driving safety.

Authors	Nastaran Moradloo, University of Tennessee Iman Mahdinia, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACS10
Session Number	Poster Session 2235
Session Title	**Transportation Safety Management Systems from Start to Finish**
Paper Number	TRBAM-24-02656
Paper Title	**Quantifying Uncertainty in Higher-Level Automated Vehicle Crashes: The Role of Disengagements, Safety Drivers, and Behaviors of Surrounding Drivers**
Abstract	Safe vehicles, a critical element of the Safe System Approach, are promising solutions to reach the vision zero goal. Higher-level Automated Vehicles (AVs) equipped with Automated Driving Systems (ADS) aim to improve transportation safety. Despite their potential, AVs face safety challenges—recent AV crashes prove this. As only limited real-world ADS crashes have occurred, their analysis involves high levels of uncertainty about relationships embedded in the data. This study analyzes the National Highway Traffic Safety Administration's nationwide ADS crash dataset between 2021-2023 (N=154). The study focuses on understanding the factors associated with impact speeds, a measure of crash severity. The primary questions explored are the roles of disengagement, safety drivers, and unlawful behaviors of crash partners (CPs). A Bayesian random-effect normal regression is estimated to address uncertainty and small sample size issue. Statistics indicate that impact speeds were mainly low, with an average of 13.88 mph. In 42.21% of crashes, AVs experienced disengagements with 54% higher average impact speed than other crashes. Results reveal that safety drivers within AVs are associated with lower impact speeds. Crashes involving unlawful behavior of CPs are associated with higher impact speeds, emphasizing the challenges posed by unpredictable behaviors. Further, disengagements are associated with higher impact speeds, highlighting the challenges related to the sudden shift from automation to manual control, especially in complex scenarios, e.g., unexpected obstacles on the roadway. Overall, this study highlights crucial factors associated with AV crash dynamics and emphasizes improving the technology of higher-level AVs.

Authors	Hisham Jashami, Oregon State University Akinfolarin Abatan, Michigan State University Derrick Hill Alejandra Meza Prem Shah Katelyn Rousch Nrushad Joshi Cleveland Yancovitz Peter Savolainen, Michigan State University
Sponsoring Committee	ACS10
Session Number	Lectern Session 3003
Session Title	**Using Connected and Automated Vehicles to Improve Transportation Safety**
Paper Number	TRBAM-24-05762
Paper Title	**Examination of factors influencing the efficacy of automatic emergency braking**
Abstract	Automated vehicles are expected to significantly reduce traffic crashes and the resultant injuries and fatalities. However, it is unclear when fully automated vehicles will be market-ready, though it is important to note that lower levels of automation have already demonstrated some of this significant safety potential. This includes technologies such as automatic emergency braking (AEB), which is proposed to be a mandatory feature in all new vehicles by 2025. This study involves an evaluation of AEB test data from the Insurance Institute for Highway Safety (IIHS). These tests include various scenarios, including those were the test vehicle encounters a balloon car, as well as “dummy” pedestrians that are walking either parallel or perpendicular to the road. These tests are conducted at various speeds and lighting conditions. Further, the test vehicles range from model year 2013 to 2023, and include a diverse range of sensor configurations. A series of random-effects logistic regression models are estimated to evaluate the efficacy of these vehicles across these test scenarios. The results provide important insights as to the potential, as well as the limitations of these systems in their current form.

Authors	Nischal Gupta, Michigan State University Hisham Jashami, Oregon State University Peter Savolainen, Michigan State University Timothy Gates, Michigan State University Timothy Barrette, Ford Motor Company Wesley Powell, Ford Motor Company
Sponsoring Committee	ACS10
Session Number	Lectern Session 3003
Session Title	**Using Connected and Automated Vehicles to Improve Transportation Safety**
Paper Number	TRBAM-24-05717
Paper Title	**Examining the Relationship between Connected Vehicle Driving Event Data and Police-Reported Traffic Crash Data at the Segment- and Event-Level**
Abstract	Police-reported crash data have been the de-facto element used by the transportation agencies in developing and implementing traffic safety projects. This approach is reactive in nature and can lead to suboptimal investment decisions due to inherent challenges in crash data analysis. Due to their large-scale and near real-time availability, the connected vehicle (CV) driving event data have emerged as a promising means to address these challenges. This study utilized CV event data for three different event types, namely, acceleration, braking, and cornering at three severity levels- easy, normal, and harsh, to examine the viability of using these data in traffic safety analysis. The results showed a strong correlation between crash frequency and CV driving event frequency. CV event data also improved the goodness-of-fit of crash frequency models. The results also showed that the relationship between CV driving events and traffic volume and roadway geometry data are generally consistent with the trends that crash data usually exhibit with the same predictors. This was true at both segment-level and individual event-level, as well as when the data were subsetted based on type. Overall, the results showed a strong case for these data to be used in traffic safety analysis in complement to or in-lieu to police-reported crash data.

Authors	Saquib Mohammed Haroon, The University of Arizona Alyssa Ryan, University of Arizona
Sponsoring Committee	ACS10
Session Number	Lectern Session 3003
Session Title	**Using Connected and Automated Vehicles to Improve Transportation Safety**
Paper Number	TRBAM-24-00697
Paper Title	**Insights into Automated Vehicle Collisions: Explainable AI Models and Comparison with Non-Automated Vehicles**
Abstract	With the growing development and deployment of automated vehicles (AVs), it is crucial to understand the associated risks and factors contributing to collisions involving AVs. California possesses an immense amount of publicly available data from AV testing due to the requirement laid out by the California Department of Motor Vehicles (DMV), which requires all automated vehicle operators to report collisions for any level of severity. However, this information is reported in specific forms and requires a laborious task to aggregate data from these reports. This study creates an automated data extraction system for these reports and analyses collision characteristics of AVs using logistic regression models as well as XGBoost models with SHapley Additive exPlanation (SHAP) interpretation. Additionally, these characteristics are matched with those of non-automated vehicles (non-AVs) in the same region. The study results indicate that rear-end collisions are the most common collision observed in currently deployed AVs. The analysis further revealed an increased likelihood of injury-prone rear-end collisions in AVs at intersections compared to non-AVs. Transportation policymakers and researchers should consider these safety concerns when addressing AV deployment and developing appropriate measures to mitigate collision risks in mixed fleet conditions.

Authors	Patrick Durham, StacheD Training
Sponsoring Committee	AMR00 ACP10 ACS10 ACS30
Session Number	Lectern Session 3146
Session Title	**Electric Vehicle Incident Response: Strategies and Best Practices**
Paper Number	P24-20871
Paper Title	**Navigating the Future of Transportation: Addressing EV Incidents and Automated Driving Challenges**
Abstract	In an era of rapidly evolving transportation technologies, the rise of electric vehicles (EVs) has revolutionized our roads, presenting both innovative opportunities and unique challenges. Understanding how to manage incidents involving electric vehicles and the inherent risks posed by their lithium-ion batteries is of paramount importance. **EV Anatomy and Battery Technology:** Explore the construction of electric vehicles, shedding light on the intricacies of lithium-ion batteries. Gain an in-depth understanding of the technology that powers EVs and the unique safety considerations it entails. **Emergency Response Strategies:** Learn how to effectively respond to EV-related emergencies, with a focus on safety protocols and handling lithium-ion battery incidents. We'll equip you with the knowledge needed to ensure the safety of both first responders and the public. **Challenges in Automated Driving:** The talk will also touch upon the challenges that automated driving systems introduce to our roadways. Understand how the increasing presence of autonomous vehicles impacts transportation infrastructure, safety, and traffic management.

Authors	Kristin Kingsley, Alliance for Automotive Innovation Alexander Epstein, Office of the Assistant Secretary for Research and Technology (OST-R)
Sponsoring Committee	A0030C ACH10 ACH20 ACH30 ACH40 ACS10 ACS20 ACS60 AKD10
Session Number	Workshop 5006
Session Title	**Mitigating the Implications of Increasing Vehicle Size and Mass on Pedestrian and Bicyclist Safety**
Paper Number	P24-20989
Paper Title	**Defining the Solution Part 2: Technological Solutions Panel Discussion**
Abstract	This panel will discuss the opportunities and challenges of proven and promising technologies like full visibility cabs, intelligent speed adaptation (ISA), and other ADAS elements like pedestrian/VRU detection and emergency braking. Panelists will also discuss research and knowledge gaps that need to be addressed.

Authors	Omar Al-Sheikh, Rowan University Mohammad Jalayer, Rowan University
Sponsoring Committee	ACS20
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-02571
Paper Title	**Investigating the Severity of Curve-Related Roadway Departure Crashes: The Role of Driver Distraction, Automation Levels, and Environmental Conditions**
Abstract	This study addresses the severity of curve-related Roadway Departure (RwD) crashes, with a focus on driver distraction, automation levels, and environmental conditions. With the advent of automated vehicles and advanced driver assistance systems (ADAS), it becomes crucial to understand how these vehicles perform under diverse driving conditions and scenarios. A novel aspect of our approach is the estimation of Levels of Automation (LoA) for each vehicle in the dataset, which allows for a nuanced understanding of the role of automation in crash severity. The data, primarily single-vehicle incidents, is analyzed using the XGBoost machine learning model and Explainable Artificial Intelligence (XAI) techniques. The model achieved an accuracy of 0.88 when the “WEIGHT” feature was included and 0.60 when it was excluded. The findings underscore the significant role of human behaviors, vehicle characteristics, and environmental conditions in determining the outcomes of RwD crashes. The study aligns with the safe systems approach to road safety, emphasizing the need to understand and address the complex interplay of factors that contribute to crashes. The study provides insights for safer roadway design and automated vehicle guidelines, acknowledging limitations such as the focus on specific crash types and data quality. Future work could explore other crash types and the role of vehicle automation levels in crash severity.

Authors	Hanlong Fu Tiantian CHEN Jinhua Zhao, Massachusetts Institute of Technology Xiaowen Fu
Sponsoring Committee	ACS20
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03250
Paper Title	**Unraveling the Enigma: New Insights into Factors Impacting the Severity of Autonomous Vehicle Crashes from Two Sources of AV Incident Records**
Abstract	As autonomous vehicles (AVs) become more prevalent on public roads, concerns have arisen over their actual safety performance. Their expected potential to reduce crash and injury rates would be overshadowed by current technological limitations. This study aims to identify the key factors affecting crash severity by analyzing real-world AV incident data from the U.S. between 2015 to 2022. The analysis employs random intercept multinomial logit models to estimate crash severity levels (i.e., non-jury, slight injury, and severe injury). The findings reveal that crashes involving engaged Level 2 AVs (with ADAS) tend to result in higher crash severity, compared with conventional driving mode. On the contrary, the injury risk was reduced by Level 3+ AVs with engaged ADS system. In addition, rear-end collisions and the presence of commercial vehicles are associated with slight injuries involving AVs. On the other hand, adverse weather, driving on highways, as well as the presence of vulnerable road users (VRUs) contribute to serious injuries. Overall, this research is expected to provide policymakers and AV manufacturers with valuable insights to enhance AV safety, emphasizing that addressing the identified factors will lead to improved AV design and control algorithms.

Authors	Yuzhi Chen, Southeast University Chen Wang, Southeast University Yuanchang Xie, University of Massachusetts, Lowell
Sponsoring Committee	ACS20
Session Number	Poster Session 3231
Session Title	**Analytical Methods of Safety Performance**
Paper Number	TRBAM-24-03338
Paper Title	**Modeling the Risk of Single-Vehicle Run-off-Road Crashes on Horizontal Curves Using Connected Vehicle Data**
Abstract	Surrogate safety measures (SSM) are widely used in safety analysis to complement crash reports. However, none of the existing SSM are specifically designed for modeling the risk of single-vehicle run-off-road (SVROR) crashes, especially those on horizontal curves. This paper proposes a novel SSM for modeling SVROR crash risk (SVROR-SSM) using connected vehicle data. The proposed SVROR-SSM is based on the concept of tetraquark in particle physics. It utilizes the adjusted position deviation risk force (Friskposi) and adjusted attitude deviation risk moment (Γriskatti) to quantify SVROR crash risk. The SVROR crash risk is then estimated by the joint probability of Friskposi and Γriskatti using a peak-over threshold approach. The risk threshold is automatically determined via a mean absolute error (MAE) computation function. The SVROR-SSM is validated using connected vehicle and crash data from 16 curves on Interstate 80 in Wyoming. The results suggest that the estimated crash risks well match historical crash records. The proposed approach bridges an important gap in SSM research and can be used to estimate SVROR crash risk and identify safe trajectories for highway horizontal curves.

Authors	Sunny Singh, QUT: Queensland University of Technology Yasir Ali Md. Mazharul Haque, Queensland University of Technology
Sponsoring Committee	ACS20
Session Number	Poster Session 4070
Session Title	**Safety Impact on Road Users Including Pedestrians, Bicyclists, and Others**
Paper Number	TRBAM-24-01198
Paper Title	**Estimating Pedestrian Crash Risks from Autonomous Vehicle Sensor Data by applying traffic conflict techniques with extreme value theory models**
Abstract	Pedestrian crash risk has traditionally been challenging to model on a corridor or network level accurately. Limitations of current data collection techniques make it difficult to capture detailed pedestrian interaction at the network or corridor level. With autonomous vehicles trialled on public roads generating massive (and unprecedented) datasets capturing all the surrounding road users, utilising such rich information for corridor-wide safety analysis is somewhat limited where it appears most relevant. This study proposes an extreme value theory modelling framework to estimate corridor-wide pedestrian crash risk using autonomous vehicle sensor/probe data. Two models were developed in the Bayesian framework, including the block maxima sampling-based model corresponding to the Generalised Extreme Value distribution and the peak-over threshold sampling-based model corresponding to the Generalised Pareto distribution. The proposed framework was applied to a subset of the Argoverse dataset, focussing on an arterial corridor in Miami, US, to extract pedestrian and vehicle trajectories. From these trajectories, vehicle-pedestrian conflicts were identified and measured using post-encroachment time. The non-stationarity of extremes was captured by vehicle volume, pedestrian volume, average vehicle speed, and average pedestrian speed. Both block maxima and peak-over threshold sampling-based models reasonably estimated historical pedestrian crash frequencies. Notably, the block maxima sampling-based model was more accurate than the peak-over threshold sampling-based model based on mean crash estimates and confidence intervals. This study demonstrates the potential of using autonomous vehicle sensor data for corridor-level safety.

Authors	Raghupathi Kandiboina, Iowa State University Varsha Mouli, Iowa State University Guillermo Basulto-Elias, Iowa State University Skylar Knickerbocker, Iowa State University Neal Hawkins, Iowa State University Anuj Sharma, Iowa State University
Sponsoring Committee	ACS20
Session Number	Poster Session 2212
Session Title	**Safety Performance and Analysis of Freeways**
Paper Number	TRBAM-24-04419
Paper Title	**A Real Time Freeway Crash Detection Framework using Connected Vehicle Waypoint Data**
Abstract	Accurate and timely detection of traffic accidents is of crucial for transportation agencies seeking swift responses and effective traffic management, particularly on freeways where crash severity and traffic flow disruptions are amplified. While several methods have been developed using cameras or infrastructure-mounted sensors, these approaches may face challenges in geographical scalability. To address this, we present a novel approach using real-time connected vehicle data, collecting continuous information at the journey-level with a market penetration rate of 4-7%. The results demonstrate promising outcomes, achieving an overall accuracy of 63.5% with 4.1% false detections and 33.4% non-detections by extracting five key features from individual journeys. This accuracy surpasses the speed-alone model using the same data by 24%. Furthermore, higher traffic volumes lead to even greater accuracy, exceeding 80% at levels of service D and 90% at level of service E. The developed algorithm also exhibits precision in crash detection, with a mean latency of only 2.5 minutes after the actual incidents. This study highlights the potential of connected vehicle data in enhancing crash prediction methods and underlines its value for future transportation systems' efficiency and safety.

Authors	Raghupathi Kandiboina, Iowa State University Gou Rui Yanyan Chen, Beijing University of Technology Yunchao Zhang
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-05175
Paper Title	**Injury Severity Model of Autonomous Vehicle Involved Incident: A Hybrid model of XGboost and Multinomial Logit Based on A Novel Multi-Source Dataset**
Abstract	Autonomous vehicle (AV) technology is expected to improve road safety by potentially eliminating human error. This study constructed a hybrid method of XGBoost based SHAP algorithm and multinomial logit model. Based on Autonomous Vehicle Operation Incident Dataset Across the Globe (AVOID) to analyze the significant features that affect the driver's injury severity at intersections through five categories of factors: incident time; environment; roadway; incident description, vehicle status. And then explore the interaction between each potential factor. The results show that there are nine characteristics that have an important impact on the driver injury degree. In addition, pre-crash movement, incident scene, pre-crash speed, contact area and automous mode have significant effects on different degrees of injury. At intersections most incident occur when was stopped or driving at low speed (60.72% below 10mph). And in this speed range, the damage severity of the vehicle driver increases when AV goes straight. The proportion of AV in automous mode at the time of the accident was 60.41%. The rear of the AV was the main damage location, accounting for 54.07%. In this case, the driver may suffer more serious damage when the AV is in lane change or manual mode. In an incident steering direction scene, in automatic mode AV drivers also have a higher probability of injury. Although AV can reduce the injury severity of the driver's in most accidents at intersections. However, it is still necessary to make fuller consideration in the current AV technology and security.

Authors	Arsalan Esmaili Mohammad Mehdi Oshanreh, University of Washington, Seattle Amelia Regan, University of Washington, Seattle
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-04925
Paper Title	**Investigation of Crash Severities Involving ADAS Level 2 and ADS Equipped Vehicles**
Abstract	As the automobile industry progresses toward autonomous vehicles, the incorporation of Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) is increasingly prevalent. This study seeks to examine the severity of crashes involving vehicles equipped with ADAS and ADS, in order to shed light on their potential implications for overall road safety. The dataset used for analysis was sourced from the National Highway Traffic Safety Administration (NHTSA) and is currently the most comprehensive available for ADAS and ADS-equipped vehicles. The results of this research unveiled noticeable differences in the frequency of crashes involving ADAS and ADS technologies. ADAS crashes were found to be more common during unfavorable conditions like wet surfaces, adverse weather, and dark environments, whereas the opposite pattern was observed for ADS crashes. Multinomial and binary logistic regression analyses were employed to examine the impact of different factors on the injury severity of crashes involving ADS and ADAS-equipped vehicles. The results demonstrate that the impact of factors on the severity of crashes involving ADAS and ADS vehicles are different. This study is one of the first attempts to explore the current AV crash data. However, the present study is a preliminary analysis, considering the preliminary nature of the available AV crash data. The findings of this study provide important insights into the current AV crash datasets. Moreover, the proposed models can be reapplied as more data and a deeper understanding of the primary safety factors of AVs becomes available.

Authors	Alican Karaer, Iteris Masoud Hamedi, Iteris
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-06151
Paper Title	**Intersection Safety Risk Scoring using Connected Vehicle Data and Machine Learning: A Case Study in Atlanta Region**
Abstract	Signalized intersections are often considered critical crash hotspots due to the presence of multiple conflicting movements. Traditional intersection safety studies have been conducted using historical crash data which is a reactive approach as it requires multiple years of crash records. The advancements in connected vehicle (CV) technology introduced a wealth of vehicle motion data, such as hard acceleration/braking events, highly granular trajectories, and segment-wise speeding proportions. This study proposes a framework utilizing these emerging data sources to demonstrate their viability on network screening for signalized intersection safety assessment even in the absence of up-to-date crash data. As proof of concept, CV event data and intersection characteristics are linked and compared with two years of crash data in the metropolitan area of Atlanta, GA covering 3,853 intersections. Exploratory analysis revealed that hard acceleration is the most significant factor followed by hard braking and traffic volume. To predict the number of crashes using this emerging dataset at each intersection, Negative Binomial Regression (NBR) and two Machine Learning (ML)-based models, namely Random Forest (RF) and Extreme Gradient Boosting (XGBoost), are employed. All models ranked the intersections with a relatively high ranking-order correlation coefficient, While ML models outperformed the NBR model. The XGBoost model predicted the number of crashes with an error margin of ±22 per intersection. By reducing reliance on historical crash data, the proposed methodology empowers stakeholders to efficiently rank signalized intersections based on safety performance and prioritize critical locations for future investments or policy development.

Authors	Abdul Razak Alozi, McMaster University Mohamed Hussein, McMaster University
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-06086
Paper Title	**Future of Autonomous Vehicles: Time-based Insights from Collision Data**
Abstract	Following the deployment of autonomous vehicles (AV) on open roads, observations from AV collision data will likely guide public acceptance. Such data records have been accumulating over the past few years, reaching sufficient volumes to draw meaningful recommendations. This study sits at the cusp of a recent release of AV collision data spanning the United States. The data cover AVs with highly automated driving systems (ADS) and low-automation advanced driver assistance systems (ADAS). This study aims to analyze the temporal trends in observed AV collisions using time-series modeling to predict future AV collisions. Further investigations are also conducted using the AV collision data reported in California to utilize the exclusive mileage data as an exposure measure. The results indicate a higher increase in ADAS collisions compared to ADS collisions over the same period. In California, while the total number of AV collisions (ADS and ADAS) increased over time, the rate of collisions per million miles traveled remained stable. In terms of future predictions, AV collisions of all automation levels do not increase significantly over a period of 12-24 months, despite a steady increase in traveled distance. This means a reduction in the rate of AV collisions, which could be indicative of AVs becoming safer over time. Interestingly, the higher market penetration rate in California coincides with a slight increase in predicted collisions compared to the national trend. The presented approach sets the pace for future research to keep track of AV safety performance as more collision data become available.

Authors	Pei Liu, Southeast University Yanyong Guo, Southeast University Pan Liu, Southeast University Jiandong Cao
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-05434
Paper Title	**Investigation the Geospatial Factors Associated with CAV Crashes Using the Geographically Weighted Regression**
Abstract	The objective of this study is to investigate the factors associated with CAV crashes by accounting for the spatial heterogeneity. Two-year CAV crash data from 2021 to 2022 was collected from collision reports from San Francisco at Traffic Analysis Zones (TAZ) level. Sociodemographic, build environment, land use, and exposure factors were collected for use as explanatory variables. Geographically Weighted Regression (GWR) was employed to capture the spatial heterogeneity that exists in the relationship between CAV crashes and explanatory variables across TAZs. The Ordinary Least Squares (OLS) was also developed for comparison. The GWR model outperforms the OLS model in handling spatial data. Model results revealed diverse effects of transportation infrastructures on crash frequencies across TAZs. Bus stop and transit lane densities showed a strong negative correlation with CAV crashes, especially in the northeast urban areas. Conversely, bicycle parking density and painted safety islands exhibited a positive correlation with CAV crashes, with the highest impact observed in the southwestern suburbs. Additionally, stop signs and traffic signal densities exhibited a negative correlation with CAV crashes, particularly in more developed city subdivisions. The study underscores the significance of well-planned transportation facilities in enhancing CAV safety and proposes recommendations for improving regional traffic safety.

Authors	Pei Li, University of Wisconsin, Madison Sikai Chen, University of Wisconsin, Madison Lishengsa Yue Yuan Xu David Noyce, University of Wisconsin, Madison
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-04377
Paper Title	**Analyzing Relationships between Latent Topics in Autonomous Vehicle Crash Narratives and Crash Severity Using Natural Language Processing Techniques and XGBoost**
Abstract	Autonomous vehicles (AVs) are expected to bring huge benefits to society, while safety is one of the most important considerations when evaluating their performance. However, existing studies have only been focusing on general descriptive statistics about AV crashes. The unstructured AV crash narratives have not been investigated comprehensively, mostly due to the additional challenges it involves. This study applied natural language processing techniques to convert unstructured crash narratives into structured latent topics (i.e., combinations of words) among AV crashes using AV crash data provided by The state of California. The structural topic model (STM) is used for extracting topics from crash narratives as it allows the incorporation of metadata (i.e., the severity and year of crashes) while developing the model. In total, 15 topics have been identified from AV crash narratives, which can be divided into behavior-related, party-related, location-related, and general topics. Results suggested that the AVs' ability to interact with vulnerable road users, perform lane-change behavior, and react to other road users' lane-change behavior needs to be further improved. Furthermore, the relationships between the extracted topics and crash severity have been validated using an XGBoost model that has an average precision of 0.931, recall of 0.925, and F1-score of 0.926 in classifying crash severity. Topics containing specific words such as minor, bicyclist, and scooters have been found to have a significant impact on the model's output. Moreover, topics containing general words may not provide enough information for classifying crash severity.

Authors	Adekunle Adebisi, University of Cincinnati John Ash, University of Cincinnati
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-02402
Paper Title	**Traffic Safety Performance Evaluation in a Connected Vehicle Environment with Queue Warning and Speed Harmonization Applications**
Abstract	With connected vehicle (CV) technologies development, safety information is becoming more available to drivers. This study investigates three main questions; (1) Do CV-based traffic management applications improve safety performance on roadways with existing infrastructurebased traffic management systems? (2) Can implementing multiple CV technologies have a greater impact on safety than implementing a single CV technology? and (3) Do geometric and traffic composition factors impact the efficiency of CV technologies? We applied a rarely used CV pilot dataset and conducted a comprehensive analysis with various conditions and CV penetration rates that studies have not considered. Two CV applications (queue warning and speed harmonization) implemented in the Intelligent Network Flow Optimization experiment in Seattle were evaluated. Results showed that the driver safety performance, in terms of speed standard deviation (SSTD) and speed percent of extreme values (SPEV) improved under the CV driving conditions, and by combining conventional variable speed limit systems with queue warning, safety is improved for CV drivers. Further, the implementation of a single CV application (queue warning) provided potential benefits in terms of the SSTD, SPEV, congestion mitigation, and reduction in the number of conflicts. With the two CV applications combined, the results were also similar, suggesting no significant differences. Lastly, with 3 lanes, the results show a decrease in the SSTD under the CV driving condition compared to the non-CV condition. With 4 lanes, no improvement was observed.

Authors	Reuben Tamakloe, University of Seoul Subasish Das, Texas State University
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-01915
Paper Title	**Patterns of Critical Factors Linked to Automated Vehicle-Involved Crashes: A Comparative Analysis of Intersection and Non-Intersection Crash Scenarios**
Abstract	This study aims to comprehensively understand how the factors associated with automated vehicle (AV) crashes differ based on the segment of the crash. The study achieves this objective by comparing homogeneous cluster-specific patterns of crash-risk factor associations influencing AV-involved crashes in both intersection and non-intersection segments in the USA. The Cluster Correspondence Analysis (CCA) was employed for the study. From the analysis, the cluster with the highest prevalence in the intersection-related crash data consisted of observations predominantly associated with dark-lighted conditions. This cluster often involved AVs with multi-point contact areas and collisions with motorists and non-motorists. On the other hand, the most representative cluster for non-intersection crashes mainly comprised AV crashes that occurred during the daytime, frequently involving collisions with parked vehicles. Crashes involving fixed objects were more common in dark unlighted conditions at non-intersections, whereas at intersections, they occurred in the daylight and often resulted in injury. Inclement weather conditions were determined to significantly influence the crashes, irrespective of the segment in which they occurred. The findings of this study provide valuable insights for traffic engineers and AV manufacturers, offering practical suggestions to develop effective countermeasures and policies to reduce the severity of AV crashes. By understanding the specific factors contributing to crashes in different roadway segments, stakeholders can make informed decisions to enhance the safety of AVs.

Authors	Iljoon Chang Jaeduk Lee, Gachon University Seyoung Ahn
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-00423
Paper Title	**Evaluation of Autonomous Driving Safety on Curved Sections**
Abstract	Autonomous vehicles minimize driver errors and can help reduce traffic accidents. However, if the autonomous system encounters an unexpected problem, control is transferred to the driver (autonomous disengagement) and driving safety is significantly impacted. 63.3% of disengagements caused by road structures are due to recognition errors on curves. The criteria for curves are not clear, and there is a lack of research on autonomous disengagement and curve radius. This study attempted to analyze the correlation between driving speed and curve radius, which affects the disengagement of autonomous driving on curved sections and thus is a risk factor for autonomous driving. By analyzing data from field driving tests, we evaluated the safety of autonomous driving along curves and compared the curve driving performance of autonomous driving systems applied to different car models. As a result, the disengagement rate varies with the curvature, and for a smaller curve radius, it is more difficult for the autonomous system to maneuver to take control and drive safely. We found differences in the safety of autonomous driving on curves according to the car model. In particular, a test car that periodically provides autonomous driving system software for driver installation exhibits significantly fewer disengagements. As the radius of the curve increased, the average speed at which ADAS was disengaged gradually increased. The driving speed in the curve has the largest impact on the disengagement of the ADAS. Hence, the driving speed in curves must be managed to ensure the safety of autonomous driving systems.

Authors	Rui Zhou Guoqing Zhang Helai Huang, Central South University Jaeyoung Lee, Central South University Yuxuan Dong Jiguang Chen
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-00318
Paper Title	**Crash-based Assessment of Autonomous Driving: How Do Autonomous Vehicles Behave in Real-World Crash Scenarios?**
Abstract	Autonomous vehicles (AVs) have the potential to revolutionize transportation by enhancing traffic safety, and safety testing is a critical step for enabling large-scale deployment of AVs. Due to the high cost and safety risk associated with public road testing, virtual simulation testing has emerged as a cost-effective and efficient method for safety verification. In this context, high-risk scenarios are particularly important as they pose significant challenges and provide valuable insights into the driving capabilities of AVs. This study proposes a method that utilizes in-depth crash data to assess the safety of AVs, focusing on real-world crash scenarios. First, the 453 real-world crashes involved 596 passenger cars from China In-depth Mobility Safety Study-Traffic Accident (CIMSS-TA) database were reconstructed. Subsequently, 596 testing scenarios were created within the simulation platform. Following this, one of the crash-involved passenger cars was replaced with Baidu Apollo, an advanced black-box automated driving system (ADS), for counterfactual simulation. Finally, the safety performance of the AV was evaluated based on the simulation results. The findings demonstrated that the AV could avoid 363 real-world crashes, accounting for approximately 60.91% of the total, and effectively mitigated injuries in the remaining 233 unavoidable scenarios compared to a human driver. Additionally, seven specific scenarios have been identified wherein the AV is unable to avoid a crash. These findings demonstrate that, compared to human drivers, the AV can avoid crashes that are difficult for humans to avoid, thereby enhancing traffic safety.

Authors	Léah Camarcat, Imperial College London, South Kensington Nicolette Formosa Mohammed Quddus, Imperial College London
Sponsoring Committee	ACS20
Session Number	Poster Session 2213
Session Title	**Safety Performance of Connected Automated Vehicles**
Paper Number	TRBAM-24-01912
Paper Title	**Developing an integrated safety surrogate measure for intelligent vehicles**
Abstract	A plethora of safety surrogate measures (SSMs) have emerged as an alternative to historical crash data for traffic safety studies. Despite their efficiency and wide-spread adoption, several limitations endure. Each conflict indicator provides a partial representation of the critical traffic events making the selection of a suitable SSM for a specific application a conundrum due to the vast array available. This paper addresses these limitations by introducing a comprehensive approach to conflict detection through the integration of a new combined metric. The metric is derived from a weighted sum of multiple SSMs including time-based, distance-based, and deceleration-based indicators, which ensures the capture of diverse aspects of potential conflicts. To evaluate its efficacy, a dataset collected by an instrumented vehicle driving on the motorway was used to calculate a variety of indicators and identify conflicts. To address the inherent imbalance in the data, this study compares two balancing techniques: random undersampling and Synthetic Minority Over-sampling Technique (SMOTE). Several optimisation techniques including logistic regression (LR), support vector machine (SVM) and genetic algorithm (GA) were employed and compared to determine the optimal weights that maximises the new index's binary classification capabilities. The GA with SMOTE demonstrated optimal performance with a sensitivity of 93.5% at only a false alarm rate of 3.9%. Although the new index is specific to the motorway, the underlying methodology is transferable to other road environments. The findings of this study hold significant potential for enhancing road safety and providing valuable insights for the development of future intelligent transport systems.

Authors	Yangzhen Zhao Xuedong Hua Baojie Wang, Chang'an University Huiying Lei Wei Wang, Southeast University
Sponsoring Committee	ACP50
Session Number	Lectern Session 2059
Session Title	**Traffic Flow with Connected and Autonomous Vehicles**
Paper Number	TRBAM-24-03239
Paper Title	**Investigating the Safety Impact of Cooperative Adaptive Cruise Control Vehicles under Subpar V2V Communication Performance**
Abstract	Cooperative adaptive cruise control (CACC) is widely recognized as an effective method to make traffic systems safer, more efficient, and more sustainable through vehicle-to-vehicle (V2V) communication. However, as a crucial component of vehicle control, V2V communication performance (V2VCP) easily becomes subpar. Previous research has primarily focused on scenarios where CACC vehicles are vulnerable to cyberattacks. However, the proportion of vehicles vulnerable to cyberattacks is relatively low, and other factors such as weather and equipment aging can also impact V2VCP, which has been overlooked in the past. This study aims to investigate the safety impact of CACC vehicles under subpar V2V communication performance (SV2VCP). To achieve this, we adopt the multi-predecessors following topology and create SV2VCP scenarios using different communication transmission latencies and packet loss rates, along with proposing five vehicle state update methods (VSUMs). Subsequently, we conduct simulation experiments of a 6-vehicle platoon only with CACC vehicles using modified CACC and ACC models. By simulating various SV2VCP and driving scenarios, we analyze the effects of different VSUMs, SV2VCP, and abnormal vehicle positions on the safety of the CACC platoon. The results demonstrate that SV2VCP significantly impacts the safety of CACC platoons, especially in intermittent SV2VCP and deceleration scenarios. The research findings also offer recommended VSUMs to mitigate the adverse effects of SV2VCP.

Authors	Abdalziz Alruwaili Kun Xie, Old Dominion University
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-00490
Paper Title	**Investigating the Impacts of Connected Vehicles on Driving Aggressiveness and Situational Awareness in Highway Crash Scenarios: A Driving Simulator Study**
Abstract	Psychological factors such as aggressiveness and situational awareness can impact driving performance. Connected vehicles (CV), equipped with advanced sensors and able to communicate safety messages to drivers, have the potential to influence driving performance by altering drivers' aggressiveness and situational awareness. This paper aims to investigate the impacts of the CVs on driving aggressiveness and situational awareness in highway crash scenarios where a primary crash has already occurred, and a second crash may occur as a result. To achieve this goal, a driving simulator experiment was conducted, and questionnaires focused on driving aggressiveness and CV effectiveness were distributed. Structural equation modeling (SEM) was used to examine the interrelationships between the use of CV alerts, psychological factors, driving behavior, and other factors. Two latent psychological factors were constructed in the SEM, namely, aggressiveness and unawareness, which were measured by statistical measures of speed, longitudinal acceleration, steering angle, brake, yaw, and lane offset while passing the crash scenes. The SEM has the advantage of achieving the measurement of latent psychological factors and interrelationship modeling simultaneously in one statistical estimation procedure. Results showed that the proposed CV alerts significantly improved aggressiveness and situational awareness. These findings provide insights into the development of driving assistance systems that take psychological factors into account.

Authors	Kun Xie, Old Dominion University Abdalziz Alruwaili
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-00779
Paper Title	**Exploring the Impact of Connected Vehicles on Driving Behaviors and Safety Outcomes in Diverse Weather Conditions**
Abstract	Equipped with advanced sensors and capable of relaying safety messages to drivers, connected vehicles (CVs) hold the potential to reduce crashes. The goal of this study is to assess the impacts of CV technologies on driving behaviors and safety outcomes in highway crash scenarios under diverse weather conditions, including clear and foggy weather. A driving simulator experiment was conducted and the multigroup structural equation modeling (SEM) was employed to explore the complex interrelationships between the propensity of traffic conflicts, utilization of CV alerts, weather, psychological factors, driving behaviors, and other relevant variables for two different crash locations, namely a straight section and a horizontal curve. Two latent psychological factors including aggressiveness and unawareness were constructed from driving behavior as vehicles passed by crash scenes such as brake, throttle, steering angle, lane offset, and yaw. The SEM can measure latent psychological factors and model interrelationships concurrently through a single statistical estimation procedure. Results of the multigroup SEM showed that CV alerts could significantly reduce the unawareness on a horizontal curve and thus lower the propensity of traffic conflicts. Additionally, the overall effect of foggy weather on conflicts was found to be positive on a horizontal curve, despite the potential benefit of improving situational awareness. In contrast, the single group SEM failed to reveal any significant interrelationships in its structural model by pooling data from both crash locations.

Authors	Zijun Du Nengchao Lyu, Wuhan University of Technology
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-01573
Paper Title	**Exploring the Effectiveness of HMI Information on Take-over Behavior during Co-driving Control Transitions**
Abstract	Human-machine co-piloting takeovers require maximizing takeover efficiency, and the role of different human-machine interaction information on driver takeover behavior is worth exploring and quantifying. Therefore, the design of human-machine interaction information during the takeover process is a significant research direction and trend. This study explores the impact of different information interaction modes on driver behavior. Two scenarios were tested: lane departure (non-emergency) and front vehicle collision (emergency). Two types of TOR (Takeover Request), namely "Beep" and "Beep + Voice," and three types of guidance, namely "No guidance," "Arrow type," and "Prohibition type," were examined for their effects on takeover performance and driving safety. The results showed that TOR only had a certain impact on drivers' takeover reaction time in non-emergency scenarios, while the display of events and the type of guidance both had an impact on drivers' takeover reaction time and driving safety. The combination of "Beep + Voice" + "Display event" + "No guidance" was more suitable for non-emergency scenarios, while the combination of "Beep + Voice" + "Display event" + "Prohibition type" was more suitable for emergency scenarios. The findings provide theoretical support for research on human-machine interactive cooperative control and lay the foundation for the adaptive design of HMI in different scenarios.

Authors	Adekunle Adebisi, University of Cincinnati John Ash, University of Cincinnati
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-02449
Paper Title	**Impacts of Connected Vehicle Warning Interfaces on Driver Safety Behavior and Preference: A Driving Simulator Based Study**
Abstract	In this study, we developed a driving simulator-based connected vehicle (CV) environment to investigate the impacts of CV safety warning interfaces on driver behavior. We developed three modalities of driver-vehicle interfaces (DVIs) including auditory, visual, and hybrid modalities. Two scenarios are designated to investigate when: (1) these warnings are active to provide dynamic safety warnings depending on the drivers' real-time conditions, and (2) they are passive to provide static warnings regardless of the driver's condition. The DVIs used in those two scenarios are assessed in the application case of providing curve speed warning. Results show that the hybrid conditions (for both passive and active warning modes) encourage safer behavior in terms of the deceleration response time , driving speed, acceleration noise, maximum steering speed, and the time spent above the speed limit, compared to the baseline and the other driving conditions (in which different warning modalities were used). Compared to the baseline scenario, for example, the active hybrid DVIs are most effective in ensuring drivers respond to CV warnings on time, with the potential to reduce the deceleration response time by up to 47% in some cases. Stratifying the data by gender, the active hybrid DVI modality was found to encourage earlier deceleration response, compared to the other DVI modalities for both male and female genders. Lastly, the subjective data showed a preference for the visual and hybrid interfaces, with most participants rating the auditory interfaces as distracting or too frequent.

Authors	Amer Abughaida Laith Daman Miao Song, Honda Research Institute USA, Inc. Yaqiong Zhang, University of Michigan, Ann Arbor Jackie Ayoub, Honda Research Institute USA, Inc.
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-02945
Paper Title	**An Intelligent Blind Spot Indicator System to Prevent Double Lane Merge Conflicts**
Abstract	This paper addresses the challenging task of predicting lane changes for remote vehicles approaching the ego vehicle from two lanes away in a highway driving scenario. Existing systems, such as the Blind Spot Indicator (BSI), detect and notify the ego vehicle's driver when a vehicle is merging adjacent to it, but these notifications are triggered only when the merging vehicle is within a pre-defined distance. However, this approach falls short when both the ego and remote vehicles are simultaneously merging into the middle lane from opposite sides, as the notification is given too late for the ego vehicle's driver to respond appropriately. The primary focus of this study is to develop a predictive model capable of discerning lane change behavior in real-time for remote vehicles approaching two lanes away. Specifically, the research concentrates on a scenario involving three vehicles on a 3-lane road. The ego vehicle (EV), situated on the left lane, aims to merge into the empty middle lane, while the lead vehicle (LV) and the target vehicle (TV) are positioned on the right lane. The TV is passing the LV and moving towards the middle lane. We developed an SVM-based model to predict, with 82% accuracy, in real-time, a lane change behavior. This allows timely notifications to the EV driver, preventing simultaneous lane changes and reducing the risk of side collisions. To determine the appropriate timing for notifications, a preliminary user study using vehicle simulation was conducted.

Authors	Muhammad Sami Irfan, University of Alabama, Tuscaloosa Mizanur Rahman, University of Alabama, Tuscaloosa Abhay Lidbe, University of Alabama Jun Liu, University of Alabama Yangming Shi, Colorado School of Mines Sheila Black
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-03212
Paper Title	**Public Perception of Autonomous Vehicles and Different External Human Machine Interface Designs: Findings from a National Survey**
Abstract	The non-verbal interaction between Vulnerable Road Users (VRUs) and human drivers play a crucial role in enabling the VRUs to make safe road crossing decisions. However, in the case of Autonomous Vehicles (AVs), such interactions are not possible due to the absence of a human driver. The risk of conflicts between AVs and VRUs become even more pronounced in settings with a high frequency of pedestrian. Several designs and concepts for external Human Machine Interfaces (eHMIs) have been proposed to help AVs to communicate their non-verbal intent to VRUs. The evaluation of these eHMIs has been an open research question. Researchers have sought to evaluate these proposed eHMIs through various means, such as survey methods, virtual reality (VR) experiments, and real-world experiments with simulated AVs. As we move towards a future with high deployment of AVs, it is important to understand the perceptions of VRUs towards these eHMI designs to determine the standard eHMI design to adopt in AVs. Motivated by this, we have conducted a national survey to understand the perceptions of VRUs towards eight different eHMI found across the literature. It is revealed that VRUs are generally distrustful of AVs. The results show that participants had the most positive perceptions towards certain eHMI designs in comparison to the others. Furthermore, regardless of their perception, the majority of participants reported they would feel safer if AVs have some form of eHMI on them.

Authors	Jialin Fan Ying Ni, Tongji University Donghu Zhao Shihan Wang, Tongji University
Sponsoring Committee	ACH30
Session Number	Poster Session 2094
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-06166
Paper Title	**Navigating Uncertainty: An Approach to Integrate Human Probing Strategy into Autonomous Vehicle Decision-Making**
Abstract	Given the heterogeneous nature of interaction entities at intersections, the complexity of interactions between autonomous vehicles (AVs) and human-driven vehicles (HVs) presents considerable challenges to the safety and efficacy of the traffic system. At present, AVs struggle to comprehend and apply common HV social norms, including the probing skills exhibited by adept human drivers in ambiguous right-of-way scenarios. In this study, we put forth a novel framework to integrate HV probing strategy into AV decision-making processes, merging data-driven reinforcement le0 vcarning (RL) with rulebased modeling. Building upon unprotected turning trajectories from real-world driving datasets, we select representative human demonstrations considering both parties intentions, facilitating strategy learning. A rule-based model employing a hidden Markov model (HMM) introduces human decision updating mechanism into AV strategy. Experimenting with unprotected turning tasks, our approach achieves balanced safety and efficiency in complex scenarios, with superior success rates via the application of probing behaviors when compared with established baselines. This enables AVs to optimize their right-of-way by consistent probing and decision updates.

Authors	Chen Chai, Tongji University Shixuan Weng Rui Feng Jixiang Wang
Sponsoring Committee	ACH50
Session Number	Poster Session 2211
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-04537
Paper Title	**Measurement of Road User Visual Attention, Stress, Fatigue, and Behavior in Myriad Contexts**
Abstract	Conditional autonomous driving vehicles face a critical safety issue since not all drivers react to unplanned takeovers promptly and appropriately. However, the current approaches to improve the takeover performance are still constrained by their low efficiency and poor targeting. This study proposed a behavioral inoculation approach directed against adverse takeover behaviors to address this issue. This intervention motivated drivers to refute the adverse behaviors and then form appropriate behaviors. Two rounds of experiments were conducted. The former (M=40) was to analyze the adverse takeover behaviors and select the drivers to be intervened. The latter (M=27) was to assess the effectiveness of behavioral intervention and education intervention. The driving test was conducted in the simulator before, immediately after, and five weeks after training. The results demonstrated that the two methods improved takeover behaviors but the behavioral inoculation could reduce individual differences and relieve takeover stress. It was also effective for a longer period compared to education intervention. Within-group standard deviations for maximum steering angle after behavioral inoculation were 2.60°, which was 1.09° less than education intervention. Besides, four drivers received stress relief after behavioral inoculation while only two in the education inoculation group. This study first proposed a behavioral inoculation method and improve takeover performance effectively. It is applicable in assisting to form appropriate behaviors for drivers who had adverse behaviors during unplanned takeovers, enhancing driver safety.

Authors	Silike Daniyaer, Wuhan University of Technology Mengfei Liu Xinpeng Yao Nengchao Lyu, Wuhan University of Technology
Sponsoring Committee	ACH50
Session Number	Poster Session 2211
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-03279
Paper Title	**A Car-Following Model with Consideration of Speed Guidance in Intelligent Connected Environment**
Abstract	In order to study the car-following issue in the context of intelligent connected environments under the influence of speed guidance information, a Velocity-Intelligent Driver Model(V-IDM) that considers the effect of onboard speed guidance information is proposed. Firstly, various Human-Machine Interface (HMI) interfaces are designed to conduct simulated driving experiments, aiming to analyze the fundamental characteristics of car-following behavior exhibited by manually driven vehicles under the influence of speed guidance information in intelligent connected environments. Subsequently, the model incorporates the cooperative and communicative features of intelligent connected vehicles to develop a car-following model that takes speed guidance into account. Model parameters are calibrated using data from simulated driving experiments. The Intelligent Driver Model (IDM) is selected for comparison with the proposed model, and the Root Mean Square Percentage Error (RMSPE) is chosen as the evaluation and validation metric for the parameter calibration results. The results demonstrate that the improved V-IDM exhibits high accuracy in fitting and is suitable for describing the influence of speed guidance on driver car-following behavior in intelligent connected environments. Finally, the model's effectiveness is verified through simulation experiments using SUMO (Simulation of Urban MObility) software. The experimental results indicate that the proposed V-IDM has significant advantages over the IDM in terms of safety and stability. It effectively reduces the risk of collisions between vehicles, achieves smoother driving, avoids road congestion, and reduces the occurrence of traffic accidents, thereby enhancing road traffic efficiency.

Authors	Sisinnio Concas, University of South Florida Achilleas Kourtellis, University of South Florida Mohsen Kamrani, University of South Florida Vishal C. Kummetha, University of South Florida
Sponsoring Committee	ACH50
Session Number	Poster Session 2211
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-02872
Paper Title	**Assessing Short- and Long-Term Impact of Connected Vehicles Warnings on Driving Volatility**
Abstract	This study investigates the treatment effect of Connected Vehicle (CV) warnings on driving behavior using select driving volatility measures. We test the hypotheses that 1) treating drivers with CV warnings affects driving volatility, 2) the treatment effect decreases over time as drivers internalize the CV exposure and revert back to their baseline driving volatility. The analysis uses a sample of daily driving data from a panel of participants from a large-scale CV deployment. The sample of drivers have a baseline silent period with their Human Machine Interface (HMI) turned off, followed by a phase with the HMI turned on. Two models measuring driving volatility as extreme departures from baseline acceleration/deceleration and its first derivative (jerk) are presented and regressed on exposure to HMI treatment, controlling for individual activity-travel behavior, socioeconomic factors, and traffic conditions. We find that the combined effect of receiving a warning and having the HMI On results in a reduction of 9.9 percent and 11.4 percent in acceleration and jerk respectively. The study also finds that the initial reduction effect in volatility brought about by the CV treatment diminishes over time and cancels out after about eight months of continued treatment as drivers revert to their baseline driving habits.

Authors	Song Wang, Chongqing Jiaotong University Zhixia Li, University of Cincinnati
Sponsoring Committee	ACH50
Session Number	Poster Session 2211
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-06042
Paper Title	**Improving Methodologies in Estimating Cognitive Distraction its Safety Impacts under Automated Driving: A Multi-dimensional Approach**
Abstract	Methodologies to measure driver distraction due to human-vehicle interaction (HVI) under automated driving are limited. Existing methods involve irrelevant tasks during manual driving, making them unrealistic for HVI-induced distraction measurement under automated driving. While existing research has improved methodologies in quantifying HVI-induced visual distraction. Another critical component, cognitive distraction, remains unexplored in terms of the enhancements in its quantificational methodology. As HVI-induced driver distraction plays a critical role in determining safe driving under automated driving, a methodology is highly needed to comprehensively measure the driver distraction, specifically focusing on cognitive distraction, under automated driving so that its impact on safety can be investigated. Therefore, this research aims to comprehensively measure HVI-induced cognitive distraction under automated driving and understand its safety impact. Eye-tracking is used to model cognitive distraction, improving measurement by capturing real-time and cumulative effects with pupil dilation performance. A driving simulator study was conducted to validate the proposed methods by recruiting drivers to experience automated driving under Level 3 automation. Drivers must wear an eye-tracker and go through two scenarios with the HVI process (takeover actions needed). Significant and positive correlations are observed between the cognitive distraction intensity and the takeover time. Discussions of cognitive distraction from the microscopic perspective further confirm the validity of the proposed methods in measuring distraction, enhancing the understanding of HVI-induced driver distraction under automated driving and how cognitive distraction intensity affects driving safety. This research redefines distraction measurement methodologies multi-dimensionally, applicable to multiple driver distraction research contexts.

Authors	Fengjiao Zou, Arcadis US Inc jennifer ogle, Clemson University Weimin Jin, Arcadis US Inc Patrick Gerard, Clemson University Daniel Petty, 6d systems Andrew Robb
Sponsoring Committee	ACH50
Session Number	Poster Session 2211
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-06132
Paper Title	**Exploring Factors Influencing Pedestrian Crossing Behavior in Interactions with Autonomous Vehicles on Unmarked Midblock Multilanes: A Virtual Reality-Based Study**
Abstract	Interactions between autonomous vehicles (AVs) and pedestrians remain a challenge on unmarked midblock multilane roads. This study uses virtual reality (VR) to study factors influencing pedestrian crossing behavior and interactions with AVs – with a particular focus on aggressive pedestrian behavior. AVs were modeled with different driving behaviors, which were communicated with pedestrians through hood-mounted signals. Signal indications included: (1) no signal, (2) negotiating behavior with a yellow signal indicating that it would be safe to cross until time-to-collision is imminent and then a red signal is displayed, and (3) a blue signal indicating the vehicle would not yield despite an active pedestrian desire to cross. Results show that pedestrian interactions occurring at the median are more likely to involve risky behaviors, such as crossing in front of AVs showing blue signals (non-yielding behavior). AV signaling significantly impacts pedestrians' crossing behavior, including their accepted gap, walking time, and waiting time. Pedestrians chose the largest gaps when AVs had no signals, they walked the slowest with a yellow signal, and those that crossed on blue accepted the smallest gaps and walked the fastest. Older pedestrians tend to wait longer at the curb for decision-making, and they are less likely to cross in front of AVs showing a blue signal with non-yielding behavior. Finally, pedestrians who self-reported prior conforming behaviors were less likely to cross in front of non-yielding AVs with blue signals, but those who self-reported prior aggressive behaviors were more likely to cross in front of AVs showing blue signals.

Authors	Szu-Fu Chao, Leidos, Inc. Ananna Ahmed, Leidos, Inc. Mafruhatul Jannat, Leidos, Inc. Michelle Arnold, Federal Highway Administration (FHWA)
Sponsoring Committee	ACH50
Session Number	Poster Session 2211
Session Title	**Human Factors of Vehicles: Connected and Automated Vehicles and Intelligent Systems**
Paper Number	TRBAM-24-02316
Paper Title	**Effects Of Truck Platoon Signing and Characteristics on Light Vehicle Driver Behavior**
Abstract	Partially automated truck platooning is an emerging technology that allows heavy trucks to follow each other at close distances via automated speed control and direct wireless communications between vehicle systems. This technology, known as cooperative adaptive cruise control (CACC), allows vehicles to detect and respond rapidly to changes in the speed of the vehicle ahead to maintain a set following gap. Automated truck platooning is expected to offer several economic and environmental benefits in mixed fleet environment, including improved traffic flow, reduced fuel consumption, and fewer emissions of harmful greenhouse gases. However, it is unclear how light vehicle drivers will respond to truck platoons on public roads. A driving simulator experiment to explore the behavior of light vehicle drivers near signed and unsigned partially automated truck platoons at critical highway conflict points was conducted. The study did not find sufficient evidence that truck mounted signs impacted light vehicle driver behavior. However, roadside-mounted signs could be beneficial. Another driving simulator experiment was further developed based upon the same roadway scenarios with additional features to evaluate the effects of platoon size and gap distance on the behavior of light vehicle drivers. The findings suggest that it might be beneficial if a platoon could adjust its size and the gap between the trucks proactively based on ongoing traffic status and highway sections. The results of the experiments could help develop guidance and recommendations for signing and operation of partially automated truck platoons in mixed fleet environment on public highways.

Authors	hanlin chen, Purdue University Simin Chen Wenyu Li Wei Yang Yiheng Feng, Purdue University
Sponsoring Committee	AED30
Session Number	Poster Session 2214
Session Title	**Information Systems and Technology**
Paper Number	TRBAM-24-06036
Paper Title	**Impact Analysis of Inference Time Attack of Perception Sensors on Autonomous Vehicles**
Abstract	As a safety-critical cyber-physical system, cybersecurity and related safety issues for Autonomous Vehicles (AVs) have been important research topics for a while. Among all the modules on AVs, perception is one of the most accessible attack surfaces, as drivers and AVs have no control over the outside environment. Most current work targeting perception security for AVs focuses on perception correctness. In this work, we propose an impact analysis based on inference time attacks for autonomous vehicles. We demonstrate in a simulation system that such inference time attacks can also threaten the safety of both the ego vehicle and other traffic participants.

Authors	Tumlumbe Juliana Chengula, South Carolina State University Judith Mwakalonge, South Carolina State University Saidi Siuhi, South Carolina State University Gurcan Comert, Benedict College
Sponsoring Committee	AED30
Session Number	Poster Session 2214
Session Title	**Information Systems and Technology**
Paper Number	TRBAM-24-05043
Paper Title	**Improving Road Safety with Ensemble Learning: Detecting Driver Anomalies Using Vehicle Inbuilt Cameras**
Abstract	The adoption of Advanced Driver Assistance Systems (ADAS) has expanded dramatically in recent years, with the goal of improving road safety and driving comfort. Driver monitoring is important to ADAS since it identifies abnormalities such as sleepiness, distraction, and impairment to guarantee safe vehicle operation. Traditional methods of detecting driver anomalies rely on intrusive physiological measures, while ADAS with built-in cameras offers a non-intrusive and cost-effective option. This study investigates the application of ensemble model learning for driver anomaly detection in automobiles employing ADAS and in-vehicle cameras. Deep learning models such as ResNet50, DenseNet 101, and Inception V3 were deployed as learner models to classify driving behavior. The raw dataset used in this study was in the form of videos obtained from the National Tsinghua Driver Drowsiness Detection (NTHUDD) dataset. Amongst the two ensemble models used, the eXtreme Gradient Boost (XGBoost) classifier pooled predictions from the learner models and attained a remarkable average accuracy and precision of 97% on the validation dataset. Classes such as laugh_talk and yawning were properly and separately distinguished. The ensemble technique capitalized on the strengths of various models while mitigating their weaknesses, resulting in robust and trustworthy forecasts. The findings highlight the potential of ensemble modeling to enhance driver anomaly detection systems, providing valuable insights for improving road safety. By continually monitoring driver behavior and detecting abnormalities, ADAS can provide timely warnings and interventions to prevent accidents and save human lives.

Authors	Yichang Shao, Southeast University Yuhan Zhang, Southeast University Wei Ye, Southeast University Yueru Xu, Southeast University Xiaomeng Shi, Southeast University Zhirui Ye, Southeast University
Sponsoring Committee	ACP50
Session Number	Poster Session 2233
Session Title	**Traffic Flow Theory, Part 1: Connected and Autonomous Vehicles (Part 2, Session 2234; Part 3, Session 4068; Part 4, Session 4069)**
Paper Number	TRBAM-24-02176
Paper Title	**Longitudinal Control Strategies based on Safety Potential Field for Autonomous Vehicles Considering Road Accident Risk**
Abstract	The advent of autonomous vehicles (AVs) has complicated traffic flow and raised safety concerns, necessitating a balance between driving safety and traffic efficiency. This paper proposes a dynamic longitudinal control strategy for AVs, based on real-time accident risk assessments. Data from traffic flow, road characteristics, and weather conditions are analyzed using a random forest algorithm, producing a real-time accident risk identification model through a support vector machine. In addition, the Perceived Risk Field Model (PRFM), a car-following model calibrated using the NGSIM dataset, considers vehicle distance, velocity, relative velocity, and acceleration. These models underpin our proposed longitudinal control strategies, tailored to variable accident risk levels. Under the normal risk control strategy, the PRFM outperforms the Intelligent Driver Model (IDM) and the Cooperative Adaptive Cruise Control Model (CACC) in stability and driving comfort. For high accident risk scenarios, our approach shows improved collision avoidance and traffic oscillation mitigation. Simulations indicate that the high accident risk control strategy offers better safety and stability than the normal risk strategy. Furthermore, traffic flow diagrams suggest an increase in road capacity as AV penetration rates rise, pointing to the promising efficiency of our proposed solution. This research provides a robust framework for AV operation, ensuring optimal traffic safety and efficiency.

Authors	hanlin chen, Purdue University Vamsi Bandaru, Purdue University Yilin Wang, Purdue University Mario Romero, Purdue University Andrew Tarko, Purdue University Yiheng Feng, Purdue University
Sponsoring Committee	ACP30 ACH30 ACH40
Session Number	Lectern Session 4051
Session Title	**Moving Automated Vehicle Research into Practice**
Paper Number	TRBAM-24-05208
Paper Title	**A Cooperative Perception System for Aiding CAVs Navigation and Improving Safety**
Abstract	Cooperative perception that integrates sensing capabilities from both infrastructure and vehicles can greatly benefit the transportation system in terms of safety and data acquisition. In this study, we develop and evaluate a prototype of such a system by integrating a portable Lidar-based infrastructure detection system (i.e., TScan) with an SAE Level 4 connected and automated vehicle (CAV). Vehicle-to-everything (V2X) communication devices are installed on both the TScan and the CAV to enable real-time message transmission of detection results in the form of SAE J2735 Basic Safety Messages (BSMs). We validate the prototype system through a case study, which aims at improving CAV situation awareness and protecting vulnerable road user (VRU) safety. Field testing results demonstrate the benefit of cooperative perception from infrastructure sensors in detecting the occluded VRU earlier and helping CAV plan safer and smoother trajectories.

Authors	Nastaran Moradloo, University of Tennessee Iman Mahdinia Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACH10
Session Number	Lectern Session 4049
Session Title	**Pedestrian Safety**
Paper Number	TRBAM-24-02568
Paper Title	**Nighttime Safety of Pedestrians: The Role of Pedestrian Autonomous Emergency Braking Systems**
Abstract	The rise in vulnerable road user fatalities, e.g., pedestrian-involved crashes, is alarming. The number of pedestrian fatalities rose from 6,565 in 2020 to 7,388 in 2021. Nighttime poses unique challenges among the various risk factors in pedestrian-involved crashes, accounting for 74% of fatalities in 2021. A promising solution to improve pedestrian safety is safe vehicles, a key element of the Safe System Approach. Vehicle automation, particularly Pedestrian Autonomous Emergency Braking (P-AEB) systems, can mitigate pedestrian-involved crashes. However, the effectiveness of P-AEB systems, especially in darkness, has remained uncertain. This study analyzes the Insurance Institute for Highway Safety nighttime dataset from 2021 to 2023 (1973 field tests) to understand the P-AEB systems' effectiveness at night and explore correlates of their performance, especially the role of headlight technologies, employed sensors, and vehicle size. Results indicate that P-AEB systems stopped vehicles in 63.6% of the cases and, on average, reduced speed by 33.12% for the occurred crashes. Using a random-effect Heckman sample selection model, the study estimates the crash probability and impact speed in case of a crash. Results reveal that P-AEB systems perform better in vehicles with light-emitting diode headlights than those with halogen headlights and are less effective in larger cars than smaller ones. Additionally, a fusion of camera and radar sensors can improve P-AEB systems' reliability instead of relying solely on cameras. Future efforts could enhance nighttime pedestrian safety by focusing on advanced headlight technologies, sensor integration, improving P-AEB systems prediction algorithms, and addressing system limitations in larger cars.

Authors	Yasir Ali Anshuman Sharma Danjue Chen, North Carolina State University
Sponsoring Committee	ACP30
Session Number	Poster Session 4028
Session Title	**Vehicle-Highway Automation, Part 3 (Part 1, Session 3162; Part 2, Session 3229)**
Paper Number	TRBAM-24-02167
Paper Title	**Comparing the lane-changing execution behaviour of human-driven and autonomous vehicles: evidence from the Waymo dataset**
Abstract	Lane-changing is a routine driving task, which is often difficult to perform because of a multitude of factors, such as different motivations and the number of drivers involved in the decision-making process. Therefore, understanding and modelling lane-changing behaviour have received significant attention in the literature. Much of this understanding pertains to human-driven vehicles, where drivers make lane-changing decisions, which are often uncertain and one of the causes of safety-critical events. However, an interesting yet unexplored research question is whether such an understanding of human-driven vehicles can be applied to autonomous vehicles, the answer of which heavily relies on obtaining empirical evidence from high-quality autonomous vehicle trajectory data. To this end, recently released autonomous vehicle datasets like Waymo can provide rich information (and unprecedented opportunities) to answer this question. As such, the study investigates and compares the lane-changing execution behaviour of autonomous vehicles with human-driven vehicles from Waymo and NGSIM datasets. Lane-changing execution times (or durations) are modelled by a random parameters hazard-based duration modelling approach, which accounts for unobserved heterogeneity. The random parameters duration model reveals heterogeneity in lane-changing execution behaviour, which is significantly higher in human-driven vehicles compared to autonomous vehicles. Whilst contradictory to a general conjecture in the literature that autonomous vehicles will eliminate human driver heterogeneity, our finding indicates that heterogeneous behaviour also exists in autonomous vehicles (although to a lesser extent than in human-driven vehicles), which can be contextual in response to prevailing traffic conditions. Overall, autonomous vehicles show safer lane-changing behaviour compared to human-driven vehicles.

Authors	Manuela Gennesseaux, Université Gustave Eiffel Veronique Cerezo, Université Gustave Eiffel Edjeou Wiyao Aboubakar Kone Minh-Tan Do
Sponsoring Committee	ACP30
Session Number	Poster Session 4028
Session Title	**Vehicle-Highway Automation, Part 3 (Part 1, Session 3162; Part 2, Session 3229)**
Paper Number	TRBAM-24-03180
Paper Title	**Effect of Pavement Surface Texture, Speed, and Water Depth on Braking Performance of Autonomous Shuttles: An Experimental Evaluation**
Abstract	Autonomous car are vehicles that can perceive their environment and operate without human intervention. They use advanced technologies such as sensors, cameras, lidar and artificial intelligence to navigate and make decisions autonomously. In adverse weather conditions, the operation of autonomous vehicles can be affected and the accuracy of sensors can be compromised, which is one of the reasons why many autonomous vehicles need human supervision. Although there are many simulations and theoretical models available, the lack of real experimental data may limit the ability of manufacturers to assess and improve the safety and performances of autonomous vehicles before their large-scale deployment. Experimentation and testing of autonomous vehicles are a key part of the technology's development. This paper was developed within the framework of the project Autonomous Shuttle Experimentation (Expérimentation Navette Autonome – in French) funded by the French Agency for Ecological Transition. The work presents an evaluation of the braking distances of an autonomous shuttle operating under different environmental conditions in order to assess its safety and comfort level. The braking tests were performed in different configurations, varying: pavement texture, water depth and vehicle speed. The manoeuvres were performed in a straight line with programmed braking and in a straight line with emergency braking.

Authors	Xiaoxia Dong, University of Pennsylvania Erick Guerra, University of Pennsylvania Ricardo Daziano, Cornell University
Sponsoring Committee	ACH10
Session Number	Poster Session 3160
Session Title	**Automation, Technology, and Pedestrian Interactions**
Paper Number	TRBAM-24-00577
Paper Title	**Will Automated Vehicles Encourage More Jaywalking? Results From a Stated Preference Experiment**
Abstract	When interacting with driverless cars, pedestrians might be emboldened to jaywalk knowing the vehicles will slow down for them automatically. Excess jaywalking disrupts traffic flow and poses challenges for traffic law enforcement. Few studies have examined pedestrians' attitudes toward driverless cars' safety implication, management strategies for the interactions between pedestrians and driverless cars, and how pedestrians would expect their street crossing behavior to change in the presence of driverless cars. We conducted an online stated preference survey study of 1,000 residents in the Philadelphia and Seattle metropolitan areas to investigate respondents' attitudes toward driverless cars and their preferences of jaywalking under different driverless car saturation levels. Through descriptive data analysis and multilevel binomial logit analysis, we find that overall pedestrians felt less safe with driverless cars on the road. Pedestrians prefer limiting the speeds of driverless cars or disabling driverless functions altogether to increasing enforcement for jaywalking laws. Pedestrians might be less concerned about jaywalking in the presence of driverless cars generate major shifts in crossing behavior. Our findings remind cities that proven street design strategies could help to ensure safer interactions between under certain road configurations and traffic conditions. Overall, however, it is unlikely that driverless cars will pedestrians and driverless cars and greater acceptance of driverless cars operating on urban streets.

Authors	Norran Novat, Western Michigan University Valerian Kwigizile, Western Michigan University Jun-Seok Oh, Western Michigan University
Sponsoring Committee	ACH10
Session Number	Poster Session 3160
Session Title	**Automation, Technology, and Pedestrian Interactions**
Paper Number	TRBAM-24-02362
Paper Title	**Impact of Slip Lanes on Pedestrian Safety at Roundabouts Considering Autonomous Vehicles.**
Abstract	The emergence of autonomous vehicles (AVs) has the potential to revolutionize transportation systems, but their impact on the safety of pedestrians in roundabouts is not fully explored. There is a significant gap in understanding the impact of safety on pedestrians in roundabouts under heterogeneous traffic conditions, particularly in the presence of a slip lane. Slip lanes have a significant impact on the speed of right-turning traffic, and vehicle merging behavior and as well they raise the risk of conflicts for pedestrians. The study focused on investigating the impact of slip lane designs on pedestrian safety. Through a combination of field observations and simulation modeling, the results highlighted significant findings. Field observations revealed that slip lane designs influenced the speed of vehicles, with traffic on slip lanes exhibiting higher speeds compared to approach traffic. This behavior had implications for pedestrian safety, particularly at entry and exit crossing points of slip lanes. Additionally, the study used simulation analysis to evaluate the impact of AVs on pedestrian safety at slip lane crossings. AVs were found to have a positive impact on reducing the occurrence of pedestrian conflicts but a negative impact on the severity of conflicts. The study suggests the need for improved speed control at slip lanes and emphasizes the importance of considering AV integration and slip lane design to ensure pedestrian safety.

Authors	Jiayu Chen, University of California, Berkeley Steven Shladover, University of California, Berkeley
Sponsoring Committee	ACP30
Session Number	Poster Session 3162
Session Title	**Vehicle-Highway Automation, Part 1 (Part 2, Session 3229; Part 3, Session 4028)**
Paper Number	TRBAM-24-05951
Paper Title	**Initial Indications of Safety of Driverless Automated Driving Systems**
Abstract	As driverless automated driving systems (ADS) start to operate on public roads, there is an urgent need to understand how safely these systems are managing real-world traffic conditions. With data from the California Public Utilities Commission (CPUC) becoming available for Transportation Network Companies (TNCs) operating in California with and without human drivers, there is an initial basis for directly comparing ADS and human driving safety. This paper analyzes the crash rates and characteristics for three types of driving: Uber ridesharing trips from the CPUC TNC Annual Report in 2020, supervised AV test driving from the California Department of Motor Vehicles (DMV) between December 2020 and November 2022, and driverless ADS deployment from Waymo and Cruise reported to CPUC between March 2022 and June 2023. All of the driving was within the city of San Francisco. The same geographical confinement allows for controlling the exposure to vulnerable road users, population density, speed limit, and other external factors such as weather and road conditions. The Miles per Crash (MPC) for both supervised and driverless automated driving was within the same order of magnitude as the Uber ride-share driving, but the data samples are not yet large enough to support conclusions about whether the current automated systems are more or less safe than human-driven vehicles in the complex San Francisco urban environment.

Authors	Md Tanvir Ashraf, Michigan State University Kakan Dey, Michigan State University
Sponsoring Committee	ACP30
Session Number	Poster Session 3162
Session Title	**Vehicle-Highway Automation, Part 1 (Part 2, Session 3229; Part 3, Session 4028)**
Paper Number	TRBAM-24-04406
Paper Title	**Rear-end collision risk estimation for Autonomous Vehicles under mixed traffic scenario using real-world perception data.**
Abstract	Rear-end crash is the predominant type of autonomous vehicle (AV)-involved crash, observed in the real-world AV crash database, maintained by California Department of Motor Vehicles. In mixed traffic, the car-following (CF) behavior of human-driven vehicles (HDVs) when following an AV can significantly affect the rear-end crash risks for AVs. Using recently released large scale Lyft Level-5 real-world AV perception dataset, this study aimed to analyze the rear-end collision risk of AVs for different CF scenarios where AV was present as a follower or leader vehicle on a roadway using surrogate safety measures. An autoencoder based anomaly detection method was used for the traffic conflict estimation. Time-to-collision (TTC) and deceleration rate to avoid collision (DRAC) were adopted as conflict indicators. A univariate generalized pareto (UGP) model was fitted to the identified traffic conflicts, and the model findings indicate that the rearend crash risk was much higher when an HDV follows an AV compared to the scenario when an AV follows an HDV. The rear-end crash risk was almost two times higher when an HDV follows an AV (HDV-AV pair) than when an HDV follows another HDV (HDV-HDV pair). The conflict indicators also show that HDV-AV pairs had generally higher TTC values than AV-HDV pairs, indicating the relatively risky driving behavior of following HDV. On the other hand, higher TTC values and low risk of rear-end crash in AV-HDV pair indicates AVs' conservative/safe driving behavior. However, AVs' larger time gap and headways could lead to low traffic efficiency.

Authors	Mary Cummings, George Mason University
Sponsoring Committee	ACP30
Session Number	Poster Session 3162
Session Title	**Vehicle-Highway Automation, Part 1 (Part 2, Session 3229; Part 3, Session 4028)**
Paper Number	TRBAM-24-00397
Paper Title	**1 Assessing Readiness of Self-Driving Vehicles**
Abstract	State agencies are increasingly faced with self-driving permit and licensing requests as self-driving operations expand. However, these expansions have led to congestion and problematic interactions with first responders, as well as increasing public distrust. To respond to these self-driving permit requests with evidence-based recommendations, government agencies need straightforward tools to help them objectively and holistically assess such requests. To this end, using self-driving disengagement data from California, as well as federal non-fatal and CA transportation network companies' crash reports, this effort demonstrates how the combination of human- and autonomy-initiated disengagements, coupled with non-fatal crash rates, can provide insight into assessing self-driving vehicle readiness for commercial operations. Additional results show that Cruise's and Waymo's robo-taxis in San Francisco are 4-8x more likely to be involved in non-fatal crashes, equivalent to the CA crash rates of Uber and Lyft. One major drawback to this approach is a lack of reporting by the majority of companies conducting self-driving operations on public roads in CA. This lack of reporting and companies' avoidance of publicly address emerging problems, while simultaneously claiming their technologies are superior to human drivers, suggests there are systemic problematic safety cultures in the self-driving community. If self-driving companies do not adopt more transparent and responsive safety practices, their non-fatal crash rates could continue to exceed that of human drivers. They also risk further eroding public sentiment, which could lead to further public rejection of what otherwise could have been a promising technology.

Authors	Shihan Wang, Tongji University Ying Ni, Tongji University Yilin Cai Jiayuan He Jian Sun, Tongji University
Sponsoring Committee	ACH20
Session Number	Poster Session 3214
Session Title	**Bicycle Safety, Planning, and Design: Research to Support Better Bicycling Conditions**
Paper Number	TRBAM-24-00599
Paper Title	**Interaction Ability Evaluation of Autonomous Vehicles with Bicycles on Mixed Traffic Road Segments**
Abstract	Autonomous Vehicles (AVs) face significant challenges when interacting with bicycles on mixed traffic road segments, given the bicycles' flexible and complex behavior. To ensure safety, it is necessary for AVs to mimic normal Human-Driven Vehicles (HVs), as behavior that are not understood by humans may lead to danger. Therefore, evaluating behavioral differences in current AV-bicycle and HV-bicycle interaction is essential. However, limited studies considered the AV-bicycle interaction behavior evaluation, particularly on real road segments. This study extracted a large number of HV-bicycle and AV-bicycle interaction data in real world using the Waymo Open Dataset and Argoverse Dataset, defined the interaction ability as the behavior similarity quantitation between AVs and HVs, proposed a distribution-oriented method to evaluate the interaction ability of AVs with bicycles on mixed traffic road segments, which can measure the behavioral characteristics of the entire interaction process. The results show that AVs from the data collected are more likely to follow the bicycle than overtake, but 63.6% of AVs could not follow like HVs, especially in terms of speed control and distance maintenance, preferring a low speed and long distance in complex scenarios. It is necessary to further optimize the interaction strategy of AVs in combination with the current analysis.

Authors	Nastaran Moradloo, University of Tennessee Iman Mahdinia, University of Tennessee, Knoxville Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACP30
Session Number	Poster Session 3229
Session Title	**Vehicle-Highway Automation, Part 2 (Part 1, Session 3162; Part 3, Session 4028)**
Paper Number	TRBAM-24-03964
Paper Title	**Who Initiates the Automated Vehicle Disengagement—Drivers or Automated Driving Systems?**
Abstract	A promising solution to reach the vision zero goal is safe vehicles, a critical element of the Safe System Approach. Automated Vehicles (AVs), especially those with Automated Driving Systems (ADS), aim to improve transportation safety by reducing human errors. However, disengagements, the vehicle control shifts from automatic to manual, pose safety concerns to ADS-equipped vehicles. This study investigates the associations between disengagement initiator (ADS vs. human) and disengagement attributes. Specifically, the study analyzes recent real-world disengagement data from the Autonomous Vehicle Tester Program published by the California Department of Motor Vehicles, integrated with vehicle data to create a unique database (N=5259). A random-effect binary logit with panel data is applied to capture the panel structure of the data (repeated observations over time for different companies) and unobserved heterogeneity across companies. Statistics indicate that drivers initiated 88.02% of disengagements. Further, disengagement predominantly occurred due to planning/prediction and perception issues. Results reveal that ADS-initiated disengagements are more likely to occur with hardware/software issues, while they are less likely to happen with perception, mapping/localization, and planning/prediction issues than control issues. The results indicate that the probability of AV-initiated disengagement is higher in Electric Vehicles (EVs) than non-EVs. Further, SUVs/Vans operating on freeways, highways, and streets have a higher probability of ADS-initiated disengagement than hatchback/sedan cars on streets. Overall, this study contributes to the knowledge of AV disengagements by utilizing the most recent data to capture the rapid changes in the AV stack and by investigating the role of vehicle characteristics in ADS performance.

Authors	Euntak Lee, Yonsei University Jimin Chae, Yonsei University Inhoe Jeong Youngjun Kim Bongsoo Son, Yonsei University
Sponsoring Committee	ACP30
Session Number	Poster Session 3229
Session Title	**Vehicle-Highway Automation, Part 2 (Part 1, Session 3162; Part 3, Session 4028)**
Paper Number	TRBAM-24-04908
Paper Title	**Safety Evaluation for Lane-Changing Behaviors of Autonomous Vehicles based on Vehicle-to-Vehicle Communication Technology**
Abstract	As the transition period of mixed traffic is expected to extend for more than 30 years, it is essential to develop autonomous vehicle (AV) technologies with vehicle-to-vehicle (V2V) communication that closely resemble human driving behavior. Understanding lane-changing (LC) behaviors is essential for traffic safety, especially in freeway weaving sections where turbulence induced by LCs is frequent. To address this challenge, this study aims to investigate how V2V communication-based AVs assess safety levels with their surrounding vehicles compared to human-driven vehicles (HVs) when conducting discretionary LCs. An integrated CF-LC model for naturalistic AV driving behavior is developed using a deep learning method with long short-term memory (LSTM). This model enables every single vehicle to make decision on acceleration and driving lane simultaneously. By applying to real-world NGSIM trajectory data in the US, the proposed model is evaluated using a surrogate safety measure time-to-collision (TTC). The results show that, compared to HVs, AVs perform more defensive behavior toward vehicles on the driving lane, more aggressive toward those on the opposite lane, and similar behavior toward those on the target lane. These findings would serve as valuable information in developing AV technologies with a focus on safety.

Authors	Handong Yao, University of Georgia Qianwen Li, University of Georgia
Sponsoring Committee	ACP30
Session Number	Poster Session 3229
Session Title	**Vehicle-Highway Automation, Part 2 (Part 1, Session 3162; Part 3, Session 4028)**
Paper Number	TRBAM-24-06205
Paper Title	**Safety Aware Predictive Control Neural Network for Connected Automated Vehicle Operations**
Abstract	Connected automated vehicles (CAVs) with trajectory prediction and planning capabilities have the potential to enhance transportation systems significantly. However, conventional studies have treated trajectory prediction and planning as separate models, leading to safety concerns due to prediction errors. To address this, a Safety-Aware Predictive Control Neural Network (SPCNN) is proposed in this study, which integrates trajectory prediction and planning into a single neural network. The SPCNN employs a car-following model-based recurrent neural layer to ensure safety. Numerical experiments demonstrate the superiority of the SPCNN over both the separated trajectory prediction and planning models and the adaptive cruise control (ACC) model. The SPCNN significantly enhances safety performance, achieving a remarkable 44% improvement compared to the separated trajectory prediction and planning models. Despite this safety boost, there is only a minor decrease in mobility, with a -7% loss. Additionally, sensitivity analysis reveals that the SPCNN excels when the prediction/planning period is relatively long. This finding further reinforces the effectiveness of the SPCNN in maintaining safety and mobility, making it a superior alternative to the ACC model for CAV operations.

Authors	Nischal Khadka, Louisiana State University Hany Hassan, Louisiana State University
Sponsoring Committee	ACP30
Session Number	Poster Session 3229
Session Title	**Vehicle-Highway Automation, Part 2 (Part 1, Session 3162; Part 3, Session 4028)**
Paper Number	TRBAM-24-05905
Paper Title	**Analyzing the Impacts of Connected and Autonomous Vehicles on Traffic Operation and Safety at Cloverleaf Interchanges**
Abstract	The rapid emergence of Connected and Autonomous Vehicles (CAVs) has sparked considerable interest in evaluating their impacts on traffic safety and operation. However, the impacts of CAVs have not yet been studied in prior studies at critical interchanges such as full cloverleaf interchanges. This research study aims to contribute to the literature by exploring the CAVs performance at three full cloverleaf interchanges located in Louisiana using the VISSIM traffic simulation software. The study examines various Market Penetration Rates (MPRs) of CAVs and their effects on travel time, delays, and safety. The findings demonstrate that as the MPR of CAVs increases, travel times exhibit a consistent improvement, particularly at on-ramps, off-ramps, and loop ramps. This enhancement is attributed to smoother traffic flow and improved merging and weaving maneuvers facilitated by CAVs. In addition, safety analysis using the Surrogate Safety Assessment Model (SSAM) reveals a considerable reduction in the number of conflicts between vehicles with increasing MPRs. This decline in conflicts' number indicates the potential of CAVs in creating a safer driving environment at cloverleaf interchanges. Overall, the study highlights the promising benefits of integrating CAVs into the transportation system at interchanges. The presence of CAVs not only enhances road safety and optimizes traffic flow but also revolutionizes the mobility experience. The insights gained from this research are valuable to transportation planners and policymakers, aiding them in making informed decisions for infrastructure design, traffic management strategies, and the seamless integration of CAVs into the broader transportation system

10 Transportation Safety Management

Frank Gross, VHB
Jaeyoung Lee, Central South University
Joy Davis, ITRE North Carolina State University
Jiayu Yang, Central South University

Ninety-one papers studying diverse perspectives of transportation safety management will be presented in five sessions sponsored by the Standing Committee on Transportation Safety Management Systems (ACS10). The five sessions include Lectern Session 2004 titled **Hot Topics in Transportation Safety Management Systems: A Lectern-Poster Session,** Lectern Session 3003 titled **Using Connected and Automated Vehicles to Improve Transportation Safety**; Poster Session 2235 titled **Transportation Safety Management Systems from Start to Finish**; Poster Session 2159 titled **Motorcycle Operation and Safety Research**; and Poster Session 2236 titled **School Transportation and Planning Research** at the 2024 TRB Annual Meeting. The following is a brief overview of the papers.

Five papers discussed the **Safe System Approach** and factors related to **Crash Severity**. McCombs et al. (24-00048) developed a corridor-level methodology to identify safety improvements for urban and suburban arterials in Florida that align with the Safe System approach. The significant factors in the model were traffic volume, intersection density and size, area type, bus stop presence, citation rate, and corridor lighting presence. Khan and Das (24-04412) conducted a systematic review of the Safe System approach and its applications in highway safety. The findings highlight the potential for the Safe System approach to create a more forgiving and resilient transportation system, offering guidance for policy decisions, future research, and interventions. Gallagher and Fisher (24-02723) performed a safety simulation to demonstrate that the Empirical Bayes method can mitigate, but never eliminate, regression-to-the-mean bias. Patel et al. (24-05730) identified factors contributing to severe injury intersection-related crashes in New Jersey. Using machine learning algorithms, the study revealed that factors such as angle crash type, posted speed limits (36 to 45 MPH and 46 to 55 MPH), and temporal elements such as summer and fall months, as well as between 6:00 and 18:00 hours, play significant roles in increasing the probability of injury severity in intersection-related crashes. Alzaffin et al. (24-03261) examined injury risk to the head, upper extremity, torso, and lower extremity for drivers and passengers involved in serious motor vehicle crashes. The results indicate that the length of hospital stay is negatively associated with injuries to the upper extremities.

Four papers investigated **effects of speed on traffic safety**. Zhang et al. (24-02956) revisited the roles of speeds in traffic crashes using a geographically weighted neural network approach. The findings indicate that the marginal effects of injury severities differ between the types of crashes in all models and there is substantial variation in marginal effects across different spatial regions. The authors conclude that incorporating neural networks into the spatial modeling framework can help identify high-risk regions for specific speeding-related crashes and targeted localized countermeasures. Afifah and Guo (24-04451) proposed a deep reinforcement learning (DRL) model to improve mobility and safety over an interconnected network considering rerouting behavior. The authors also assess the

transferability of the control algorithm across different traffic and driving behavior attributes as well as the efficacy of various control algorithms and the impacts of VSLC implementations in different locations. Xiong and Chen (24-01069) developed risk-informed speed limits using an augmented reliability problem with multi-fidelity enhancement. The proposed method can facilitate variable speed limits based on the changing driving environment and support proactive traffic safety management during weather events. Hasan and Abdel-Aty (24-02247) focused on setting appropriate speeds under different traffic conditions on freeways and its impact on crash frequency. The results indicate that crash frequency is expected to increase as the average vehicle spacing as a proportion of the stopping distance decreases, while traffic flow remains constant.

Six papers explored **traffic safety during the COVID-19 pandemic**. Banerjee et al. (24-00205) investigated distracted driving crashes pre-COVID (2018-2019) and post-COVID (2020-2021) in Kentucky. Systemic safety analysis showed that factors related to severe distraction-related crashes changed from pre- to post-pandemic. Raha et al. (24-00688) investigated the impact of COVID-19 on crash injury outcomes among different demographic groups in California. Results revealed that young drivers and Black drivers were more likely to experience severe crashes during the height of the pandemic compared to other age and racial groups, respectively. Marshall et al. (24-02893) explored the long-term effects of COVID-19 on crash occurrence in Maine. Results showed that speeding increased significantly during and after the stay-at-home order. On urban roadways, the odds of fatal and injury crash occurrence increased by 87% in 2021 for evening peak hours and by 79% for off-peak hours compared to the pre-restriction period (2018-19). Crash odds decreased during morning peak hours, representing a temporal shift in crash occurrence. Marshall et al. (24-02963) also presented lessons learned and research gaps based on a review of studies on COVID-19. They noted that research studies show the rate of severe injury crashes, as well as aggressive driving (e.g., speeding) increased in most places during the travel restrictions, and continued even after these restrictions were lifted. Zheng and Sharmeen (24-04418) assessed regional road traffic safety in Sweden through dynamic panel data analysis to identify the influence of policies and COVID-19. It also evaluates the impact of planned policy interventions (i.e., vision Zero policy) and the effects of sudden unplanned events (COVID-19). The findings reveal that the speed limit changes were effective in reducing fatalities and severe injuries. COVID-19 further reduced traffic crashes during the pandemic period. Chengula et al. (24-04693) used the Empirical Bayes method to investigate abnormal traffic conditions during COVID-19. Results indicate that ignoring the influence of confounding variables could lead to less accurate predictions of the pandemic's impact on fatal crashes.

Thirteen papers discussed emerging technology, including 11 papers on **connected and automated vehicles**, 1 paper on a safety 'GPT'-type platform, and 1 paper on a real-time safety evaluation system. Haroon and Ryan (24-00697) provided insights into automated vehicle collisions using AI models to compare AVs with non-AVs. Tang and Li (24-02627) proposed a driving risk assessment approach, based on the theory of artificial potential field, to assess and analyze the safety of mixed driving environments (i.e., mixed vehicle fleet of autonomous vehicles (AVs) and human-driven vehicles (HVs)). Moradloo et al. (24-02656) analyzed nationwide automated driving system (ADS) crash data from 2021-2023 to better understand the factors associated with impact speeds. Impact speeds with ADS were mainly low (average 13.88 mph), while crashes involving unlawful road user behavior were associated with higher impact speeds, emphasizing the challenges posed by unpredictable behaviors. Goodall (24-02913) compared automated vehicle and baseline human-driven crash databases to assess comparability. The paper recommends opportunities to improve comparability, both in terms

of normalization and contextualization, as well as additional data fields that can be incorporated into existing databases. Dong et al. (24-03775) explored how environmental and road factors impact AV (SAE level 2) safety performance using a network and coupling analysis. Results indicate that snow and traffic incidents or work zones are exclusively associated with collisions involving fixed object and vehicle, respectively. The authors also recommend safety enhancements for AVs based on the findings. Rajia et al. (24-04924) examined the behavioral models from preceding studies to understand appropriate parameter settings and evaluate the corresponding crash risk for AVs under mixed traffic operation. The safety assessment showed that crash risk can be reduced by 21.9%, 22.3%, and 17.6% under normal, cautious, and all-knowing driving behaviors, respectively, with mixed scenarios. Jashami et al. (24-05762) examined factors influencing the efficacy of automatic emergency braking (AEB). The results provide insights into the potential benefits and limitations of these systems in their current form. Wang and Li (24-06058) quantified safety improvements and human-machine trade-offs in the transition to automated driving. Safety performance is evaluated by considering possible types of human errors at each automation level. Cottam et al. (24-04770) investigated interactions between sidewalk autonomous delivery robots and vehicular traffic at stop-controlled crosswalks. Observed behaviors included pedestrians intervening in SADR operations, drivers waiting for excessive amounts of time as they were unsure of delivery robots crossing intentions, and drivers having to move delivery robots that were blocking crosswalks. Okafor et al. (24-03029) conducted a statewide correlation analysis of connected vehicle event data to examine the potential of using hard braking events as a surrogate for crashes in Alabama. Spearman's rank-order correlation results indicated a moderate correlation between hard braking events and crashes on principal arterials, minor arterials, and major collectors, and a weak correlation on interstates. Gupta et al. (24-05717) examined the relationship between connected vehicle driving event data (acceleration, braking, and cornering) and police-reported crashes. The results showed a strong case for these data to be used in traffic safety analysis in complement to or in-lieu of police-reported crash data. Zheng et al. (24-01497) introduced TrafficSafetyGPT, a Large Language Model Meta AI-based model that is similar to ChatGPT but safety-focused. Wu et al. (24-05833) developed a real-time safety performance evaluation system for road segments. The probability and severity of potential collisions are estimated using real-time vehicle trajectories, and a real-time risk score is defined to assess the safety performance of road segments.

Eight papers explored **safety analysis methods**, including network screening and risk assessment methodologies to prioritize sites with potential for safety improvement. Lee et al. (24-00694) evaluated the driving safety of AVs and manual vehicles on urban roads to determine priority for further diagnosis and improvement. The results indicated that sections with a high number of signalized intersections showed lower driving safety and could be prioritized to improve safety for both AVs and manual vehicles. Zhao et al. (24-01471) propose an improved generative adversarial network (GAN) to model collision avoidance behaviors of multiple agents when predicting their trajectories. The proposed framework captures the pattern of collision avoidance behaviors of multiple agents, which has potential to serve as an effective way to enhance traffic safety at unsignalized intersections. Park et al. (24-01876) developed a two-stage crash severity model of 'at-port' and 'near-port' regions using a support vector machine and a Bayesian multinomial model. The methodology can be used for policy development to increase traffic safety in port cities. Seo et al. (24-03694) developed a methodology to classify important words in unstructured data describing traffic crash situations into standardized data. The text classification model provides a method to interpret text-based traffic crash descriptions and facilitate an improved understanding of the specific nature of traffic crashes. Cui et

al. (24-05299) propose an early safety warning method based on a risk map. This study constructs a vehicle warning risk map in the connected vehicle environment and provides a research foundation for enhancing highway safety, which is not only suitable for the current stage of manual driving and assisted driving but can also be applied to future autonomous driving. Garbier et al. (24-02502) created a resource for jurisdictions developing a high-injury network based on work from the District of Columbia (DC). In addition to summarizing findings, the paper lays out in detail DDOTs experience updating the District HIN to illustrate how to develop a methodology incorporating standard practices while responding to local goals and context. Valencia-Cardenas et al. (24-04297) performed a spatial analysis of crashes in Medellin, Colombia. The study identifies the characteristics of high-risk areas and provides information to support rapid response systems. Ma et al. (24-01136) introduced the concept of "risk pair" to decompose the joint actions of multiple traffic participants into pairwise interactions. The results show that both vector summation (VS) and scalar summation (SS) of the Mass-based Omni-directional Risk Indicator (MORI) demonstrate strong risk quantification capabilities with different directions.

Ten papers focused on **road user behavior and other crash contributing factors**. Ma et al. (24-04734) modeled heterogeneities of risky driving behaviors in taxi-involved severe crashes. The top three contributing factors were overtaking, running red lights, and sudden acceleration/ deceleration; however, there is a great heterogeneity in the top three factors. Jang et al. (24-05539) reviewed the characteristics, behaviors, and crash outcomes of riders ages 40 and older. The authors reported that older riders are significantly more likely to ride motorcycles with large engine capacities and many are new motorcyclists or have recently returned after a substantial break from riding. They also note that middle age riders (40 - 59 years of age) appear to be the least likely to wear helmets and the most likely to ride while under the influence of drugs or alcohol. Shi et al. (24-06014) deployed questionnaire surveys in seven countries (China, Egypt, Italy, Japan, Qatar, the United Arab Emirates and the United Kingdom) to study how drivers' attitudes affect traffic violations. Results indicate that high-risk drivers, which tended to have male, young and high driving frequency characteristics, were more likely to violate traffic laws and rules. In addition, the high-risk and low-risk groups exhibited different tendencies in influencing factors of traffic violation. Cabe and Tsai (24-03168) studied crash characteristics and contributing factors in elderly driver crashes. The authors report that most fatal senior driver crashes involve angle collisions with another vehicle, whereas most non-senior driver related fatal crashes are not due to a collision with another motor vehicle. Additionally, senior driver related crashes were 47% more likely to be attributable to a failure to yield. Banerjee et al. (24-01057) investigated severe distraction-related crashes along Kentucky’s rural two-lane roads. Presence of horizontal curves, wider shoulder widths, posted speed limit (55 mph), and lower annual average daily traffic (AADT) were associated with increased severe distraction-related crash frequency, whereas mountainous terrain was associated with reduced severe distraction-related crashes. Faiza et al. (24-02930) analyzed the relationship between the built environment, road encroachment, and road safety. The findings revealed a strong association between highly encroached intersections and utility-based land use patterns. It also underscored that illegally parked vehicles creates visibility obstruction and discontinuity in pedestrian movement. Yang et al. (24-03351) analyzed factors affecting traffic safety risks on the national trunk highway system using a machine learning framework. Main effects show variables positively associated with safety risk include the difference between average speed and speed limit, speed standard deviation, and the number of roadway entrances and exits. Variables negatively correlated with safety risk include the proportion of trucks, inclement weather, and the

number of median openings. Park et al. (24-03846) created a taxonomy of factors related to traffic crashes. Road type/shape, weather, and road surface were the most used factors. weather, road type/shape, and road surface were the factors with the highest number of significant relationships with traffic crashes, while speed, traffic volume, and drunk driving had the highest number of significant relationships relative to the number of uses. Kutela et al. (24-04709) used mobile automated traffic camera data to explore the influence of roadway characteristics and built environment on excessive speeding. This study revealed that increased posted speed limit and summertime are associated with increased propensity for drivers to exceed the speed limit. The built environment variables indicated mixed findings. Takyi et al. (24-05521) conducted a spatial analysis of traffic patterns, speed limits, and proximity of telemetered traffic monitoring stations to critical facilities to identify possible areas of concern.

Four papers focused on **countermeasures** to address risk factors and crash contributing factors. Zhou and Priyanka (24-01270) studied the impact of low-cost median opening treatments at unsignalized intersections on rural divided highways. Treated intersections had 8% to 40% fewer conflict rates than non-treated intersections and a 30% reduction in expected crash frequency. Kim et al. (24-02791) evaluated the safety effectiveness of temporary short-term rumble strips (STRS) and long-term rumble strips (LTRS) in work zones. The results confirm the effectiveness of STRS and LTRS over no rumble strips in speed reduction. The speed reduction effect was larger for STRS than LTRS; however, the two coefficients overlapped within the ranges of standard errors. Pineda-Mendez et al. (24-04854) estimated the safety effect of operational strategies using risk-based safety management tools. The authors propose advanced risk-based safety management to identify where and when variable speed limits are likely to deliver safety benefits. Yang et al. (24-06024) evaluated the left turn calming program in New York City. The authors report the program can reduce crashes by 28%, pedestrian-related fatalities and injuries by 29.7%, and cyclist-related fatalities and injuries by 23.2%.

Eight papers investigated **traffic safety of vulnerable road users**. Zhu et al. (24-00322) explored disparities in roadway safety, including direct and indirect factors contributing to disparities in non-motorist crashes in Houston, Texas. Rúa et al. (24-02720) documented a real-world case study using digital twin technology to proactively address safety for vulnerable road users. Elmasry et al. (24-03410) performed an evaluation of the safety and environmental impacts of microcars. Shi et al. (24-04373) studied pedestrian and vehicle occupant casualties, reflecting on a 9-year span of the Vision Zero Program in New York City. Patwary and Khattak (24-04785) explored how urban form, demographics, and disadvantaged communities are linked with pedestrian and bicycle safety. Sharma et al. (24-05875) used machine learning to assess motorized two-wheeler riders' perceptions of road safety and infrastructure demands in mixed traffic conditions. Joshi et al. (24-06325) developed a vulnerable road user safety screening method that combines site level and area level analysis using a wide range of equity level variables and site characteristics.

Two papers discussed **emergency response and incident management**. Mojumder and Schrock (24-05342) aimed to identify the determining factors for patients involved in a traffic crash to arrive at the trauma center within the ‘golden hour.’ Crashes that occurred during dark conditions with no streetlights experienced the highest total transport time. This study also showed that the distance between the crash location and the trauma center was not the only factor for increased total transport time, particularly if a crash goes unnoticed for a long period of time or if time is needed to extricate the patients. Lee et al. (24-03068) defined a model to analyze crash duration on highways using

dynamic (e.g., vehicle detection and weather sensor) and static (e.g., historical accident database and roadway geometry designs) datasets. The results show that differences in truck, rain, rollover, and temporal traffic characteristics increase the duration time.

One paper discussed **equity**. Bredikhina et al. (24-05324) assessed the crash characteristics associated with female drivers at different life stages.

Twenty-three papers analyzed **safety of motorcycles**. Zlatkovic et al. (24-00164) assessed motorcycle crash severity in Wyoming using Bayesian regression model. The study revealed that animal involvement, reduced lighting conditions, inclement weather, poor road conditions, and not wearing a helmet increase the probability of fatal, severe injury, or both. Wang et al. (24-00169) evaluated helmet-wearing single-vehicle over-speeding motorcycle crashes using parsimonious pooled random parameters logit and ordered probit models considering temporal instability. The result showed that age, cloudy and weekday indicators illustrate temporal instability and non-transferability. Khan and Velaga (24-00286) investigated risk riding behavior of food delivery agents using motorcycle rider behavior questionnaire (MRBQ). The findings suggest that the riding behavior of the food delivery agents is mostly influenced by prevailing road environment and individual riding behavior; but least influenced by risky driving performed by surrounding traffic. Hsu and Rodriguez (24-00356) explored association between traffic injuries and ambient meteorological conditions in Kaohsiung. The results show that high temperatures in summer are associated with the increased risks while high wind speed in the same season had the opposite effect. High atmospheric pressure and ground-level ozone concentrations are also associated with the increased risk. Kumar et al. (24-00532) developed motorcycle safety performance functions on rural two-lane undivided road segments in Kentucky for the pre- and post-COVID-19. The results revealed that presence of horizontal curves, mountainous terrain, and AADT were significantly associated with increased motorcycle crash frequencies in both periods. Meanwhile, for the pre-pandemic period, presence of roadside guardrails, posted speed limit (50-55 mph), and wider right shoulders were associated with the reduced motorcycle crash frequency; whereas for the post-pandemic, only the presence of roadside guardrails reduced the frequency. Kanitpong et al. (24-00596) investigated factors affecting motorcycle crash severity in Thailand. The findings disclosed that the types of opponent vehicles, crash areas, the time of the crash, riders' age, possession of a motorcycle license, riders' attention failure, types of human failure, collision avoidance, alcohol use, helmet use, headlight, and traveled speed affected the motorcycle crash severity. Essa et al. (24-00646) studied lateral interactions between motorcycles and vehicles in mixed traffic using fully parametric survival approach. The findings indicated that the probability of lateral interaction increases at higher motorcycle speeds, vehicle speeds, and motorcycle volume; but the probability decreases as motorcycle's yaw rate or motorcycle-vehicle acceleration difference increases. Hu et al. (24-01082) predicted risk of vehicle collisions involving motorcycles using the combined neural network of CNN (convolutional neural network) and LSTM (long short-term memory), which showed a superior performance. Dutta et al. (24-01703) studied role of the built environment on two-wheelers in India. The findings suggest that the probability of fatal and serious injury in two-wheeler crashes is more likely to occur in rural areas, on highways, far from intersections, in open areas, and on straight road sections. Bamney et al. (24-02140) analyzed factors affecting injury severity in Connecticut with multinomial logit approach. The results showed that factors increasing the severe injury include wearing a helmet, speeding, rider impairments (e.g., intoxicated by alcohol, drugs, medication), older and sports motorcycles, higher speed limits, warmer months (from May to August), pandemic period (2020-21), collision with fixed objects, negotiating a curve, manner of collision, etc. Saini and Kathuria

(24-02293) examined whether segregating motorcyclists can enhance safety on non-urban highways. The findings indicated that implementing exclusive motorcycle lanes improves the safety of motorcyclists and other road users by reducing their interactions. Saini and Kathuria (24-002298) further investigated impact of segregating motorcyclists on safety on non-urban highways based on extreme value theory. The peak-over threshold model revealed reduced rear-end conflicts and crash probability after implementing the exclusive motorcycle lanes.

Chu et al. (24-02639) looked into psychological factors behind motorcyclists crossing behavior on undivided roads in mixed traffic conditions in Vietnam. The findings disclosed a substantial difference in the intentions of motorcyclists who make complying maneuvers versus those who make illegal maneuvers. The intention of motorcyclists making complying maneuvers can be explained by facilitating circumstances, their subjective norms, and their descriptive norms. On the other hand, the intention of motorcyclists making illegal maneuvers can be explained by their advantage beliefs, their descriptive norms, facilitating circumstances, their subjective norms, and their driving situation awareness. Zhao et al. (24-03421) examined role of run-over on injury severity in two-wheeler to motor vehicle crashes with path analysis approach. The result suggested that riders' age, crash location, two-wheeler's length, roadworks influence the occurrence of run-over. Moreover, the run-over significantly increases the injury severity of two-wheeler riders by 31.7%. Gupta et al. (24-03527) validated motorized two-wheeler simulator by considering distraction, road infrastructure, and individual characteristics. The study showed that (1) riders maintained a higher speed in the riding simulator compared to real-world driving; (2) there are relative variations across various road sections; (3) and distracted driving conditions are similar in both riding simulator and actual field conditions. Samalla et al. (24-03608) determined conflict thresholds and crash risk of powered two-wheelers in mixed traffic conditions with extreme value theory approach. The conflict thresholds for rear-end conflicts were found to be higher than side-swipe conflicts except for the powered two-wheeler-powered two wheeler pair. Further, the conflict thresholds corresponding to rear-end and side-swipe conflicts increase with the interacting vehicle size. Dong et al. (24-03914) evaluated equity towards motorcyclists on crash accountability. The results showed that if the driver is a motorcyclist, there is a 19.7% and 7.8% higher probability of being assigned as at-fault in California and Ohio, respectively. These percentages combine the actual likelihood of causing a crash and bias together. The findings imply a potential bias towards motorcyclists in at-fault assignment. Khan et al. (24-04626) delved into seasonal variability patterns in motorcycle crash injury types using association rules mining. The findings include: (1) in spring, fatal crashes are connected with high traffic volume, aggressive behavior, and high-speed roadways; (2) in summer, fatal crashes are associated with aggressive behavior, dark unlighted conditions, and clear weather; and (3) in winter, fatal crashes are linked with two-way undivided roadways, angle collision, and young riders. Dzinyela et al. (24-04774) analyzed motorcyclists' crash severity using cluster correspondence and hierarchical binary logit approaches. The modeling results indicated that among the crash-contributing factors the motorcyclist age, roadway alignment, roadside safety systems and temporal factors significantly contribute to motorcyclist crash severities. Haule and Dumbaugh (24-04809) examined factors contributing to motorcycle crashes with left-turning vehicles at urban intersections. The findings suggested that the type of intersection and traffic control, time of day, age of drivers, sex of the motorcyclist, roadway type, and weather are significantly associated with motorcyclists' susceptibility to collisions with left-turning vehicles. Adeel et al. (24-04833) explored associations of rider's age and experience on motorcycle injury crash risk based on case-control study. The findings revealed that younger riders

have a heightened injury crash risk, which reduces with increasing age. Each year of rider experience is linked with a 2.7% reduction in the odds of an injury crash. Khan et al. (24-05047) investigated motorcycle crash severity patterns using association rules mining. The generated rules identified many associations. For instance, fatal crashes are associated predominantly with aggressive driving, along with nighttime riding in unlighted conditions, summer season driving, collisions with barriers, and urban driving. Putra et al. (24-05071) identified related factors of food delivery motorcycle crash severity in Taipei. The results indicated that roads with higher speed limits, straight lanes, intersections, and restaurants in sub-urban areas are associated with a higher crash severity level.

Seven papers assessed **school transportation safety**. Lee et al. (24-02363) developed a Master Plan using a data-driven approach to prioritize schools for a Safe Routes to School (SRTS) Program. The study investigated roadway infrastructure, socioeconomic and demographic conditions and land use characteristics to identify risk factors impacting the safety of bicyclists and pedestrians around schools. Significant factors included school location, number of schools in the service area, intersections with stop signs, retail land uses, median age of population in the service area, median household income, and the proportion of the white population. Farid et al. (24-01582) analyzed the severity of school zone crashes from an equity perspective. The results indicated that socioeconomic status of school neighborhood induces mixed effects on the injury severity risk. Bahrami et al. (24-06499) explored vehicle-pedestrian and vehicle-bike crash severity within a 15-minute walking distance around schools. Using network buffer zones revealed that the proximity of the crash to schools can affect the injury severity level. Furthermore, results indicate that several driver, roadway, weather, lighting and school related factors influence injury severity in school zones. Ahangarfabrik (24-06053) evaluated California's Active Transportation Program to understand the safety benefits of Safe Routes and Crossings to School Projects in Santa Cruz, CA. The study focused on school radar speed feedback signs and flashing beacons. The study provides evidence of the safety improvements associated with 22 project sites across Santa Cruz County. Das et al. (24-03757) investigated crashes in school zones in Louisiana. Results indicated that factors such as vehicle speed, pedestrian and cyclist exposure, presence of crossing guards, and adherence to traffic signals impact crash severity levels. Guo and He (24-03155) investigated the impact of school-age children's travel mode choices based on the degree to which parent-child schedules match. The findings suggest that time matching affects children's travel. Specifically, time-mismatched households tend to use a vehicle to escort children to and from school, as compared to time-matched households. He and Guo (24-01449) established a method to assess accessibility for primary schools. The results suggest that: 1) accessibility of primary education facilities can be evaluated more accurately based on the improved model; 2) accessibility of primary schools in Kunming is generally poor; 3) accessibility has limited impact on children's school travel; 4) spatial-temporal constraints of parents are key factors affecting children's travel patterns.

Authors	John McCombs, Ph.D. Candidate Haitham Al-Deek, Ph.D., P.E., Professor of Engineering Adrian Sandt, Ph.D., Research Associate Nizam Uddin, Ph.D.,, Professor of Statistics Grady Carrick, Ph.D.
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00048
Paper Title	Identifying Corridor-Level Safety Improvements for Urban and Suburban Arterials in Florida Within a Safe System Framework
Abstract	Many agencies have adopted a Safe System approach to improving roadway safety. The Highway Safety Manual (HSM) provides methods for assessing safety, but these models are site-specific and require extensive data, making them difficult to use at large scales. This paper develops a corridor-level methodology for holistically looking at corridors made of consecutive intersections and roadway segments to identify safety improvements which align with the Safe System approach while requiring less data than HSM methods. Using a standardized definition, 549 corridors on urban and suburban arterials across Florida were identified which experienced over 10,000 fatal and serious injury (FSI) crashes from 2017 through 2021. A negative binomial regression model was developed to predict mean FSI (MFSI) crashes at the corridor level (using corridor length as exposure), with the predicted values adjusted using the Empirical Bayes method to provide more accurate results. The significant factors in the model were traffic volume, intersection densities and sizing, area type, bus stop presence, citation rate, and corridor lighting presence. Increasing citation rates (citations/year/mile) for unsafe driving behaviors by one unit was predicted to reduce MFSI crash frequency in corridors by 2%, and corridors without lighting were predicted to experience 2.85 times more MFSI crashes compared to corridors with lighting. Two sister corridors in South Florida with similar roadway characteristics but different crash frequencies were also analyzed. Improvements to lighting and access control in the identified high-risk corridor could help reduce FSI crashes. Overall, this corridor approach can help agencies proactively improve roadway safety.

Authors	Arunabha Banerjee, Ph.D. William Pemberton Tyaha Woodard Benjamin McElroy Bharat Kumar Pathivada, Ph.D. Kirolos Maged Haleem
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00205
Paper Title	Safety Investigation of Distracted Driving Crashes in Kentucky Pre- and Post-COVID-19 Pandemic
Abstract	This study investigates and compares the pattern of distraction-related crashes pre-COVID-19 pandemic (2018-2019) and post-COVID-19 pandemic (2020-2021) in the state of Kentucky. Comprehensive crash (e.g., manner of collision, at-fault vehicle type, and time of crash), driver (e.g., at-fault driver age), roadway (e.g., roadway condition and type), and environmental (e.g., season and weather) characteristics were investigated and contrasted pre- and post-pandemic. The systemic safety analysis showed that severe distraction-related crashes occurred along urban undivided 1-2 lane roads with 30-40 miles per hour (mph) speed limit and annual average daily traffic (AADT) $\geqslant$ 5,000-10,000. However, post-pandemic, severe distraction-related crashes occurred along rural undivided 2-lane roads with 55 mph speed limit and AADT $\leqslant$ 5,000. Post-pandemic, total distraction-related angle crashes increased by 1.89%, and involvement of light trucks as at-fault vehicle increased by 2.77% (possibly due to the increase in online shopping and on-demand delivery). Off-peak morning crashes increased by 4.53% post-pandemic and involvement of young drivers remained the highest (37.67%), probably due to young drivers being highly distracted by cell phones and in-vehicle music systems. The chi-square test of independence showed that weather was a significant factor impacting severe distraction-related crashes post-pandemic. The odds of being involved in severe distraction-related crashes remained the highest for head-on and motorcycle-related collisions pre- and post-pandemic. Implementation of dynamic message signs with more installation of rumble strips to alert inattentive drivers, stronger enforcement of cell phone use, educational campaigns on distracted driving safety challenges, and training young drivers are potential countermeasures to reduce severe distraction-related crashes.

Authors	Chunwu Zhu Bahar Dadashova Chanam Lee Xinyue Ye Charles T. Brown
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00322
Paper Title	Disparities in Roadway Safety: Exploring Direct and Indirect Pathways Contributing to Disparities in Non-Motorist Crashes in Houston, Texas
Abstract	Environmental justice is of significant concern in roadway safety research, and an important part of the strategic goals in federal, state, and local level transportation planning. However, existing empirical evidence is limited due to inadequate consideration of intercorrelations between crash-related factors and traffic exposure in most prior studies. In this research, we apply a Structural Equation Model (SEM) approach to explore the underlying mechanism of disparity in non-motorist crashes in Houston, Texas by examining the mediating effect of two transportation modes, motor vehicle and active transportation. The results suggest that disadvantaged neighborhoods tend to have a positive direct and total effect to non-motorist crashes. We also found a positive mediating effect of motor vehicle mode, suggesting that this disparity is partially due to denser roadway environments and higher vehicular exposure in disadvantaged neighborhoods. On the other hand, inadequate active transportation infrastructure and active transportation exposure showed negative mediating efforts, indicating their roles in mitigating non-motorist crash risk to some extent. This research offers conceptual insights for urban and transportation planners to better consider environmental justice in roadway safety practices and supporting evidence for providing active transportation infrastructure and mitigating traffic exposure in disadvantaged communities to improve transportation equity.
Authors	Faria Yeasmin Raha Brendan Russo, Ph.D., P.E. Alyssa Ryan, Ph.D.
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00688
Paper Title	Investigating the Impact of the COVID-19 Pandemic on Traffic Crash Injury Outcomes among Different Demographic Groups
Abstract	Recent research suggests that COVID-19-associated stay-at-home conditions affected the motor vehicle crash rate throughout the world. While total crashes reduced, risky driving increased, which led to more fatal and severe injury crashes. It is crucial to advance our knowledge in the transportation system following drastic changes to this system with respect to which group(s) of people are most impacted. As such, this study investigated the impact of the COVID-19 pandemic on different demographic groups in resulting traffic crash injury severity in California. Logistic regression analyses were developed to identify the interaction of pandemic effect and demographic characteristics (age, race, and sex) of drivers on crash injury outcomes. The investigation was performed by utilizing police-reported public vehicle collision data gathered from the California Highway Patrol from January 1, 2019, to April 30, 2021. The analysis included over 1.4 million motor vehicle collision records. Analysis results reveal that young drivers and Black drivers were more likely to experience severe crashes during the height of the pandemic compared to other age and racial groups, respectively. Additionally, the relationship between the pandemic and driver gender was investigated to reveal potential connections; however, no significant relationships were found in the data. These observations provide a data-driven framework for prioritizing road safety strategies based on specific demographic groups to reduce the impact of both the current and potential future pandemic waves as well as similar disruptions to the transportation system.

Authors	Sangjae Lee Young Jo Juneyoung Park Cheol Oh, PhD
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-00694
Paper Title	Prioritizing Safety-Vulnerable Interrupted Road Facilities for Mixed Car-Following Situations: Methodology and Application
Abstract	With the advancement of autonomous driving technology, it is expected that autonomous vehicles (AVs) and manually driven vehicles (MVs) will coexist and operate soon. The different driving behaviors of AVs and MVs can potentially impact the driving safety on existing road infrastructure. This study tries to evaluate the driving safety of AVs and MVs in the context of following events on urban roads and determine priority for evaluation and improvement. The multi agent driving simulator (MADS) was utilized to simulate AV maneuvering control algorithms and urban road, enabling the derivation of longitudinal, lateral, and inter-vehicle driving safety indicators. To provide a relative comparison of driving safety, the change rate in safety indicators for each road section was compared against the tangent section on a level road. The analysis revealed that longitudinal safety decreased by 11 times and inter-vehicle safety decreased by 150 times compared to the tangent section on a level road, particularly in signalized and unsignalized intersections that require frequent acceleration and deceleration. Furthermore, the lateral driving safety in roundabout and U-turn sections, which necessitate significant steering controls, was found to be 17 times lower. Additionally, by applying the developed safety evaluation methodology to a real-world mobility testbed to find urban road sections requiring safety improvement. The analysis results indicated that sections with a high number of signalized intersections showed lower driving safety. Based on the prioritization of urban road sections derived from this analysis, vulnerable sections for AV mixed traffic can be identified in terms of driving safety.

Authors	Saquib Mohammed Haroon Alyssa Ryan, Ph.D.
Sponsoring Committee	ACS10
Session Number	Lectern Session 3003
Session Title	Using Connected and Automated Vehicles to Improve Transportation Safety
Paper Number	TRBAM-24-00697
Paper Title	Insights into Automated Vehicle Collisions: Explainable AI Models and Comparison with Non-Automated Vehicles
Abstract	With the growing development and deployment of automated vehicles (AVs), it is crucial to understand the associated risks and factors contributing to collisions involving AVs. California possesses an immense amount of publicly available data from AV testing due to the requirement laid out by the California Department of Motor Vehicles (DMV), which requires all automated vehicle operators to report collisions for any level of severity. However, this information is reported in specific forms and requires a laborious task to aggregate data from these reports. This study creates an automated data extraction system for these reports and analyses collision characteristics of AVs using logistic regression models as well as XGBoost models with SHapley Additive exPlanation (SHAP) interpretation. Additionally, these characteristics are matched with those of non-automated vehicles (non-AVs) in the same region. The study results indicate that rear-end collisions are the most common collision observed in currently deployed AVs. The analysis further revealed an increased likelihood of injury-prone rear-end collisions in AVs at intersections compared to non-AVs. Transportation policymakers and researchers should consider these safety concerns when addressing AV deployment and developing appropriate measures to mitigate collision risks in mixed fleet conditions.

Authors	Arunabha Banerjee, Ph.D. Bharat Kumar Pathivada, Ph.D. Dylan Justice Kirolos Maged Haleem
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01057
Paper Title	Comprehensive Investigation of Severe Distraction-Related Crashes along Kentucky's Rural Two-Lane Roads
Abstract	This study develops safety performance functions (SPFs) for severe ("KA" or "fatal & suspected serious injury") distraction-related crashes along Kentucky's rural two-lane undivided road segments. Recent four-year (2018-2021) of distraction-related crash records and police narratives were carefully reviewed. The systemic safety analysis revealed that severe distraction-related crashes frequently occurred along rural two-lane roadways; thus, SPFs were fitted for this facility. To account for under-dispersion when the crash variance is less than its mean, Conway-Maxwell-Poisson (CMP) model and CMP-based models, including the heterogeneous Conway-Maxwell-Poisson (HTCMP), zero-inflated Conway-Maxwell-Poisson (ZI-CMP), and zero-inflated heterogeneous Conway-Maxwell-Poisson (ZI-HTCMP), were fitted and compared. The ZI-HTCMP model outperformed the other comparative models in terms of goodness-of-fit measures (e.g., Akaike information criterion "AIC", Bayesian information criterion "BIC", and pseudo R2). From the developed SPFs, presence of horizontal curves, wider shoulder widths, posted speed limit (55 mph), and lower annual average daily traffic (AADT) were associated with increased severe distraction-related crash frequency, whereas mountainous terrain was associated with reduced severe distraction-related crashes. The empirical Bayes (EB) method was then used to rank the top ten high distraction-related crash locations (HCLs). The HCL in-depth investigation revealed that single-vehicle distraction-related crashes were the most frequent crash type. Furthermore, "using cell phones", "falling asleep", and "driving under the influence" were the common forms of distraction. Countermeasures were proposed to help reduce severe distraction-related crashes on rural two-lane segments, including installation of chevron signs before sharp curves, installation of edge rumble strips, and use of high visibility dynamic message signs on overhead digital billboards.

Authors	Ziluo Xiong Suren Chen
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01069
Paper Title	Developing Risk-informed Speed Limits against Single-vehicle Crashes by Exploiting an Augmented Reliability Problem with Multi-fidelity Enhancement
Abstract	Excessive speed has been blamed as a primary contributory and aggravating factor of single-vehicle crashes (SVCs), especially for vehicles under adverse driving environments (e.g., slippery road surface and strong wind). Rational advisory speed limits (SLs) that can adapt to time-varying environments become critical to ameliorating SVC risks while maintaining optimal traffic mobility. Existing SVC modeling and associated SL strategy are either over-simplified with questionable accuracy or too complicated and computationally expensive to accommodate timely risk prediction and potential mitigation. In this regard, a novel risk-informed SL strategy against SVCs is developed. Rather than performing reliability-based optimization for SL with traditionally repeated reliability analyses, an augmented reliability problem (ARP) is formulated. The accuracy is guaranteed by exploiting the ARP through the efficient non-parametric stochastic subset optimization with a high-fidelity SVC model, and a low-fidelity SVC model is incorporated to further improve efficiency. Demonstrations are conducted based on several examples designed with AASHTO Green Book. The results indicate that, in degraded driving environments, the original SL can induce increasing SVC risks, and the optimal SL with acceptable SVC risks decreases significantly. The proposed method can facilitate a reliable SL modulation that can quickly adapt to the changing driving environment with only a small number of high-fidelity simulations. It bears great potential to build an intelligent and proactive traffic management system against SVCs with informed and consistent risk levels in response to forthcoming hazardous weather events.

Authors	Haozhan Ma | Southeast University Linheng Li| Southeast University Bocheng An| Southeast University Ziwei Yi| Southeast University Xu Qu| Southeast University Bin Ran| Southeast University
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01136
Paper Title	Mass-based Omni-directional Risk Indicator (MORI): A Novel Approach for Quantifying Risk in Multi-Participant, Two-Dimensional Traffic Scenarios
Abstract	Real-time quantified risk indicators are crucial for improving driving safety and must be tailored to the specific characteristics of the CAV environment. To this end, this paper introduces the concept of "risk pair" to decompose the joint actions of multiple traffic participants into pairwise interactions. First, an Omnidirectional Risk Indicator (ORI) is developed to describe the effect of "risk pairs", and the superposition of ORI based on quality is proposed as the Mass-based Omni-directional Risk Indicator (MORI). Furthermore, in the context of car-following scenarios, a comparison between MORI and existing risk substitute indicators shows that MORI has good performance in quantifying one-dimensional scenarios. Finally, in two-dimensional scenarios involving multiple participating entities, MORI provides two quantitative results: vector summation (VS) and scalar summation (SS). The results show that both VS and SS of MORI demonstrate strong risk quantification capabilities with different directions. Although some limitations of MORI still exist, it is expected that this approach will provide a scientifically effective means of risk quantification for two-dimensional complex scenarios.

Authors	Huaguo Zhou, Auburn University| Auburn University Humayra Priyanka| HNTB
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems
Paper Number	TRBAM-24-01270
Paper Title	Effectiveness of Median Treatments in Enhancing Unsignalized Intersection Safety: A Comprehensive Evaluation of Driver Behavior, Conflicts, and Crash Reduction
Abstract	This study examines the impact of low-cost median opening treatments at unsignalized intersections on rural divided highways. Naturalistic Driving Study (NDS) and field video data are analyzed to understand driver behavior. Traffic conflict analysis and crash data analysis are conducted to evaluate safety effectiveness. A Crash Modification Factor (CMF) was developed to quantify treatment effectiveness, addressing the absence of this type of CMF in the clearing house. NDS data includes 428 trips by 65 participants, highlighting major road traffic volume and speed's influence on driver behavior. Conflict analysis shows that treated intersections have 8% to 40% fewer conflict rates than non-treated intersections. Using the cross-sectional Empirical Bayes (EB) method, CMFs are developed with a combined CMF of 0.70 (30% reduction in expected crash frequency). These findings aid in project-level decision-making, providing insights to improve safety at unsignalized intersections through low-cost median opening treatments.

Authors	Lei Zhao Sixuan Xu Wei Zhou Yuzhi Chen Chen Wang
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01471
Paper Title	Multi-agent trajectory prediction at unsignalized intersections: an improved generative adversarial network accounting for collision avoidance behaviors
Abstract	Accurate trajectory prediction for multiple agents (i.e., vehicles, bicyclists, and pedestrians) is the premise of launching proactive interventions, which can serve as an effective way to improve traffic safety at unsignalized intersections. The distinctive characteristic of unsignalized intersections lies in their disorderly traffic organization, prompting traffic agents to be extra vigilant towards other agents to prevent collisions. As such, the primary focus of multi-agent trajectory prediction lies in acquiring a deep understanding of their interactive behavior patterns when encountering potential collisions. To achieve this, this study proposes an improved generative adversarial network (GAN) that can properly model collision avoidance behaviors of multiple agents when predicting their trajectories. Specifically, attention pooling modules are employed to capture pedestrian-pedestrian, vehicle-vehicle and pedestrian-vehicle interactions. A graph convolution network (GCN) based collision extraction module is applied to identify potential collisions and model the collision avoidance behaviors of traffic agents. Experimental results on inD dataset demonstrate that the proposed framework attained a more accurate and reliable performance compared with some baselines. In different interactive scenarios, such as when vehicles yield or don't yield, the results illustrated via the Distance-velocity (DV) diagram display a significant level of robustness. Furthermore, the conflict points and Post-Encroachment Time, as computed from these predicted trajectories, also align well with the ground truth. This indicates that the proposed framework effectively captures the pattern of collision avoidance behaviors of multiple agents, which has potential to serve as an effective way to enhance traffic safety at unsignalized intersections.

Authors	Ou Zheng Mohamed Abdel-Aty Dongdong Wang Chenzhu Wang Shengxuan Ding
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01497
Paper Title	TrafficSafetyGPT: Tuning a Pre-trained Large Language Model to a Domain-Specific Expert in Transportation Safety
Abstract	Large Language Models (LLMs) have shown remarkable effectiveness in various general-domain natural language processing (NLP) tasks. However, their performance in the transportation safety domain tasks has been suboptimal, primarily attributed to the requirement for specialized transportation safety expertise in generating accurate responses. To address this challenge, we introduce TrafficSafetyGPT, a novel LLaMA (Large Language Model Meta AI) -based model, which has undergone supervised fine-tuning using TrafficSafety-2K dataset which has human labels from government produced guiding books and ChatGPT-generated instruction-output pairs. Our proposed TrafficSafetyGPT model and TrafficSafety2K train dataset are accessible at https://github.com/ozheng1993/TrafficSafetyGPT

Authors	Nuri Park, Ph.D. Student Hyeonseo Kim, M.S. Hojae Kim, M.S. Student Juneyoung Park, Ph.D. Chunho Yeom, Ph.D.
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-01876
Paper Title	Port-Locate Area Safety Analysis with Spatial Heterogeneous Based on Regional Characteristics
Abstract	In port cities, traffic safety management should take into account various types of cargo that will shift in the trucks and containers. This is true not only in the case of 'at port', but also 'near-port' areas within a 4-8-km radius. This is important for traffic safety because the crash severity can be high as there are many trucks that can cause large-scale crashes in 'at port' and 'near port' areas. Therefore, to prepare management strategies for port safety, it is necessary to identify risk factors that affect the crash severity in each port area. This study developed a two-stage crash severity model of 'at-port' and 'near-port' regions using a support vector machine and a Bayesian multinomial model. Additionally, a severity model suitable for Korean ports was proposed that considered multilevel spatial heterogeneity in the Bayesian multilevel multinomial model. Findings derived from this study can be used for policy development to increase traffic safety in port cities.

Authors	Tarek Hasan Mohamed Abdel-Aty, Ph.D., P.E.
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-02247
Paper Title	Safety Considerations for Setting Variable Speed Limits on Freeways
Abstract	This study focuses on determining the appropriate speed at which vehicles should travel under different traffic conditions on freeways and its impact on crash frequency. The common belief is that lower speed result in fewer crashes since reduced speed provide drivers with more time to react effectively and avoid collisions. However, this perspective overlooks the interplay among traffic speed, average spacing between consecutive vehicles, and distance available for stopping a vehicle. Hence, in this research, the authors evaluated a safety parameter termed ‘Safety Correlate’ (SCORE), which is defined as the proportion of average spacing relative to the stopping distance. To determine the relationship between SCORE and crash frequency, data from 366 two-lanes (per direction) urban freeway segments located in Virginia was analyzed and a Poisson Lognormal model was developed. The obtained result indicated that the safety parameter SCORE is negatively associated with the annual hourly crash frequency, implying that the lesser the average spacing as a proportion of the stopping distance while traffic flow remains constant, the more frequent will be the crashes. Additionally, this study presents an implication of SCORE in setting variable speed limits under various traffic flows. Overall, the study results provide valuable insights by investigating SCORE to improve traffic safety. Also, this research would help practitioners and policymakers to incorporate safety aspects while setting variable speed limits on freeways.

Authors	Nastaran Moradloo Iman Mahdinia Asad J. Khattak
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-02656
Paper Title	Quantifying Uncertainty in Higher-Level Automated Vehicle Crashes: The Role of Disengagements, Safety Drivers, and Behaviors of Surrounding Drivers
Abstract	Safe vehicles, a critical element of the Safe System Approach, are promising solutions to reach the vision zero goal. Higher-level Automated Vehicles (AVs) equipped with Automated Driving Systems (ADS) aim to improve transportation safety. Despite their potential, AVs face safety challenges—recent AV crashes prove this. As only limited real-world ADS crashes have occurred, their analysis involves high levels of uncertainty about relationships embedded in the data. This study analyzes the National Highway Traffic Safety Administration's nationwide ADS crash dataset between 2021-2023 (N=154). The study focuses on understanding the factors associated with impact speeds, a measure of crash severity. The primary questions explored are the roles of disengagement, safety drivers, and unlawful behaviors of crash partners (CPs). A Bayesian random-effect normal regression is estimated to address uncertainty and small sample size issue. Statistics indicate that impact speeds were mainly low, with an average of 13.88 mph. In 42.21% of crashes, AVs experienced disengagements with 54% higher average impact speed than other crashes. Results reveal that safety drivers within AVs are associated with lower impact speeds. Crashes involving unlawful behavior of CPs are associated with higher impact speeds, emphasizing the challenges posed by unpredictable behaviors. Further, disengagements are associated with higher impact speeds, highlighting the challenges related to the sudden shift from automation to manual control, especially in complex scenarios, e.g., unexpected obstacles on the roadway. Overall, this study highlights crucial factors associated with AV crash dynamics and emphasizes improving the technology of higher-level AVs.

Authors	Noah Goodall
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-02913
Paper Title	Comparability of Automated Vehicle Crash Databases
Abstract	Advanced driving assistance systems are available on many late-model vehicles, and automated driving systems are testing on public roads. Regulators and developers continue to assess the safety of these vehicles by comparing automated vehicle crash rates to baseline, human-driven crash rates. While there are several widely-cited automated vehicle and conventional vehicle crash databases, these databases have different underlying assumptions and inclusion criteria. Crash rates among databases may be directly comparable only with significant filtering and normalization, if at all. This paper reviews current automated vehicle and baseline human-driven crash databases and evaluates their comparability. Recommendations are presented to improve their comparability, both in terms of normalization and contextualization, as well as additional data fields that can be incorporated into existing databases. These findings may assist researchers, regulators, and automated vehicle developers attempting to evaluate the safety of driving automation systems.

Authors	Haiyi Yang Xiaohua Zhao Sen Luan, Ph.D. Hang Qi Yujia Xiang
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-03351
Paper Title	Analysis of Factors Affecting Traffic Safety Risks in National Trunk Highway System: Using Interpretable Machine Learning Framework
Abstract	The prevailing approach to traffic safety risk assessment relies on scarce and challenging-to-access accident-related data. Aggressive Driving Behaviors (ADBs) are a significant cause of accidents, but few studies have explored risk assessment methods based on ADBs and traffic status data. In this study, Non-negative Matrix Factorization (NMF) extracts latent risk variables to compute the Traffic Risk Score (TRS). Prominent machine learning algorithms establish the relationship between traffic risk levels and traffic status, road, environment, and periods characteristics. The Partial Dependence Plots (PDP) algorithm identifies influencing factors. Results indicate: 1) TRS effectively distinguishes high and low-risk roads, with more fatal accidents associated with higher TRS; 2) The CatBoost algorithm demonstrates superior performance, with traffic status characteristics having the most significant impact on identifying safety risk levels, followed by road characteristics; 3) Main effects show risk variables positively associated with safety risk include the difference between average speed and speed limit, speed standard deviation, and the number of roadway entrances and exits. Conversely, risk variables negatively correlated with safety risk include the proportion of trucks, inclement weather, and the number of median openings; 4) Interaction analysis shows that when the difference between average speed and speed limit exceeds 17.5 km/h, an increase in road section entrances and exits intensifies traffic safety risk. Additionally, with two or fewer median openings, the negative impact of speed standard deviation on safety risk diminishes as it increases. The proposed analysis framework provides valuable insights for further research on real-time traffic safety evaluation.

Authors	Maria Catalina Valencia-Cardenas, M.Sc. Juan C. Lopez Miguel Jaller
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems
Paper Number	TRBAM-24-04297
Paper Title	Spatial analysis of road crashes: A case study in Medellin, Colombia
Abstract	The transportation and safety sectors aim to reduce road crashes and their societal and economic effects. By studying these events and examining related variables and their location and patterns, local authorities can identify critical zones to establish successful road safety initiatives and mitigate the negative consequences of their occurrence. This study aims to analyze traffic crashes' spatial and temporal patterns in Medellin, Colombia, to identify the characteristics of the high-risk areas and provide helpful information to authorities for having rapid response systems. To this end, spatial, temporal, and traffic variables provide vital information for predicting the number of crashes in various city areas. The study proposes a methodology integrating point pattern analysis, descriptive statistics, statistical characterization, and clustering analysis using a k-prototype model to capture a simple representation of similarities among crash data. The study also estimated a negative binomial (NB) model to identify the spatial and traffic parameters that help explain crash occurrences. The results show a concentration of crashes in Downtown Medellin, the area with the highest trip generation in the city. Road hierarchy, land use, and traffic variables correlate highly with crashes and influence spatial patterns. The clustering process found two main clusters with significant differences in the hierarchy and traffic conditions, and the NB unveiled a high correlation between the crash count and the large vehicle flow.

Authors	Ge Shi Yu Song Carol Atkinson-Palombo Norman Garrick
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems
Paper Number	TRBAM-24-04373
Paper Title	Pedestrian and Car Occupant Crash Casualties over a 9-Year Span of Vision Zero in New York City
Abstract	Vision zero has been increasingly embraced by jurisdictions in the U.S. Existing research primarily focuses on the theoretical principles and the effectiveness of some specific engineering measures. However, there is still limited understanding of the holistic effects of vision zero treatments, in the context of street types and urban environment. In this study, we developed a street typology framework to categorize street segments using four street design and operational features: street width, traffic direction (one-way vs. two-way), number of travel lanes, and presence of on-street parking. We applied a sample-based Partitioning Around Medoids algorithm to classify 90,327 street segments in NYC. This process results in six distinctive types of street segments. To integrate the neighborhood level factors (e.g., land use variables and socio-demographics), we aggregated street segments of a given street type for each neighborhood. Negative binomial regression models were developed for pedestrian and car occupant crash injuries and fatalities for three periods separately- 2014-2016, 2017-2019, and 2020-2022. Our findings show that street groups with narrower, two-way sections, and higher tree canopy coverage are significantly associated with a lower risk of casualties for both pedestrians and motorized users. Conversely, street groups located in neighborhood with a larger percentage of African American suffered significantly greater risk of injuries and fatalities. Vision zero treatments had mixed effects on safety outcomes. Street groups treated with leading pedestrian interval showed a lower risk of casualties. Neighborhood slow zones and arterials slow zones were associated with lower risk of car occupants' injuries and fatalities.

Authors	Jingfeng Ma Gang Ren Shunchao Wang Jingcai Yu Bingtong Wang
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-04734
Paper Title	Modelling the Heterogeneities of Risky Driving Behaviours in Taxi-involved Severities
Abstract	Although taxis play an important role in daily travels of urban residents, few concerns have been devoted to taxi-involved safety issues related to risky driving behaviours of taxi drivers. This study positions itself at modelling the heterogeneous influences of risky driving behaviours on taxi-involved crash injuries and the injury mechanism. Based on 8327 valid police-reported taxi crashes (2011-2020), the distributions of injury severities and 10 risky driving behaviours are analysed. As an unsupervised approach, latent class clustering (LCC) is applied to identify the number of clusters by maximizing the homogeneities within each cluster and the heterogeneities across clusters. The most suitable number of clusters is determined as four, based on the AIC, BIC, and entropy-based values of the LCC test. Partial proportion odds (PPO) models are employed to characterize the heterogeneity for the whole dataset and each sub-dataset. The model results evidence that sub-models significantly own a better fitness than modelling the whole dataset. Marginal effects are implemented to further quantify the unobserved heterogeneities in 10 risky driving behaviours. The results reveal that the remarkable heterogeneities across clusters do exist. The top three contributing factors are dangerous overtaking, running red lights, and sudden acceleration/ deceleration (maximum marginal effects exceeding +31%). However, there is a great heterogeneity in the top three factors across clusters. Notably, aggressive driving behaviours have greater heterogenous effects, especially the influences of dangerous overtaking (moderate: +16.43%, severe: +36.88%). These findings could support taxi-related policy-making to reduce crash losses.

Authors	Adrian Cottam Xiaofeng Li, Ph.D. Cynthia Navarro Yao-Jan Wu, Ph.D., P.E.
Sponsoring Committee	ACS10
Session Number	Lectern Session 3003
Session Title	Using Connected and Automated Vehicles to Improve Transportation Safety
Paper Number	TRBAM-24-04770
Paper Title	Investigating Interactions between Sidewalk Autonomous Delivery Robots and Vehicular Traffic at Stop-Controlled Crosswalks
Abstract	Sidewalk autonomous delivery robots (SADRs) are a recent introduction to last-mile logistics which became popular for contactless deliveries during the COVID-19 pandemic. In some locations, including the University of Arizona (UA) campus, SADRs are required to cross roadways using crosswalks to make deliveries, leading to interactions between SADRs and vehicular traffic. It is unclear whether drivers are aware of how to interact with these emerging robots. Therefore, in this study, a qualitative and quantitative analysis of the interactions between SADRs and vehicular traffic at stop-controlled crosswalks is performed. A combined 44 hours of video was recorded at two study sites at intersections located on the UA campus. The videos were meticulously analyzed manually, collecting several quantitative analysis variables, and observing anomalous behaviors for qualitative analysis. These observed behaviors included pedestrians intervening in SADR operations, drivers waiting for excessive amounts of time as they were unsure of SADR crossing intentions, and drivers having to move SADRs that were blocking crosswalks. A linear regression was used to analyze the quantitative impacts of SADRs on vehicular stop times at crosswalks, finding that SADRs induce an additional one to three seconds of vehicular delay. Furthermore, a binary logistic regression was used to evaluate variables' impacts on SADR failure to yield, finding that nighttime increases yield failure probability, and SADRs are more likely to fail to yield to golf carts and vehicles colored red or yellow. This study can provide practical insights to policymakers and manufacturers about the interactions between SADRs and vehicular traffic.

Authors	Raul Andres Pineda-Mendez, Ph.D. Mario Romero, Ph.D. Andrew Tarko, Ph.D.
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-04854
Paper Title	Estimating the Effect of Operational Safety Countermeasures via Risk-based Safety Management Tools
Abstract	Highway safety management is a systematic approach to identifying and reducing roadway hazards. The effectiveness of these efforts is reflected in fewer crashes and lower severity of injuries. In current engineering practice, count-based crash models are the most prevailing safety management tools. Such models estimate the safety performance of roadway elements based on aggregate traffic exposure and basic geometric characteristics. The estimated safety performance is compared to the corresponding long-term crash counts, usually over 3 to 5 years, to determine whether a target roadway element requires further inspection. Despite the value of existing highway SMS, intrinsic data aggregation precludes capturing the temporal and spatial fluctuation of crash risk. With the recent advancement in data collection techniques and the proliferation of instrumentation across vehicles and on roads, a vast amount of high-resolution time-dependent data has become available. In this paper, advanced risk-based safety management is proposed to identify locations where and periods when variable speed limits are likely to deliver safety benefits. Implementation of this novel approach is discussed for rural freeways in high-risk high-speed conditions. In a general case, the benefits of implementing risk-based safety management tools include: the ability to continuously monitor the crash risk, the improved temporal analysis of contributing risk factors, and identifying temporary conditions that should trigger operational interventions.

Authors	Sultana Rajia Yasunori Muromachi Moinul Hossain
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-04924
Paper Title	Safety Assessment of Automated Vehicle (AV) Driving Logics under Mixed Traffic Using Real-Time Crash Prediction Model
Abstract	Successful implementation of automated vehicle (AV) technology can be achieved through proper safety evaluation which in the future will be required for informative decision-making during large scale deployment of automated vehicles (AVs). The focus of this paper is two folds: understanding appropriate parameter setting for AVs by examining the behavioral models from preceding studies, and evaluate the corresponding crash risks under mixed traffic operation. After reviewing the preceding studies and two large scale real-world projects: CoEXist Project and UK Autodrive, parameters were set for three driving environments - normal, cautions, and all-knowing. Safety assessment for these driving environments were conducted using a Dynamic Bayesian Network (DBN) based real-time crash prediction model. The safety assessment showed that crash risk can be reduced by 21.9%, 22.3%, and 17.6% under normal, cautious, and all-knowing driving behaviors, respectively, with mixed scenarios. Results also exhibited that with higher market penetration rates, some of the driving volatility measures were reduced such as less lane changing, maintaining homogeneous speed and headways. Furthermore, difference of up and downstream speed has significant impact on crash risk estimation and its reduction was found to be associated with lower levels of risk.

Authors	Chuang CUI Bocheng AN Linheng LI Xu QU
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems
Paper Number	TRBAM-24-05299
Paper Title	A Vehicle Safety Early Warning Method Based on Risk Map
Abstract	Traffic safety has always been a focal point of concern, especially on highways where vehicles travel at high speeds, and the harm caused by traffic accidents is more severe. To evaluate the driving risks of highway vehicles and reduce the accident rate on highways, this study proposes a highway vehicle safety warning method based on a risk map. Firstly, a two-dimensional feature indicator MTTC (Modified Time to Collision) is selected to describe the driving risk between vehicles, and it is subjected to probabilistic processing. Then, the probabilistic risk values are mapped onto road segments. The risk map is obtained by overlaying them, which is used to depict the driving risks around vehicles. After that, highway vehicle warning is performed based on the risk map. When the risk value is higher than the warning threshold, high-risk vehicles are given a warning alert. Finally, the effectiveness and timeliness of the proposed method are verified through simulation in VISSIM. The experimental results show that the proposed method is effective and timely. This study constructs a vehicle warning risk map in the connected vehicle environment and provides a research foundation for enhancing highway driving safety, which is not only suitable for the current stage of manual driving and assisted driving but can also be applied to future autonomous driving.

Authors	Hisham Jashami Akinfolarin Abatan Derrick Hill Alejandra Meza Prem Shah Katelyn Rousch Nrushad Joshi Cleveland Yancovitz Peter Savolainen
Sponsoring Committee	ACS10
Session Number	Lectern Session 3003
Session Title	Using Connected and Automated Vehicles to Improve Transportation Safety
Paper Number	TRBAM-24-05762
Paper Title	Examination of factors influencing the efficacy of automatic emergency braking
Abstract	Automated vehicles are expected to significantly reduce traffic crashes and the resultant injuries and fatalities. However, it is unclear when fully automated vehicles will be market-ready, though it is important to note that lower levels of automation have already demonstrated some of this significant safety potential. This includes technologies such as automatic emergency braking (AEB), which is proposed to be a mandatory feature in all new vehicles by 2025. This study involves an evaluation of AEB test data from the Insurance Institute for Highway Safety (IIHS). These tests include various scenarios, including those were the test vehicle encounters a balloon car, as well as “dummy” pedestrians that are walking either parallel or perpendicular to the road. These tests are conducted at various speeds and lighting conditions. Further, the test vehicles range from model year 2013 to 2023, and include a diverse range of sensor configurations. A series of random-effects logistic regression models are estimated to evaluate the efficacy of these vehicles across these test scenarios. The results provide important insights as to the potential, as well as the limitations of these systems in their current form.

Authors	Yujia Shi Chaopeng Tan, PhD Hong Zhu, PhD Keshuang Tang, PhD
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems
Paper Number	TRBAM-24-06014
Paper Title	How Drivers' Attitudes Affecting Traffic Violations: An International Study based on Seven Countries Questionnaire Surveys
Abstract	Traffic violations are regarded as one of the main causes of road traffic accidents, and are closely related to drivers' attitudes. Understanding the relationship between drivers' attitudes toward traffic safety and their individual attributes is important for traffic accident analysis and prevention. Thus, this study intends to understand how drivers' attitudes affect traffic violations, based on an international questionnaire survey conducted in seven countries including China, Egypt, Italy, Japan, Qatar, the United Arab Emirates and the United Kingdom. Firstly, average scores of drivers' attitudes towards safety among seven countries were analyzed and compared. Then, the Principal Component Analysis (PCA) method was applied to reduce the dimension of drivers' attitudes. Based on the PCA results, total samples were classified into two groups, namely, the High Risk Driving Group (HRDG) and the Low Risk Driving Group (LRDG), using the K-means clustering algorithm. Finally, two Structural Equation Models were built for the two groups based on a modified Theory of Planned Behavior to explore the effect of drivers' safety attitudes on traffic violations. Results indicate that, the HRDG drivers, who tended to have male, young and high driving frequency characteristics, were more likely to violate traffic laws and rules. In addition, the two groups exhibited different tendencies in influencing factors of traffic violation. More specially, the HRDG drivers' attitudes toward traffic safety policies had the greatest influence, followed by the attitudes toward risky driving behaviors. While, for the LRDG drivers, the attitudes of others toward risky driving behaviors played the greatest role.

Authors	Song Wang, Ph.D. Zhixia Li
Sponsoring Committee	ACS10
Session Number	2235
Session Title	Transportation Safety Management Systems from Start to Finish
Paper Number	TRBAM-24-06058
Paper Title	Quantification of Safety Improvements and Human-Machine Trade-Offs in the Transition to Automated Driving
Abstract	The assumption of reduced human error-related crashes with increasing levels of automation in the pursuit of Level 5 automation lacks empirical evidence. As automation levels rise, human error-induced safety hazards are anticipated to decrease while machine error-induced hazards increase. However, a quantitative index capturing this trade-off is absent. Theoretical modeling of safety improvements during the transition to automated driving, particularly concerning the reduction of human error-related hazards, remains unexplored. These limitations impede the understanding of safety from human and machine perspectives for Automated Vehicle (AV) specialists and manufacturers. This research addresses these gaps by investigating safety performance associations between human and machine factors using the "Human-Machine conflict reduction ratio" (H-M ratio). The study aims to establish safety improvements related to human errors under various automation levels. Sixty participants completed driving tasks at Levels 0, 4, 3, and 2 on a driving simulator. Safety performance measures, including conflict frequency and severity, were computed. As a result, Level 4 exhibits the largest decrease (93.3%) compared to manual driving, followed by Level 2 (70.7%) and Level 3 (40.5%). The H-M ratio measures the trade-off between reducing human and machine error-induced hazards, with Level 2 demonstrating the highest ratio, followed by Levels 4 and 3. Safety performance is evaluated by considering all possible types of human errors at each automation level. Theoretical models from a human factor's perspective are employed to estimate safety improvements at each level. This research contributes to a comprehensive understanding of safety in the "human-machine cooperative driving" phase.

Authors	Manmohan Joshi, MSc Mohammad Razaur Rahman Shaon, Ph.D., PE, RSP1 Saki Rezwana Kai Wang, PhD Shanshan Zhao, PhD John Ivan, PhD Eric Jackson, PhD
Sponsoring Committee	ACS10
Session Number	Lectern Session 2004
Session Title	Hot Topics in Transportation Safety Management Systems
Paper Number	TRBAM-24-06325
Paper Title	Developing A Comprehensive Vulnerable Road User Safety Screening Method Using Multi-Level Data
Abstract	Despite significant advancements in motor vehicle safety, the number of fatalities resulting from road crashes has been increasing in recent years. The resultant injuries from roadway crashes are more severe for vulnerable road users (VRU), i.e., pedestrians and bicyclists. High disparity is observed in the distribution of the burden of these crashes across areas, ethnic and race groups and hence FHWA requires states to incorporate equity-related variables in the analysis of vulnerable road user safety. Conventionally, Highway Safety Manual (HSM) provides methodologies for identifying high crash risk locations, but those methods are not enough to prioritize low volume sites with a higher crash rate, as is the case of vulnerable road users. This study first explores a wide range of equity level variables in addition to site characteristics of state-maintained signalized intersections in Connecticut and then provides a framework to combine site level and area level analysis to generate an aggregate network screening result, using Bayesian Thurstonian model and a mean score ranking method. The exploration and combining framework is a novel practice in transportation safety analysis and shows promising results for network screening based on systemic safety principles.

Authors	Milan Zlatkovic, University of Wyoming Isaac Baah, UW: University of Wyoming Sarah Zlatkovic, Claremont Graduate University Zorica Cvijovic, Trihydro Corporation
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00164
Paper Title	Assessment of Motorcycle Crash Severity in Wyoming through Bayesian Regression
Abstract	Approximately 15% of all traffic fatalities in the United States involve motorcycle riders and passengers. According to the National Highway Traffic Safety Administration (NHTSA), the crash rate for motorcyclists is 15 times higher than for passenger car occupants. To evaluate the characteristics of motorcycle safety in Wyoming, this study analyzed 12 years of motorcycle related crash data from the Wyoming Department of Transportation crash database. Utilizing Bayesian regression modeling, the study found that alcohol and animal involvement, reduced lighting conditions, inclement weather, poor road conditions, and driver actions increase the odds of fatal and severe injury crashes. Additionally, not wearing a helmet, particularly in rural areas, was seen to increase the odds of fatal crashes. The Bayesian models on the vehicle level also showed that the vehicle's level of damage is related to the crash severity level. On the person level, young and old drivers were found to have a higher risk of fatal and severe injury outcomes, while alcohol and drug use, rider distraction, and out-of-state riders were seen to have a lower odd of fatal and severe injuries. The study recommended several countermeasures for improved safety, such as installing motorcycle-friendly guardrails, minimizing the use of rubberized bituminous asphalt as surface treatments, maintaining high-traffic roadways more frequently during the riding season, and providing adequate education and training for motorcyclists.

Authors	Chenzhu Wang, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Said M Easa, Toronto Metropolitan University Fei Chen, Southeast University Jianchuan Cheng, Southeast University Arshad Jamal, Imam Abdulrahman Bin Faisal University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00169
Paper Title	Evaluating Helmet-Wearing of Single-Vehicle Overspeeding Motorcycle Crashes: Insights from Temporal Instability in Parsimonious Pooled Framework
Abstract	Objectives: A lower helmet-wearing rate and overspeeding in Pakistan are critical risk behaviors of motorcyclists, causing severe injuries. To explore the differences in the determinants affecting the injury severities among helmeted and non-helmeted motorcyclists in motorcycle crashes caused by overspeeding behavior, single-vehicle motorcycle crash data in Rawalpindi city for 2017-2019 is collected. Considering three possible crash injury severity outcomes of motorcyclists: fatal injury, severe injury and minor injury, the rider, roadway, environmental, and temporal characteristics are estimated. Methods: To provide a mathematically simpler framework, the current study introduces parsimonious pooled random parameters logit and ordered probit models. Then, the standard pooled random parameters logit and ordered probit models without considering temporal effects are also simulated for comparison. By comparing the goodness of fit measure and estimation results, the parsimonious pooled random parameters logit model performs better in capturing the temporal instability. Then, the non-transferability among helmeted and non-helmeted overspeeding motorcycle crashes is illustrated by likelihood ratio tests and out-of-sample prediction, and four types of models provide robust results. The marginal effects are also calculated. Results: And several variables, such as age, cloudy and weekday indicators illustrate temporal instability and non-transferability (several variables are only significant in non-helmeted models). More educational campaigns, regulation and enforcement, and management countermeasures should be organized for non-helmeted motorcyclists and overspeeding behavior. Such findings also provide research reference for the risk-compensating behavior and self-selected group issues under overspeeding riding considering the usage of helmets.

Authors	Tathagatha Khan, Indian Institute of Technology, Dhanbad Nagendra Velaga, Indian Institute of Technology, Bombay
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00286
Paper Title	Investigating the Risky Riding Behaviour of Food Delivery Agents
Abstract	This study investigates the associations between factors which influences risky riding behaviour of Food Delivery Agent (FDAs), uses motorized two-wheeler (2W) for delivery. A prominent surge in 2W accidents resulting in deaths has raised serious concern and warrants for immediate research to understand their riding behaviour. A state-of-the-art Motorcycle rider behaviour questionnaire (MRBQ) is designed, considering FDAs opinion to study their riding behaviour. A total of 431 responses have been collected by one-to-one interaction with FDAs. The exploratory factor analysis loaded with 31 items which are divided into five-factor solution and it is confirmed by confirmatory factor analysis. These factors are individual riding behaviour of FDAs (consists of traffic error, traffic violation and control error), prevailing road environment condition and risky driving performed by surrounding traffic. Structural equation modelling technique is employed to analyse the interrelationships among aforementioned factors and their collective influence on the overall riding behaviour of FDAs. The results suggest that the overall riding behaviour of FDAs is mostly influenced by prevailing road environment ($\gamma = 0.56$) followed by Individual riding behaviour of FDAs ($\gamma = 0.40$) and least influenced by risky driving performed by surrounding traffic ($\gamma = 0.30$). In Individual riding behaviour constructs, traffic error ($\gamma = 0.88$) has the highest factor loading followed by traffic violation ($\gamma = 0.83$) and control error ($\gamma = 0.78$). This study will be useful in road safety policy development, such as imposing heavy penalties on traffic violation and performance of risky maneuver can be reduced through awareness programs.

Authors	Cheng-Kai Hsu, University of California, Berkeley Daniel Rodriguez, University of California, Berkeley
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00356
Paper Title	Ambient Temperatures and Road Traffic Injuries in Kaohsiung, a Tropical and Motorcycle-dominant City in Taiwan
Abstract	Road traffic injuries (RTIs) are a major global health concern, causing around 1.35 million deaths annually. Over 20% of these deaths occur among powered two-wheeler fleets, a transportation mode gaining popularity, especially in Asia, Africa, and Latin America. Despite a growing body of literature on the association between RTIs and ambient exposure factors, including temperatures, there is limited empirical data in tropical, motorcycle-dense locations like Taiwanese cities. This study investigates the effects of ambient exposure factors (temperature, wind speed, atmospheric pressure, and ground-level ozone) on RTIs in Kaohsiung, Taiwan—a city with dense motorcycle usage, high temperatures, and poor air quality—considering seasons and transportation modes of the injured party. Our findings reveal varying effects of ambient exposures on RTI risks. High temperatures, particularly in summer, are associated with increased road risks, while high wind speed in summer exhibits protective effects but is harmful on non-summer days. High atmospheric pressure may adversely impact road safety, possibly due to decreased thermal comfort. Additionally, higher ground-level ozone concentrations are associated with increased RTIs. Compared to car users, motorcycle users have higher susceptibilities to some of these effects. We highlight alarming magnitudes of temperature effects in a tropical and motorcycle-dominant context, exceeding findings in other non-tropical locations. As climate change increases extreme heat events globally, understanding the impact of ambient heat becomes even more critical. As micromobility innovations are emerging, further research is needed to explore how ambient exposures affect road safety of travelers using open transportation modes like electric bicycles and scooters.

Authors	Bharat Kumar Pathivada, Western Kentucky University Arunabha Banerjee, Western Kentucky University Kirolos Haleem, Western Kentucky University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00532
Paper Title	Developing Motorcycle Crash-Specific Safety Performance Functions along Rural Two-Lane Undivided Road Segments in Kentucky Pre- and Post-COVID-19 Pandemic
Abstract	This study develops safety performance functions (SPFs) for motorcycle crashes along rural twolane undivided roadway segments in Kentucky, separately in each of the pre-COVID-19 pandemic (2015-2019) and post-COVID-19 pandemic (2020-2022) periods. Motorcycle crash records and various road-specific features (e.g., shoulder width, speed limit, and annual average daily traffic "AADT") were used. The systemic safety analysis using crash tree diagrams revealed that motorcycle crashes were frequently occurring on rural two-lane undivided roadways; hence, SPFs were fitted on this facility type. Conway-Maxwell-Poisson (CMP) and heterogeneous ConwayMaxwell-Poisson (HTCMP) models were applied and compared (since both models account for under-dispersed motorcycle crashes, i.e., with variance being less than the mean). For both pre- and post-pandemic period, the HTCMP model (with a varying dispersion parameter) outperformed its CMP counterpart using various goodness-of-fit measures (e.g., Akaike information criterion "AIC", Bayesian information criterion "BIC", and McFadden pseudo R2). The empirical Bayes (EB) method was then used to rank the top ten high-crash roadway segments pre- and postpandemic. From the developed SPFs, for both pre- and post-pandemic, presence of horizontal curves, mountainous terrain, and AADT were significantly associated with increased motorcycle crash frequencies. For the pre-pandemic period, presence of roadside guardrails, posted speed limit (50-55 mph), and wider right shoulders were associated with reduced motorcycle crash frequency, whereas post-pandemic, only the presence of roadside guardrails significantly reduced motorcycle crash frequency. Several motorcycle safety countermeasures were proposed, such as installing chevrons on curved road sections along with grooved rumble strips on the edge of the road.

Authors	Kunnawee Kanitpong (kanitpon@ait.ac.th), Asian Institute of Technology Auearree Jensupakarn, Asian Institute of Technology Pathumporn Dabsomsri, Asian Institute of Technology Kannika Issalakul, Asian Institute of Technology
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00596
Paper Title	Factors Affecting Motorcycle Crash Severity in Thailand: Evidence from In-Depth Crash Investigation
Abstract	Motorcycles are vehicles with the highest risk of involvement in crashes. Based on the integrated data of road crash fatalities reported by the police, hospitals, and insurance companies, motorcycle crashes account for more than 80 percent of all crashes in Thailand, and the number of fatalities from motorcycle crashes was as high as 84 percent of the total fatalities from road crashes in the country. This study conducted an in-depth motorcycle crash investigation to identify the contributing factors affecting the severity of motorcycle crashes in Thailand. The types of opponent vehicles, crash areas, the time of the crash, riders' age, possession of a motorcycle license, riders' attention failure, types of human failure, collision avoidance, alcohol use, helmet use, headlight, and traveled speed were discovered to be significant factors affecting motorcycle crash severity. Based on the findings of this study, it has been suggested that to reduce the number of fatalities from motorcycle crashes, the related government agencies should seriously consider how to improve the safe riding skills of motorcycle users. The need for basic safety skills should be practiced by all riders, such as defensive driving skills, knowledge of alcohol risks, proper helmet use, and proper collision avoidance maneuvers. Proper rider training courses are necessary to provide basic knowledge for safe motorcycle operation in traffic, as well as safe traffic strategy and collision avoidance skills.

Authors	Ali Essa, University of British Columbia Rushdi Alsaleh, University Canada West Tarek Sayed, University of British Columbia
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-00646
Paper Title	Modeling Lateral Interactions between Motorcycles and Vehicles in Mixed Traffic: A Fully Parametric Survival Approach
Abstract	There is growing research interest in evaluating the safety of motorcyclists because of the increasing motorcycling global population coupled with the higher risk motorcyclists are exposed to as vulnerable road users. An important safety concern for motorcyclists is their lateral interactions with vehicles where a collision avoidance maneuver is needed because of the small lateral separation between vehicles and motorcycles. This study investigates the lateral interaction between motorcycles and vehicles by modeling the critical lateral distance (CLD) between them. The analysis utilized a dataset of motorcycle and vehicle trajectories collected from an urban road network in Athens, Greece. To model the CLD and relate it to various dynamic behavioral and traffic variables (e.g., speed, acceleration, volume, and yaw rate), a fully parametric accelerated failure time duration model with Gamma frailty was applied. The CLD was shown to follow a Weibull distribution, and the gamma frailty was used to account for the unobserved heterogeneity. The results indicate that the probability of lateral interaction increases at higher motorcycle speeds, vehicle speeds, and motorcycle volume. However, the lateral interaction's probability decreases as motorcycle's yaw rate or motorcycle-vehicle acceleration difference increases.

Authors	Ta-Yin Hu, National Cheng Kung University Chen-Yang Hsieh, National Cheng Kung University Tsai-Yun Liao, National Chiayi University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-01082
Paper Title	Risk Prediction of Vehicle Collision Involved with Motorbikes: An Application of A Combined Neural Network of CNN and LSTM
Abstract	Advanced Driver Assistance Systems (ADAS), such as collision mitigation, vehicle control systems, detection, and warning mechanisms, have been implemented to help drivers to avoid accidents. ADAS monitor the vehicle surrounding by data from active sensors. Different data, especially collisions involved with motorbikes, are collected to study the possible benefits of ADAS, and deep learning techniques are applied to examine the data. This motorbike-collision data is provided by the Tainan City Traffic Accident Investigation Committee, including the video recorded by dashcam or closed-circuit television (CCTV) to simulate the sensor of ADAS and train the risk prediction models to avoid vehicle collision. Previous research confirmed that deep learning methods perform better than machine learning or traditional regression methods. A Convolutional Neural Network (CNN) can capture spatiotemporal dependence through distributed and hierarchical feature extraction. A long short-term memory (LSTM) network can capture the temporal features of videos. This study collects two types of data: static data from accident reports and image data from collected video clips. Five models based on CNN or LSTM are constructed to predict vehicle collisions. The ResNet-50 network, a pre-trained CNN, captures image features from each video frame. LSTM captures the temporal features of videos. The results show that integrating CNN and LSTM using vehicle dynamic feature data and video data provides higher performance. Regarding practical applications, if vehicles are equipped with sensors, Models III and V can support ADAS with pre-warning alarms. Drivers or vehicles can respond to these alarms to take appropriate actions to avoid collisions.

Authors	Bhupali Dutta, National Institute of Technology, Calicut Ankit Raj, National Institute of Technology, Calicut Suprag Patel, National Institute of Technology, Calicut Shubham Yadav, National Institute of Technology, Calicut Ripunjoy Gogoi, Amity University, Madhya Pradesh Gwalior
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-01703
Paper Title	Role of the built environment on vulnerable road users in a developing country: A case study of Jamshedpur, India
Abstract	This paper investigates the role of the built environment on vulnerable road users (two-wheelers) in India. The study uses simple analytical tools such as the Poisson distribution model, the biserial co-relation coefficient analysis and logistic regression to explore the effect of the built environment factors on vulnerable road user crashes. Three months of accident data for the year 2022 in Jamshedpur, India are used for the analysis. Two-wheeler-vehicle accidents are analyzed for fatal and serious injury collisions. Exploratory variables that are used in the analysis include, type of area (rural or urban), type of road (highway or city road), type of road environment (open or others), type of intersection (junction versus not in junction), and type of road section (straight versus curved). The study suggests that the probability of fatal and serious injury in two-wheeler crashes is more likely to occur in rural areas, on highways, away from junctions, in open areas, and on straight road sections. The findings can raise public awareness of risks associated with riding two-wheelers on certain types of roads and in certain areas, and thus serve to reduce risk of traffic accidents in such areas.

Authors	Anshu Bamney, University of Connecticut Niloufar Shirani, University of Connecticut Yu Song, University of Wyoming Eric Jackson, Connecticut Transportation Institute
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-02140
Paper Title	Analyzing the Factors Affecting Injury Severity of Motorcyclists in Connecticut: A Multinomial Logit Approach for Single-Vehicle and Multi-Vehicle Crashes
Abstract	Motorcycle safety is a public health issue around the world. The magnitude of this problem can be estimated by the national statistics of the United States which shows motorcycles represent only 3.5 percent of the registered vehicles but account for 14 percent of traffic fatalities. The present study aims to explore the factors contributing to single-vehicle and multi-vehicle motorcycle crashes in Connecticut using the data from Connecticut Crash Data Repository and NHTSA's VIN decoder. A series of multinomial logit models were used for these analyses and various environmental (roadway surface, lighting), driver (age, speeding behavior, helmet), vehicle (motorcycle make year), temporal (month, year), and crash-related (manner of collision, crash type, crash location, etc.) characteristics were considered. In general, the results of this study show several factors increase severe injuries such as not wearing a helmet, speeding, rider impairments (intoxicated by alcohol, drugs, medication, etc.), older and sports motorcycles, higher speed limits, summer or warmer months (May-August), pandemic years (2020-21), collision with fixed objects, negotiating a curve, manner of collision, and others. The findings of this study can be used to update motorcycle endorsement programs and formulate policies to reduce severe injuries such as stricter helmet laws. It can also be used to develop educational safety campaigns aimed at reducing risky behaviors such as impaired driving and speeding. To reduce injury severity other strategies such as the use of high-quality reflectors on fixed objects (e.g., trees and poles), rumble strips, and shoulder widening are also recommended.

Authors	Harish Saini, IIT Jammu: Indian Institute of Technology Jammu Ankit Kathuria, Indian Institute of Technology, Jammu
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-02293
Paper Title	Can Segregating Motorcyclists Enhances the Safety of Non-urban Highways?
Abstract	Developing countries like India accommodate a significant share of motorized two-wheelers (MTW) in a traffic stream, resulting in increased MTW crashes. Previous research highlighted that separating MTW from the main traffic stream by providing a dedicated lane for motorcyclists effectively reduces crashes. In this study, the safety performance of an exclusive motorcycle lane (EMCL) was evaluated using the traffic conflict technique (TCT). However, EMCLs are not currently operational in India; thus, temporary implementation of EMCLs was carried out on non-urban highways to collect the field data. Safety analysis of EMCL was carried out to assess the conflict severity using surrogate safety measures (SSM). The motorcycle interaction with other vehicles was investigated, and a support vector machine (SVM), a classification algorithm, was used to categorize the interactions into critical, mild, and safe based on SSM. The results indicate that implementing EMCL improves the safety of motorcyclists and other road users by reducing critical interactions. Overall, the research showed that the motorcycle segregation strategy enhances the safety performance of non-urban highways.

Authors	Harish Saini, IIT Jammu: Indian Institute of Technology Jammu Ankit Kathuria, Indian Institute of Technology, Jammu
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-02298
Paper Title	Investigating the Impact of Segregating Motorcyclists on Safety of Non-urban highways: An application of Extreme Value Theory
Abstract	Developing countries like India accommodate a significant share of motorized two-wheelers (MTW) in a traffic stream, resulting in increased MTW crashes. Previous research highlighted that separating MTW from the main traffic stream by providing a dedicated lane for motorcyclists effectively reduces crashes. However, the safety analysis of exclusive motorcycle lanes (EMCL) was missing in the literature. This study applies a conflict-based safety assessment framework to compare the rear-end conflict and crash probability before-after implementing EMCL. Two popularly used surrogate safety indicators, i.e., time-to-collision and deceleration rate to avoid a crash, were used to analyze the safety. Since EMCLs are not currently operational in India; thus, temporary implementation of EMCLs was carried out on non-urban highways to collect the field data. The vehicular trajectory data were extracted and analyzed using traffic conflict techniques. The threshold was identified using a mean residual life plot and threshold stability plot based on the extracted data. Later, the peak-over threshold (POT) model was established for the different thresholds in the suitable ranges for individual conflict indicators. Then, the conflict and crash risk probability of rear-end collision at the mid-block section were analyzed. The POT model suggests low rear-end conflict and crash probability after implementing EMCL compared to before. The findings were consistent for both conflict and crash probability estimates obtained from the surrogate safety indicators used in this study. The significant results of this study will provide valuable insights for transportation planners, government agencies, and researchers.

Authors	Minh Chu, Ho Chi Minh City University of Technology Hai Duong, Ho Chi Minh City University of Technology Nathan Huynh, University of Nebraska, Lincoln
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-02639
Paper Title	Understanding Psychological Factors Behind Motorcyclists Crossing Behavior on Undivided Roads in Mixed Traffic Conditions: A Case Study of Hau Giang, Vietnam
Abstract	Motorcycle crashes are a common occurrence in developing countries with mixed traffic. A contributing factor to these crashes is the crossing maneuvers of motorcyclists on undivided roadways. This study applies the Theory of Planned Behavior to understand the intentions of these motorcyclists when making such maneuvers. It utilizes data from two surveys conducted in Hau Giang, Vietnam. The first survey aimed to elicit the motorcyclists' behavioral beliefs and control beliefs when making crossing maneuvers that complied with traffic rules (complying maneuvers, CM), and the second survey aimed to elicit motorcyclists' beliefs when making crossing maneuvers that violated traffic rules (illegal maneuvers, IM). The results show a remarkable difference in the intentions of motorcyclists who make CMs versus those who make IMs. More specifically, the intention of motorcyclists making CMs can be explained by facilitating circumstances, their subjective norms, and their descriptive norms, whereas the intention of motorcyclists making IMs can be explained by their advantage beliefs, their descriptive norms, facilitating circumstances, their subjective norms, and their driving situation awareness. These findings suggest that a reduction in IMs can be achieved by developing safety intervention strategies (e.g., explaining the consequences of advantage beliefs of IMs and enhancing riders' situation awareness and understanding of risks in driver education and training courses) to reduce the number of road-crossing-related crashes.

Authors	Yunfei Zhao, Chang'an University Peng Wang, China Automotive Technology and Research Center Wenjian Jia, Chang'an University Tong Zhu, Chang'an University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03421
Paper Title	Examining the Role of Run-Over on Injury Severity in Two Wheeler-Motor Vehicle Crashes: a Path Analysis Modeling Approach
Abstract	This paper examines injury severity of Two-wheeler (TW) riders with three objectives: 1) identify the main causes of occurrence of run-over; 2) quantify the effect of run-over on the injury severity; and 3) understand how the occurrence of run-over mediates the relationship between the injury severity and other influencing factors. Random-parameter binary logit model, random-parameter ordered logit model, and path analysis are developed based on the China In-Depth Accident Study Database from 2017 to 2020. Model results show that riders' age, crash location, TW length, roadworks influence the occurrence of run-over. Moreover, run-over significantly affects injury severity of two-wheeler riders. When the riders are run over, they are 31.70% more likely to be involved in severe crashes. Additionally, path analysis results reveal the direct and/or indirect effects of various influential factors on injury severity. For example, the motor vehicle collision speed shows only direct effects on injury severity, whereas the presence of roadworks is not directly correlated with injury severity but indirectly increases injury severity through exerting impacts on the occurrence of run-over. Riders' age and TW major crash position show both direct and indirect effects on injury severity. Findings of this study highlight the mediating role of run-over in modeling injury severity of TW riders. Practically, the findings provide insights for the design of road systems and the installation of equipment to avoid occurrence of runover and concomitant severe injuries.

Authors	Monik Gupta, Indian Institute of Technology, Bombay Rajesh Meena, Indian Institute of Technology, Bombay Nagendra Velaga, Indian Institute of Technology, Bombay
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03527
Paper Title	The Validation of Motorized Two-Wheeler Simulator: Evaluation of Relative Validity Considering Distraction, Road Infrastructure, and Individual Characteristics
Abstract	The driving simulators provide the flexibility to perform experiments in better controlled conditions without compromising the safety of the drivers. However, before inferring the concluding evidence from simulator-based studies it is required to evaluate the limitations and validity of the driving simulator. In this study a comparison of motorized two-wheeler simulator with naturalistic field data is performed to analyze the validity of the simulator. This study considered distracted driving condition, road geometry variation, and individual characteristics as the control factor for evaluating the relative validity of the simulator. The mixed linear models were developed to analyze the impact of control factors on riders' speed by considering the simulator or field driving as grouping variable. This study showed that riders generally maintained a higher speed in the riding simulator compared to real-world driving. However, the developed models revealed that relative variation across various road sections, distracted driving conditions are similar in both riding simulator and actual field conditions. This study also evaluated the impact of perceived realism and exposure of electronic devices on the riders' performance in simulator. The results suggested that riders' realistic performance can be improved if the roadside infrastructure is replicated adequately while designing the simulator experiment. The findings also suggested that older drivers have more variability in their performance on simulator since they tend to experience higher simulator sickness than younger drivers. Overall, this study found an overall relative validity for the riding simulator and suggested insights to be considered while conducting and analyzing the simulator-based studies.

Authors	Shivasai Samalla, IIT: Indian Institute of Technology Guwahati Pranab Kar, No Organization Suvin Padinjare Venthuruthiyil, Indian Institute of Technology, Hyderabad Mallikarjuna Chunchu, Indian Institute of Technology, Guwahati
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03608
Paper Title	Determination of Conflict Thresholds and Crash Risk of Powered Two-wheelers in Mixed Traffic Conditions: An Extreme Value Theory Approach
Abstract	In low and middle-income countries (LMICs), powered two-wheelers (PTWs) are widely used because of their low maintenance costs and ease of usage. There is a growing concern for the safety of PTWs, but safety studies are still lacking in LMICs. The present study investigates the crash risk of PTWs involved in multiple conflict types, with different vehicle classes constituting a mixed traffic stream. A state-of-art surrogate safety measure (SSM) called Anticipated Collision Time (ACT) was used to evaluate the crash risk. This study uses the extreme value theory to estimate the crash risk by establishing the conflict thresholds for potential rear-end and side-swipe conflicts. The conflict thresholds for rear-end conflicts were found to be higher than side-swipe conflicts except for the PTW-PTW vehicle pair. Further, the conflict thresholds corresponding to rear-end and side-swipe conflicts increase with the interacting vehicle size. The findings indicate the necessity to determine the conflict thresholds corresponding to each conflicting vehicle type for PTWs-dominated urban traffic. The crash risk of PTW varies depending on the type of conflict and conflicting vehicle type. Further, the crash risk of side-swipe conflicts is relatively higher for all PTW-vehicle pairs than the rear-end conflict, except for the PTW-Bus pair. Hence, to improve PTWs' safety, filtering and swerving maneuvers of PTWs should be restricted in mixed and weak lane-disciplined driving conditions.

Authors	Maroa Mumtarin, Iowa State University Ye Dong, Iowa State University Sudesh Bhagat, Iowa State University Jonathan Wood, Iowa State University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-03914
Paper Title	At-Fault or At-Bias: Evaluation of Equity Towards Motorcyclists on Accident Accountability
Abstract	Motorcyclists face a unique set of challenges on the roadways. Firstly, they are exposed to a higher fatality rate in the event of a crash. On top of that, they are perceived as exhibiting higher risk-taking propensities compared to drivers of other vehicles and are more likely to get assigned the “at-fault” status if involved in a crash. This raises a pertinent question of whether there is any bias towards motorcyclists being assigned the at-fault status. Exploring this aspect of motorcycle crashes is germane to ensure equity in traffic safety. Hence, this study attempts to examine if there is any potential bias towards the motorcyclists in assigning at-fault in a traffic accident. This paper also delves into different driver, vehicle and crash-related attributes to understand their influence on at-fault assignment. For this purpose, the binary logistic regression model has been employed to investigate the California and Ohio data from the HSIS database. The results show that if the driver is a motorcyclist, there is a 19.7% and 7.79% higher chance of being assigned as at fault in California and Ohio, respectively. This percentage combines the actual likelihood of causing a crash and bias together. Additionally, significant difference for Ohio and California is reported. Results of this research contribute towards evidence of potential biases towards the motorcyclists in at-fault assignment.

Authors	Md Nasim Khan, AtkinsRéalis Subasish Das, Texas State University Jinli Liu, Texas State University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-04626
Paper Title	Investigating Seasonal Variability Patterns in Motorcycle Crash Injury Types Using Association Rules Mining
Abstract	This study investigates the contributing factors and temporal variation in motorcycle crashes, with a particular focus on the differing severity levels: fatal, injury, and property damage only (PDO). Using five years of Massachusetts Department of Transportation (MassDOT) motorcycle crash severity data from 2016 to 2020, a comprehensive dataset was constructed comprising variables related to roadway geometry, crash characteristics, environmental conditions, and driver characteristics. Motorcycle-related crashes were grouped into four temporal clusters, namely summer, fall, winter, and spring, based on seasons. A comparative analysis approach was employed using association rules mining to uncover patterns and identify crash-contributing factors. By generating, evaluating, and visualizing association rules for each severity level within each cluster, significant findings were unearthed. Significant associations are observed between fatal crashes in summer and factors such as aggressive driver behavior, dark unlit conditions, and clear weather. Similarly, factors including collisions with other motor vehicles and driving on roadways without a right shoulder are linked to PDO crashes in summer. In winter, fatal crashes are associated with conditions such as driving on two-way undivided roadways and angle collision types, with young riders identified as particularly vulnerable. Spring fatal crashes demonstrate frequent connections with high traffic volumes, aggressive driving behavior, and high-speed roadways. This study provides valuable insights for stakeholders, aiding the development of strategies for motorcycle safety improvements like roadway enhancements, safety campaigns, and better lighting and traffic management.

Authors	Richard Dzinyela, Texas A&M Transportation Institute Bahar Dadashova, Texas A&M Transportation Institute Grant Westfall, Texas A&M University Subasish Das, Texas State University Chiara Silvestri-Dobrovolny, Hill and Smith, Inc. Dominique Lord, Texas A&M University, College Station
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-04774
Paper Title	Analysis of Motorcyclists Crash Severity using Cluster Correspondence and Hierarchical Binary Logit Models
Abstract	Crashes involving motorcyclists account for a significant portion of traffic-related injuries and fatalities. Despite motorcycles making only three percent of all registered vehicles, motorcyclists account for 14 percent of all roadway fatalities. As the number of motorcyclists increase, there is an urgent need to understand the factors contributing to crash injuries and severity involving motorcyclists. In this paper, we use the cluster correspondence analysis (CCA) and a hierarchical binary logit model to explore the factors associated with the motorcyclist crash injuries and fatalities in Utah between 2016 and 2020. Cluster correspondence analysis is used to cluster the crash data into seven groups, while hierarchical binary logit model is used to identify the significant factors affecting the KA (severe injuries) and BCO (non-severe injuries) crashes involving motorcyclists. The results of this study indicate that among the crash-contributing factors the motorcyclist age, roadway alignment, roadside safety systems and temporal factors significantly contribute to motorcyclist crash severities. The model results are not only significantly better than results from the binary logit model, but also accounts for the correlation within the clusters found within the crash data. Results from this approach are better and can help decision makers to implement targeted countermeasures to improve motorcyclist safety.

Authors	Henrick Haule, University of Arizona Eric Dumbaugh, Florida Atlantic University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-04809
Paper Title	Examining Factors Contributing to Motorcycle Collisions with Left-turning Vehicles at Urban Intersection Locations
Abstract	Motorcycle crashes account for a significant proportion of traffic-related fatalities on U.S. roadways. Compared to motor vehicles, motorcycles traveling straight ahead are more susceptible to collisions with left-turning vehicles at intersections. The limited knowledge of the causes and influences of this specific type of crash deters efforts to improve motorcycle crashes and is partly influenced by two issues. First, significant variables are unknown; second, motorcycles comprise a small proportion of vehicles in the traffic stream. This study sought to understand the factors that may contribute to the disproportionate crash risk left-turning vehicles pose for motorcyclists while accounting for the imbalance of vehicle proportions. Data containing motorcycle and motor vehicle crashes involving left-turning vehicles at intersections in South Florida were collected from 2015 to 2017. The study applied the logistic regression on a balanced dataset generated using the random oversampling technique. The proposed model improved the predictive accuracy and enabled the identification of factors contributing to motorcycle crashes with left-turning vehicles. A Bayesian Network (B.N.) analysis was also applied to the balanced data to analyze the interrelationship of factors associated with motorcycle crashes with left-turning vehicles. Results indicated that the type of intersection and traffic control, time of day, age of drivers, sex of the motorcyclist, roadway type, and weather were significantly associated with motorcyclists' susceptibility to collisions with left-turning vehicles. Recognizing these attributes could help devise engineering measures and policies for promoting motorcycle safety.

Authors	Muhammad Adeel, The University of Tennessee Knoxville Numan Ahmad, NUST: National University of Sciences and Technology Behram Wali, Urban Design 4 Health, Inc. Asad Khattak, The University of Tennessee Knoxville
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-04833
Paper Title	Exploring the Associations of Rider Age and Experience on Motorcycle Injury Crash Risk: Evidence from A Case-Control Study
Abstract	Motorcycle riding offers travel options, freedom, and thrill to road users. However, motorcyclists are more vulnerable to a substantially higher risk of crashes and severe injuries than motorized users. Understanding the factors contributing to motorcycle crash risk, especially rider age, experience, and training, is essential for developing effective safety measures. This study explores the relationships between these variables and motorcycle crash risk to identify potential safety interventions. Rider age, experience, and training can account for a substantial portion of the risk. Using a unique and comprehensive matched case-control database of the Motorcycle Crash Causation Study, this study analyzes the dependencies of injury crash risk on riders' age, inexperience, and training levels while controlling for other factors, such as alcohol use by the rider. The data consists of 350 cases (injury crash-involved riders) vis-à-vis 700 controls (similarly-at-risk non-crash-involved riders). Based on a conditional logit analysis accounting for the matched case-control structure of the data, "risk curves" are created to understand the relationships between rider age and injury crash risk. Results suggest that younger riders have a heightened injury crash risk, which reduces with increasing age. Each additional year is associated with a 3.31% reduction in the odds of an injury crash - although a non-linear specification is also tested. Each year of rider experience is associated with a 2.69% reduction in the odds of an injury crash, and participation in training programs during recent years is associated with lower crash risks.

Authors	Md Nasim Khan, AtkinsRéalis Subasish Das, Texas State University Ryan Benton, University of South Alabama Mohammad Jalayer, Rowan University Ahmed Hasan, Rowan University
Sponsoring Committee	ACS10
Session Number	Poster Session 2159
Session Title	Motorcycle Operation and Safety Research
Paper Number	TRBAM-24-05047
Paper Title	Uncovering Motorcycle Crash Severity Patterns through Association Rules Mining
Abstract	Motorcycle crashes have raised significant concerns due to their disproportionate impact on overall vehicle fatalities in the U.S., necessitating in-depth analyses into the complex factors influencing their likelihood. Thus, the primary aim of this study was to employ association rules mining, a robust data mining approach, to examine the contributing factors leading to motorcycle crashes and unveil patterns related to crash severity levels, namely fatal, injury, and property damage only (PDO). To accomplish this objective, a five-year dataset (2016-2020) of motorcycle crash severity data obtained from the Massachusetts Department of Transportation (MassDOT) was utilized. Subsequently, comprehensive rule generation, evaluation, and visualization were conducted for the three crash severity levels, with crash severity levels considered as consequents and other variables as antecedents. The generated rules highlighted aggressive driving as the predominant attribute associated with fatal crashes, along with factors including nighttime riding in unlighted conditions, summer season driving, collisions with barriers, and urban driving. Likewise, the rules identified associations between injury crashes and single motorcycle incidents, daytime riding in the summer, rollover crashes, two-way undivided roadways, middle-aged drivers, and specific road types. Additionally, rules for PDO crashes indicated high associations with adverse weather conditions, winter season driving, collisions with roadside fixed objects, angle crashes, and the absence of traffic control devices on roadways. The study's findings provide valuable insights for policy development, resource allocation, and interventions aimed at mitigating the risks associated with motorcycle crashes.

Authors I Gede Brawiswa Putra, National Cheng Kung University
Pei-Fen Kuo, National Cheng Kung University
Umroh Dian Sulistyah, National Cheng Kung University

Sponsoring Committee ACS10
Session Number Poster Session 2159
Session Title Motorcycle Operation and Safety Research
Paper Number TRBAM-24-05071
Paper Title Identifying the Related Factors of Food Delivery Motorcycle Crash Severity

Abstract The COVID-19 pandemic has resulted in a remarkable upsurge in the popularity of online food delivery services in recent years. This escalating demand has intensified the competition among delivery companies, leading them to prioritize providing the fastest service and incentivizing drivers to prioritize speed over safety. Consequently, this emphasis on speed has doubled the number of injury crashes associated with delivery services compared to typical motorcycles used for daily commuting. While existing research has predominantly focused on the relationship between food delivery bicycles or e-bikes and driving behavior, there remains a noticeable gap in investigating the specific role of food delivery motorcycles and their potential spatial relationships with built environmental factors (e.g., points of interest). Moreover, most food delivery crash severity-related studies have relied on the non-spatial model, potentially biased the estimation results. To address these research gaps, we employed a geographically weighted ordinal regression (GWOR) to identify the factors contributing to the severity of food delivery-related motorcycle accidents while accounting for spatial heterogeneity. Utilizing data from 2020, which included 2,314 food delivery motorcycle crashes in Taipei City, the results indicated that roads with higher speed limits, straight lanes, intersections, and restaurants in sub-urban areas were associated with a higher crash severity level. Similarly, male riders and traffic signal violations exhibited a significant positive association with the severity of food delivery crashes. These findings hold important implications for formulating more effective policies for food delivery drivers in different regions.

11 Interacting Committees

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

- Pedestrians – ACH10;
- Bicycle Transportation – ACH20
- Human Factors of Vehicles – ACH30;
- Human Factors of Infrastructure Design and Operations – ACH40;
- Regional Transportation Systems Management and Operations – ACP10;
- Managed Lanes – ACP35;
- Traffic Law Enforcement – ACS30;
- Truck and Bus Safety – ACS60;
- Performance Effects of Geometric Design – AKD10;
- Pavement Condition Evaluation – AKP10;
- Pavement Surface Properties and Vehicle Interaction – AKP50.